pivotal

Developing a Better Way to View Patient Information

Final Report, July 28, 2010 **EXTERNAL VERSION**

Carnegie Mellon

pivotal

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ABOUT THE EXTERNAL VERSION

This version of our design report is intended for interested parties outside of GE Healthcare. As such, many names and photos have been removed from this document for the protection of our client and our research participants.

EXECUTIVE SUMMARY

About the Project
Team PIVOTAL is a group of five Master's students in the Human-Computer Interaction Institute at Carnegie Mellon University. The unique background and experience of each team member provides the advantage of an interdisciplinary approach to understanding the complex problem space. This capstone project constitutes the culmination of our studies. In association with GE Healthcare, we have researched, designed and developed a patient information view (PIV) application. This application will serve doctors and other healthcare practitioners who need a quick and easy way to get a complete picture of patient information.

Research
In order to fully understand our problem space, we spent four months performing interviews and observations with healthcare practitioners from numerous hospitals across North America. The focus of our visits was to see doctors in their natural work context to get a complete understanding of their workflow. We concluded that poorly integrated systems, overly rigid user interfaces and communication breakdowns were the biggest challenges faced by doctors using technology. Additionally, we found that technology often interfered in the patient-doctor interaction by being bulky, poorly located, and time-consuming to use.

Design Process
Building from our extensive research, our design phase is best exemplified by constant iteration and improvement. After coming to a shared direction with our client, we immediately started brainstorming and sketching our ideas. From there we quickly moved to low-fidelity wireframes, high-fidelity mockups, and eventually our working HTML prototype.

The Patient Information View
The PIV design completely rethinks the interaction between a doctor and electronic patient information. Unlike other medical software, the PIV is consistently minimal, and simple to understand. The PIV consists of five major components which work together harmoniously to make understanding complex patient information as simple as possible.

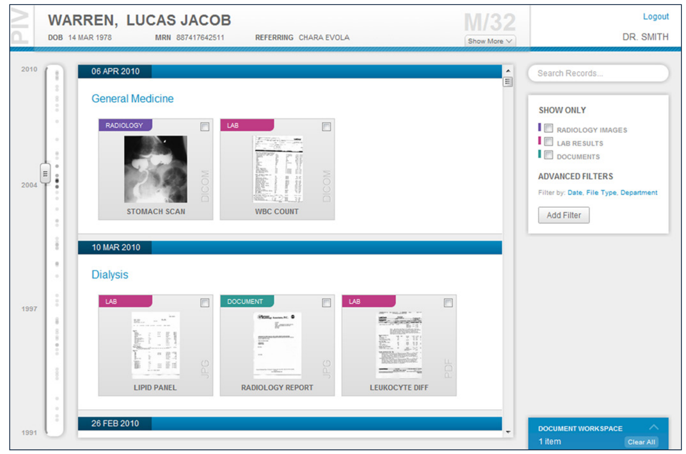
The header of the PIV was meticulously designed to provide the right amount of patient information while preserving valuable screen real estate for the more frequently used components. The header is constant and consistent throughout the application, and provides an expanding drop-down view for additional patient information.

The timeline component is the hallmark feature of the PIV. It provides a concise, glanceable summary of all records for any given patient. The timeline is not only step-up-and-use intuitive, but also extremely powerful as a navigation tool. A doctor can scrub through hundreds of patient records in seconds, and skip to any record with just one click. No other medical software provides a timeline like the PIV.

The history view presents thumbnails of radiology images, lab results and other documents in a large pane in the middle of the screen. This is the central location for doctors to quickly scan patient information and select documents to view in higher resolution.

Advanced filters allow the user to narrow down the patient data with ease. Filtering can be performed on many different criteria, and can stack up to create extremely precise results. In addition to the standard interface, there is also a powerful search box that allows the user to quickly enter search terms that instantly get added to the active filters.

The document view instantly displays any clicked history item in a clutter-free built-in viewer. Viewing two items side-by-side is as easy as dragging an item from the document workspace onto the viewer. A basic toolset is included to minimize application switching.



The PIV enables doctors to quickly and easily find patient information and view documents and images directly within the applicaiton.


JOHNSON, BILL
Purell
HAND SANITIZER
DELL

Testing
Breaking the components of the system apart enabled rapid iteration on designs at multiple levels of fidelity. Even when we only had rough sketches, we shared these with outside users to get early feedback before committing to any particular design or idea. Similar work was done in the click-through prototyping phase, where participants interacted with low-fidelity prototypes on a computer. Finally, a complete implementation with final style was produced and tested in multiple rounds. The first round revealed that participants did not notice several significant features of the system, such as filters. This was often the result of poor interface styling. In the second round of testing, users noticed more features but did not necessarily understand how to use them. Clear labeling and information on hover were added to provide a more intuitive interface for first time users. The third round of usability testing proved to be highly successful, with our participants able to perform their tasks quickly and easily. From a qualitative standpoint, the doctors who had tested the system hailed it as being not only more intuitive than what they were used to, but actually enjoyable to use.

The Vision for a Future PIV
We also present a vision for an ideal future design of the PIV. In the course of our research we found many opportunity areas for the PIV. Unfortunately, due to many different constraints, we could only focus on a specific subset of features. Our vision for the PIV is a fully-featured healthcare application, integrating features currently separated into EMR, PACS, and other medical software. To achieve this, the PIV would include features such as full, searchable patient records and a dashboard for quickly viewing patient status. Further, the vision for the PIV includes a tablet version, allowing doctors to take patient information with them to the patient's bedside. While our vision design did not undergo the same rigor of usability testing as our deliverable design, all of the decisions were based on our research on hospital culture and work practice.

Conclusion
This project has seen the PIV take shape from in-depth contextual research to design activities through to prototype implementation and usability testing. User research and usability testing have been constants throughout our process. We have constantly iterated and tested with real doctors who have provided invaluable feedback along the way. The design and development of the PIV has been driven by these insights and substantially addresses many of the difficulties of modern medical software.

The PIV has taken a fresh, new approach to viewing patient information. We think this is big.

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INTRODUCTION


GE Healthcare

ABOUT THE PROJECT

An end-to-end research, design and development project

Team PIVOTAL worked with GE Healthcare to design and prototype the interface for a future Patient Information View (PIV) which will allow doctors to more efficiently and effectively understand a patient's medical history. This software will provide healthcare practitioners with a longitudinal view of medical data. Additionally, it will facilitate easy access to digital artifacts such as radiology images and scanned documents.

The project consisted of two phases. The first phase comprised research and analysis, with the goal of understanding the needs of doctors and other healthcare workers who interact with patient information. This included not only how patient information is utilized, but also the general workflow in which patient information is used. The results of this phase can be found in our Spring Research Report*.

The second phase, detailed in this report, consisted of brainstorming, designing and prototyping possible user interfaces for the system as well as the subsequent testing and iterating of the developed prototypes. Products of this phase include design ideas, wireframes, prototypes and usability testing results.

CLIENT CHARGE

To define and identify the users of the PIV; design a usable interface for the software, with focus on Generation Y users; define workflows for each user type based upon the data they want to view and how they want to interact with the system; and define and design the types of data to be displayed and how it needs to be displayed.

HUNT STATEMENT

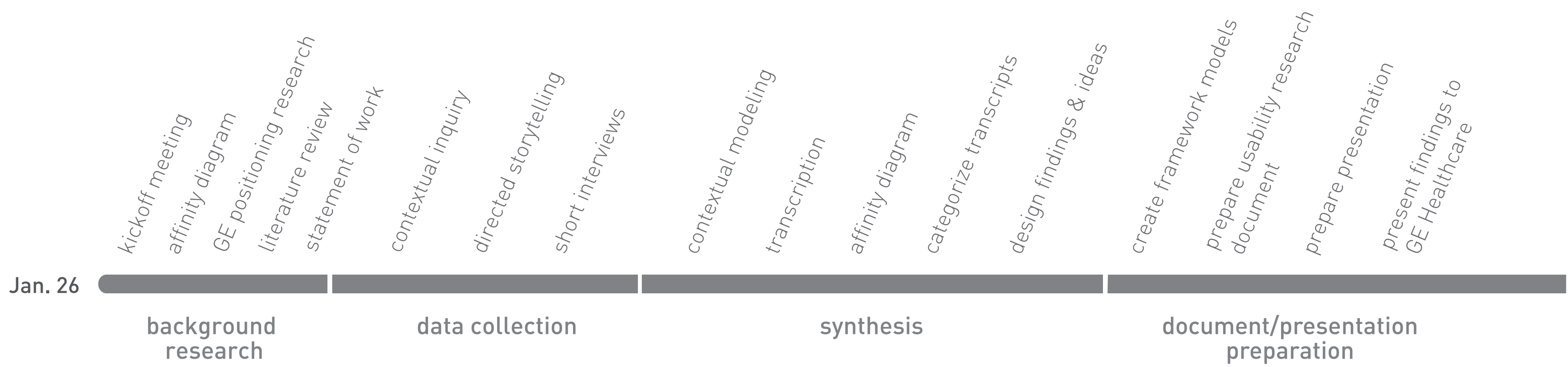
To research the workflows, patient information usage, communication and collaboration among healthcare practitioners in order to understand how to efficiently and effectively present a unified view of patient information.

** Designing a Better Way to View Patient Information: Spring Research Report, May 11, 2010*

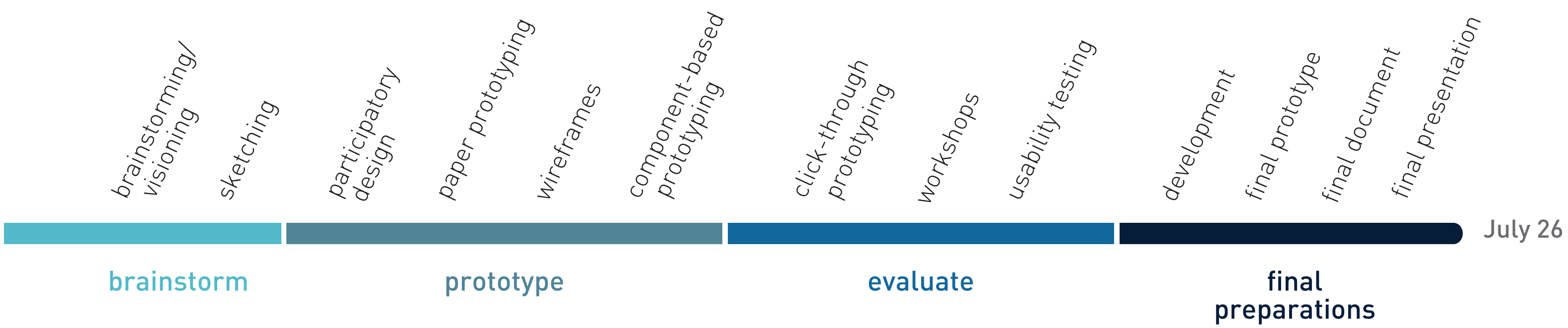
PROJECT TIMELINE

A seven month capstone project

Beginning in late January, at our kickoff meeting, we established an early understanding of what the project would entail. From there we embarked on a contextual research phase which culminated in our Spring Research Report*. Using design directions and insights drawn from this, we jumped straight into our design and implementation phase. We designed, developed and tested throughout the entire summer, resulting in our final deliverables and this design report.



** Designing a Better Way to View Patient Information: Spring Research Report, May 11, 2010*


brainstorming/ visioning
sketching
participatory design
paper prototyping
wireframes
component-based prototyping
click-through prototyping
workshops
usability testing
development
final prototype
final document
final presentation
July 26
brainstorm
prototype
evaluate
final preparations

USER RESEARCH PHASE

Findings, insights and design directions from contextual research

To understand the needs of doctors and the workflows present within hospitals, we visited six hospitals and clinics and interviewed 22 key stakeholders. From talking to doctors, nurses and other hospital staff we came to many findings, as well as recommendations for each. These findings were then categorized into four higher-level insights which served as launching points for our design work: integration, usability, patient interaction and presenting relevant information. More information about our research is available in our Spring Research Report*.

Integration

Doctors utilize many different systems to enter, process and retrieve all of the information they need. Unfortunately, these systems are often disjointed and disconnected — accessing related information from a different system is difficult, if not impossible. Even if two systems do connect and share information, they often look and behave differently, further contributing to the lack of consistency. An ideal workflow sees all of these applications combined into a unified system, allowing for all data to be quickly and easily accessed from one application.

Usability

Doctors are often frustrated with their existing systems because they don't behave in the way they expect them to, making the systems difficult to learn and use. Additionally, the rigidity of these interfaces conflicts with the highly dynamic and variable nature of physician workflows. The cluttered and complex nature of these interfaces increases the time it takes doctors to find the information they want and decreases the overall ease of use of the system.

Patient Interaction

Doctors want to interact directly with their patients, including sharing patient-facing content with them. Doctors dislike the mobile computing stations (or "COWs", for computers-on-wheels) often employed on hospital floors due to their bulky nature. They fear that such technology creates a barrier between them and their patients, and that using a computer away from the patient during an encounter can give the impression that they are distracted or disinterested. Numerous doctors we spoke to mentioned their desire to have a small, mobile tablet to access information during patient encounters.

Presenting Relevant Information

Our findings in this category included a need for more glanceable patient information. This could take the form of symbols, color-coding, text-highlighting and an overall rethinking of information hierarchy. We also found that physicians are usually most interested in seeing information that is relevant to their specialization or the current complaint. Minimizing the amount of "excess" information could solve the information overload problem experienced by many physicians. Based on our research, as well as discussion with stakeholders within GE Healthcare, we emphasized this direction in our design of the PIV.

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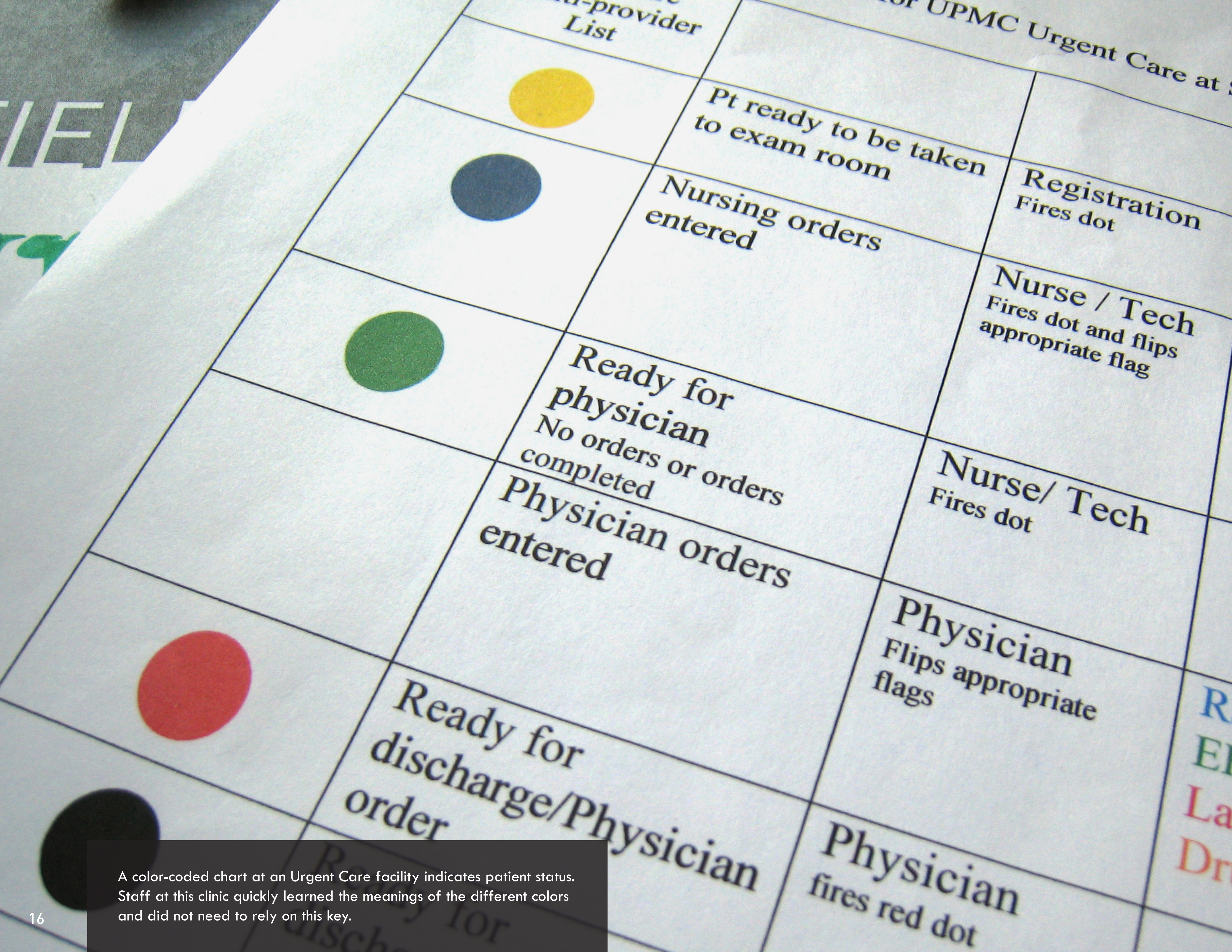


A color-coded chart at an Urgent Care facility indicates patient status. Staff at this clinic quickly learned the meanings of the different colors and did not need to rely on this key.

CHOOSING A DESIGN DIRECTION

Presenting relevant information

In order to guide the design and implementation phase, we conducted a workshop as a follow-up to our research presentation at GE Healthcare. The goal of the workshop was to understand the stakeholder's interest in PIV and determine a direction for our work. From our research, we were able to abstract four main focus areas to improve on: integration, presenting relevant information, usability, and patient interaction. By running a brainstorming session and narrowing down the focus areas with GE Healthcare engineers, marketing personnel, and top-level managers, we were able to determine that designing the presentation of relevant information is the design direction currently in line with GE's goals.

By building a system that presents relevant information to physicians, GE Healthcare has a strong opportunity to dramatically improve physician workflow and ease a number of existing frustrations. Recent developments in electronic medical records make entering information and storing documents incredibly easy compared to their analog counterparts. While this wealth of information is valuable for the sake of having a complete medical history for a patient, it can be overwhelming for a physician to view documents from every medical encounter that a patient has had. In the context of a particular patient complaint, a physician may only need very specific information, while the rest of the patient's medical record is less important.

Providing mechanisms for highlighting or customizing the granularity of data can help achieve this goal. Information placement can further aid in ensuring the most important data is easily seen. Information visualizations such as timelines can help make a patient record more glanceable and easily navigable. Additionally, information filtering allows physicians to narrow down a patient's record to view only the information they are looking for.

By providing glanceable information, we are supporting cases in which a physician wants to gain an overall understanding of a patient's health and medical history. On the other hand, physicians often know precisely what document they are looking for and have very direct goals when interacting with clinical documents. Filters and navigation tools make it easy to quickly and effectively locate a specific document.

At our workshop on May 11, 2010, we met with GE Healthcare employees to discuss our contextual research findings and future directions for the summer deliverable.

DELIVERABLES

A pragmatic design and an ideal future vision

As practitioners of Human-Computer Interaction, our goal is not only to achieve the best solution for the current implementation but to also imagine the ideal future vision of the project. As such, we developed two different versions of the PIV — the design, which factors in all of the constraints currently on the system, and the vision, which illustrates the ideal future state of patient information. Both the design and vision are based on our research, outlined in the Spring Research Report*.

Design

The "design" version, takes into account things like the data available to the PIV, the limitations of XDS metadata, and the separation of features already existing in other GE applications.

This version can be found beginning on pg. 22 of this report.

Vision

The "vision" looks further into the future and is meant to serve primarily as a direction for further development. This version assumes that many of the constraints currently in place could be overcome in the next few years to enable a system that best supports the practice of doctors.

Moving toward the future state outlined in the vision will help ensure that GE Healthcare remains a leader in the healthcare technology sector. Based on our research, this is not only the direction that will most help doctors, but also the direction in which new software developments are moving. We strongly believe that the most successful PIV will be one that moves toward this vision, incorporating other healthcare applications into one robust, mobile-accessible tool.

The vision is discussed beginning on pg. 124 of this report.

** Designing a Better Way to View Patient Information: Spring Research Report, May 11, 2010*

OUR DESIGN

ABSTRACT

CONCRETE FEATURES

INTEGRATION

All Systems Integrated
One fluid system

PRESENTING RELEVANT INFORMATION

Search
Quick search by different keywords without learning specific search syntax

Header
Necessary & useful information; quickly comprehensible

Timeline
Longitudinal view of patient's visits; serves as navigational tool

History View
All content from encounters; easy to find and read; shortcuts for most relevant content

Viewer
Improved way to view & compare images & documents

Filters
Quickly filter by content, department, file type, and episode

Dashboard
Glanceable patient overview; today's & most recent visit, radiology imgs, & lab results

Specialized Tools
Calculators: ABG, APACHE, dosage, and other reference guides facilitate workflow

Allergies & Medication List
Most crucial information; immediately impacts treatment and diagnosis

CUSTOMIZATION

Modular Layout
Accomodate doctors' work preferences & specializations

Customizable Settings
Preserve time by saving state for filters and searches

PATIENT INTERACTION

Portable / Mobile Device
Facilitate doctor workflow

Patient-facing Content
Bring patient into the technology experience

Deliverables (blue)

Additional Ideas for Vision (gray)

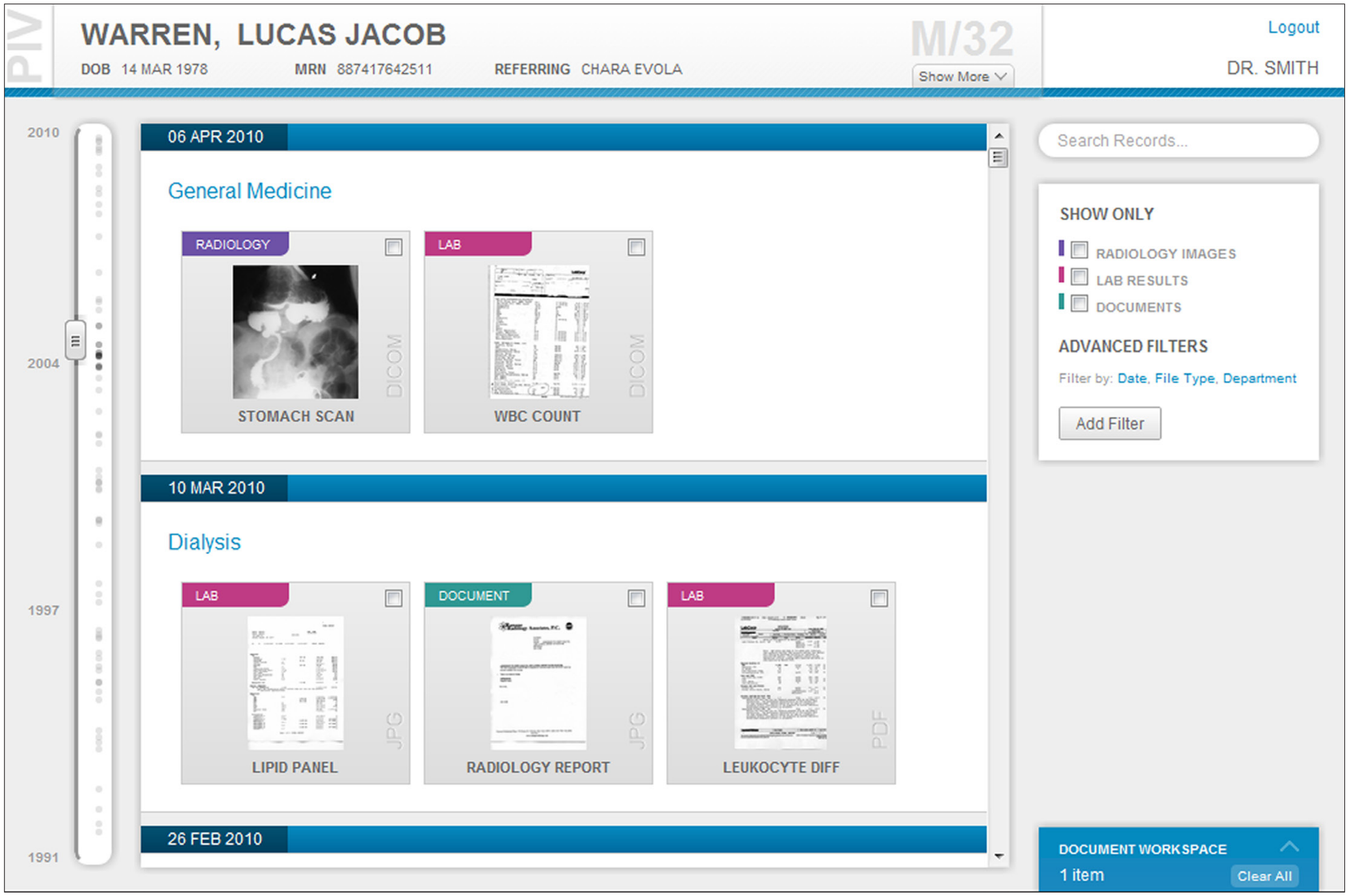
DESIGN OVERVIEW

A fully designed and tested proof-of-concept for the PIV

Through research and iterative design based on user feedback, the PIV has evolved to be a complete system for accessing medical records. The combination of components provide many different ways for users to interact with the system, ensuring that many different workflows are supported. A doctor seeking information from a specific visit can use the timeline to quickly find the information by date. Meanwhile, a doctor seeking a more general look into a patient's health can browse through all records, or apply filters to narrow down the information set to increase the likelihood that the displayed records are relevant to the patient's current complaint.

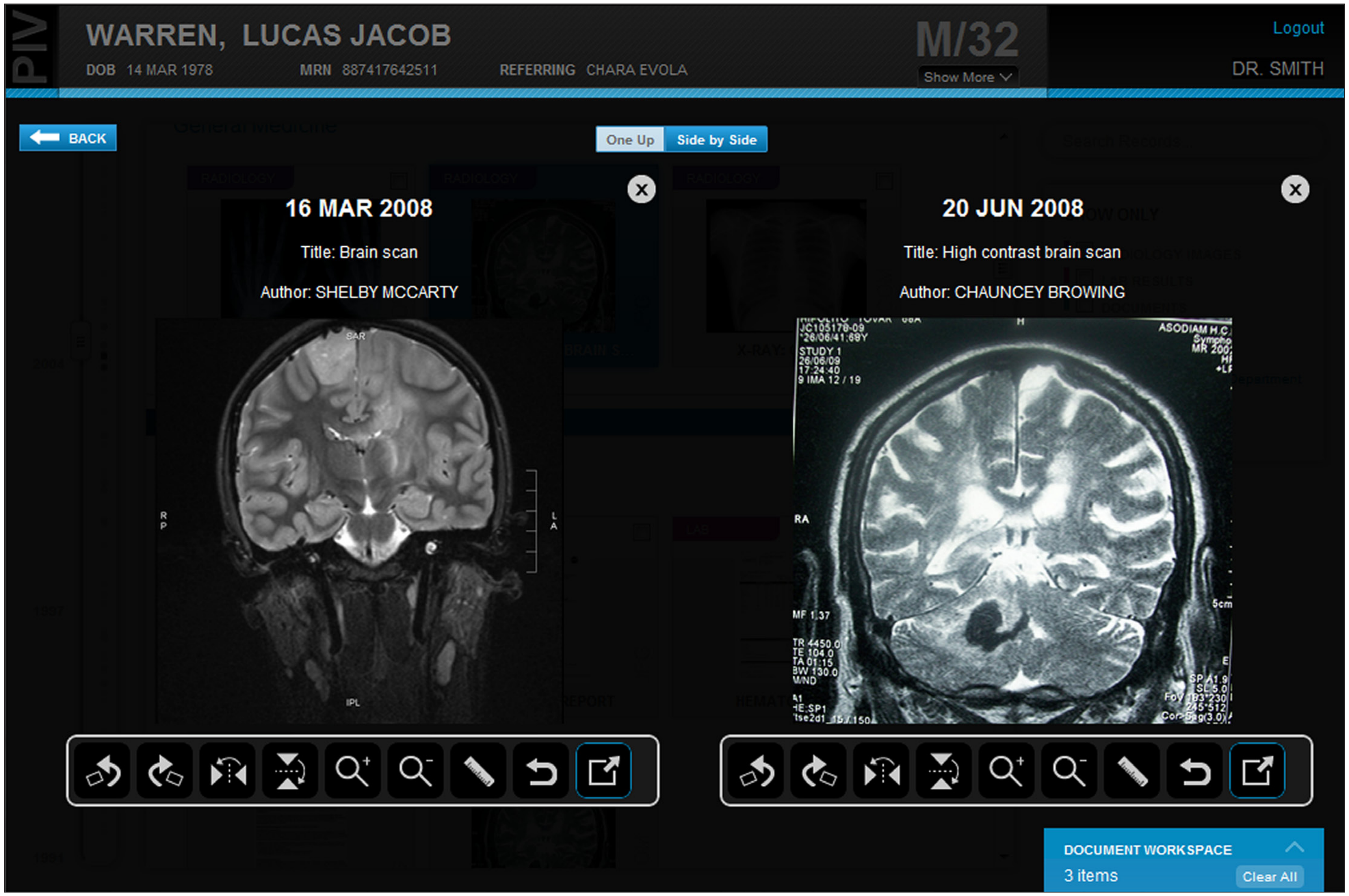
The interface remains consistent through any workflow, to ensure that the user need only learn the system once. Further, through repeated usability testing and design iteration, the PIV has been designed to be easily approachable, so even new users can quickly pick it up without the need for formal training. Whether checking a lab score from a month ago, or looking for diagnostic clues in a patient's medical history, the PIV provides a quick, effective solution for accessing the necessary information.

History View



The main screen of the interface, the history view contains the header, timeline, chronological view of a patient's records, and filters.

Document View



The document view provides a way to view one or two images. Selecting and navigating these images is prvoided by the document workspace, while a toolbar enables image manipulation.


DOB 14 MAR 1978
MRN 887417642511
REFERRING CHARA EVOLA
DR. SMITH
Show More
BACK
One Up
Side by Side
14 SEP 2004
Title: Anterior Cruciate Ligament Rupture
Author: MARIA FAILLA
Drag Item to Compare
DOCUMENT WORKSPACE
14 SEP 2004
ANTERIOR CRUCIA
View Item
21 APR 1998
PHYSICIAN NOTES
View Item
2 items
Clear All
HP L1950g

THE PIV IN PRACTICE

A guided tour through the PIV

To help illustrate the functionality of the PIV, we have created four example walk-through scenarios. These scenarios are intended to be the same common, everyday tasks that doctors would actually use the PIV application for. We have based these tasks off our extensive research which highlighted the need for well-presented, relevant information. Each scenario runs through the steps a user would take to achieve the end goal. To demonstrate the breadth of the PIV, these scenarios vary between quick and simple to long, and complex.

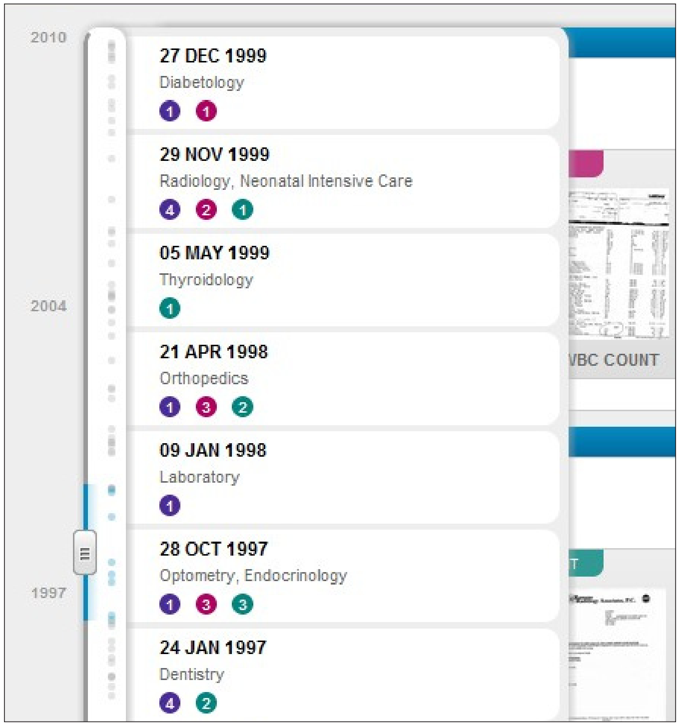
THE PIV IN PRACTICE

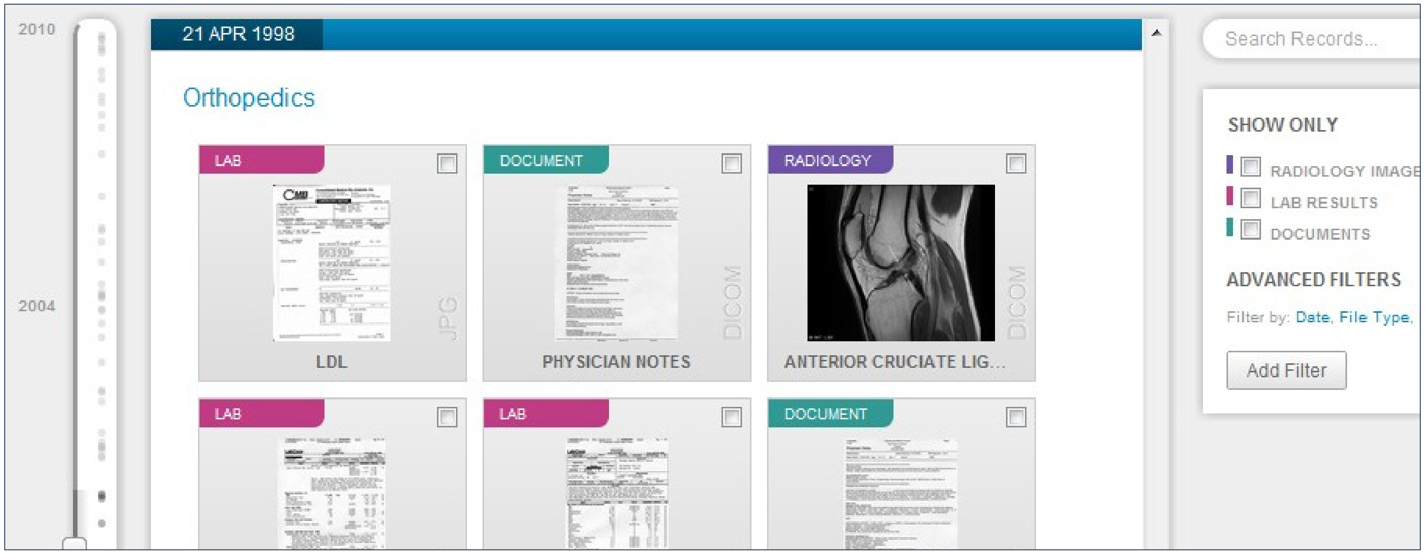
Using the timeline to find a visit

Dr. Johnson, an orthopedic doctor at UPMC, is seeing her first patient of the day. The patient, Lucas Warren, first fractured his tibia in April of 1998, and is experiencing sharp pains where he had surgery.

① Dr. Johnson goes to the timeline of the PIV. By moving the thumb on the left side of the timeline, she can change the information that is shown on the right side. The dots corresponding to the highlighted visits also turn blue. Additionally, the designated blue area scales automatically based on the density of results.

② On the right side of the timeline, she can see summary information for each encounter, including date, department, and number and type of documents (purple representing radiology images, pink representing lab results, and green representing documents) . She finds the entry for the date she is looking for and notices that it is in the Orthopedics department and contains two documents.





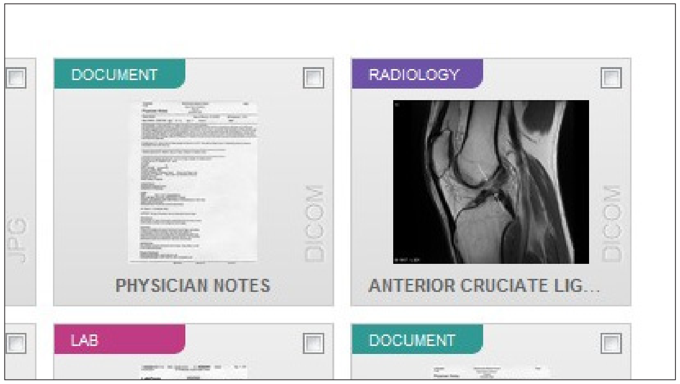
③ When she clicks on the timeline indicator for the visit, the history view scrolls to the corresponding visit, showing thumbnails for the documents she is looking for.

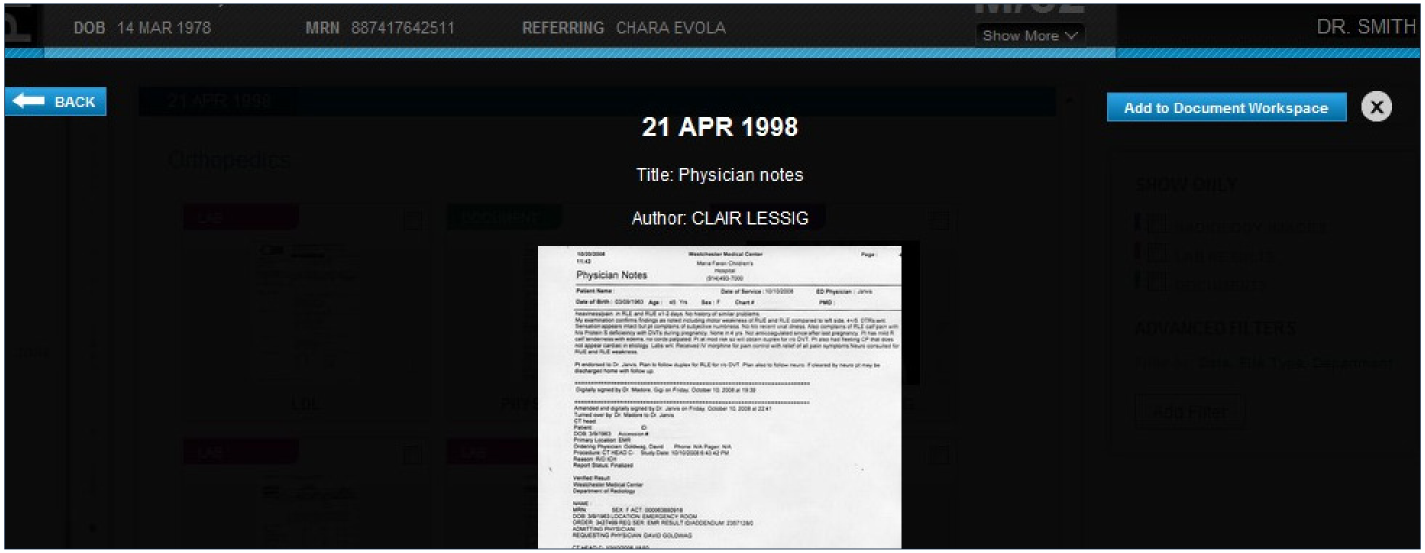
THE PIV IN PRACTICE

Viewing documents in the document view

Having found the visit she was looking for, Dr. Johnson decides to takes a look at the documents.

1 Dr. Johnson begins by looking at the thumbnail for the first record. It contains a green color-coded indicator of the record's content, which lets her know that it is a document. There is also a label for the document's file type, and a document name. There is also a checkbox in the top-right corner. For now, she opts to click on the thumbnail.





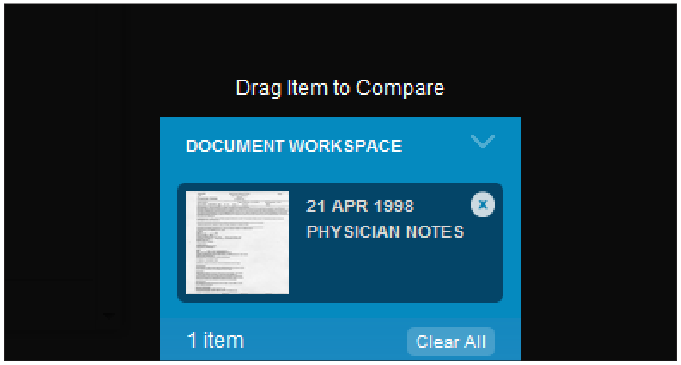
② The PIV is now displaying the document against a dark background, providing better contrast for her to view documents. This screen also provides the name of the author in addition to the title and date.

③ Upon reading the note, Dr. Johnson realizes that she wants to review another document as well. She clicks on the "Add to Document Workspace" button to add the note to her document workspace.

THE PIV IN PRACTICE

Viewing documents in the document view (continued)

4 She sees that the document appears in the workspace in the bottom-right corner of the screen and presses the “Back” button to return to the history view. Once in the history view, she looks for a radiology image from 2004 that Lucas has told her about.



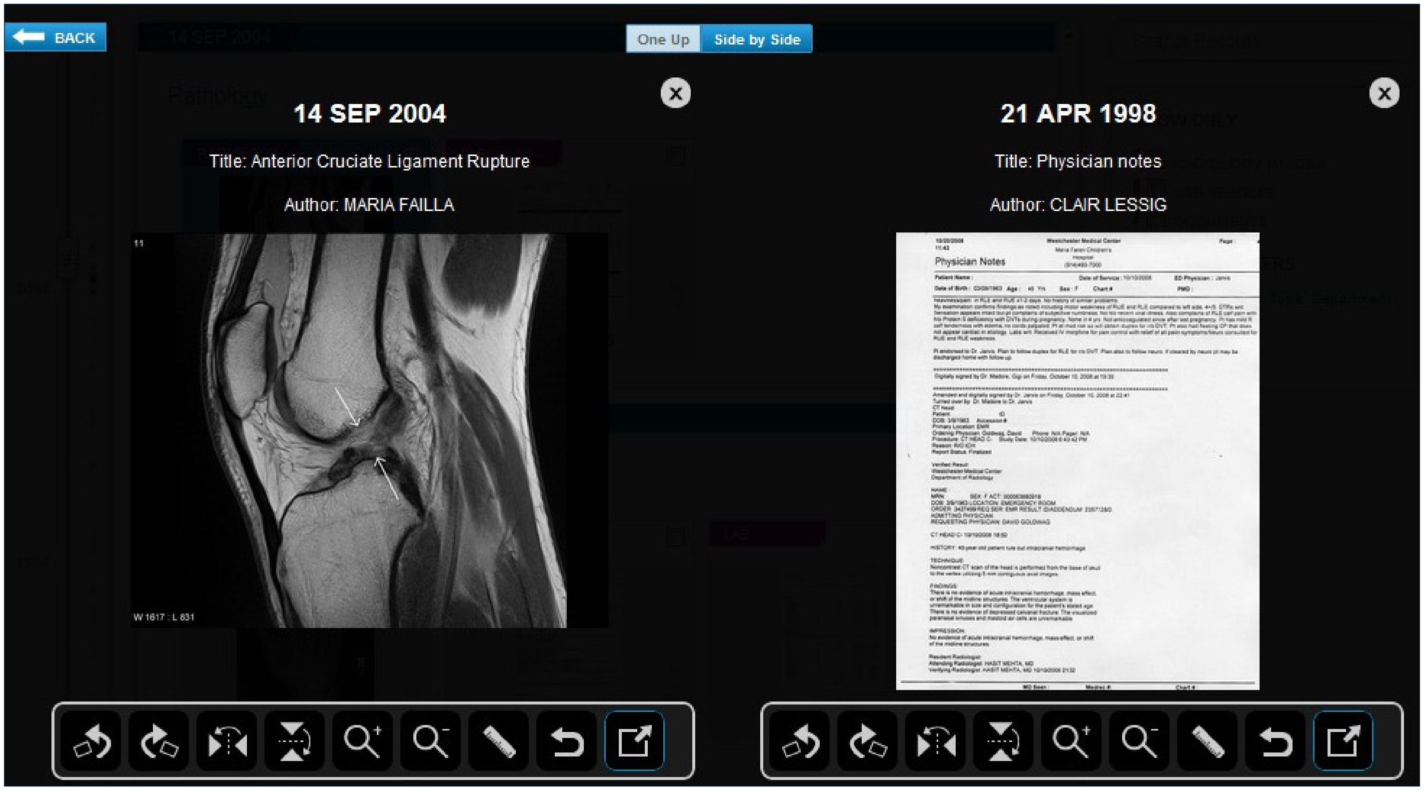
5 In the history view, she uses the timeline to navigate to the visit she is looking for, from September 14, 2004. Seeing the thumbnail for this image, she hovers over the checkbox where she sees a tip that says “Add to document workspace”. Selecting this checkbox adds the thumbnail to the workspace.

⑥ She clicks on the icon in the workspace to jump to the document view. The workspace persists across the two views in order to provide consistency. Dr. Johnson notices that she can switch between the two images by selecting them in the workspace, but she decides she wants to view them side-by-side.

THE PIV IN PRACTICE

Viewing documents in the document view (continued)

⑦ When she clicks on the "Side by Side" button, the current image moves to the left and a highlighted area appears on the right. By dragging documents into this area, she can view them side-by-side and make comparisons.



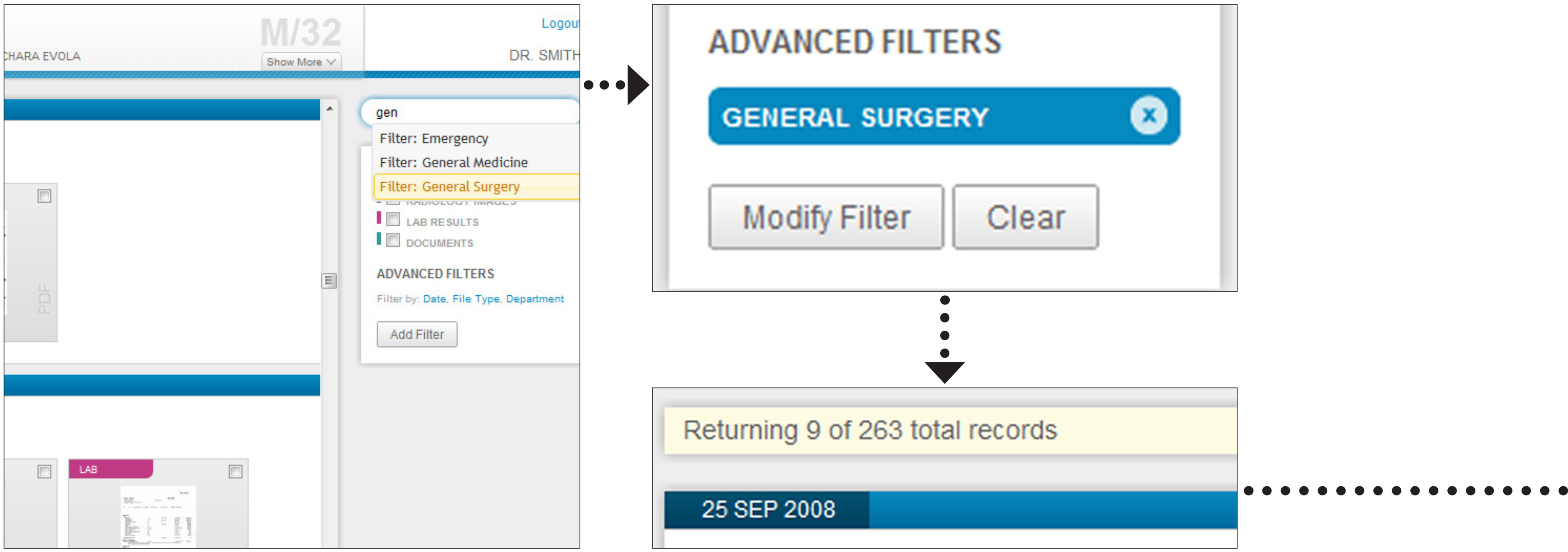
8

She can now see the images side-by-side, including descriptive information and toolbars. These toolbars allow her to rotate, flip, zoom, measure, or reset documents. There is also a button, highlighted in blue, to launch an external application for additional image manipulation tools.

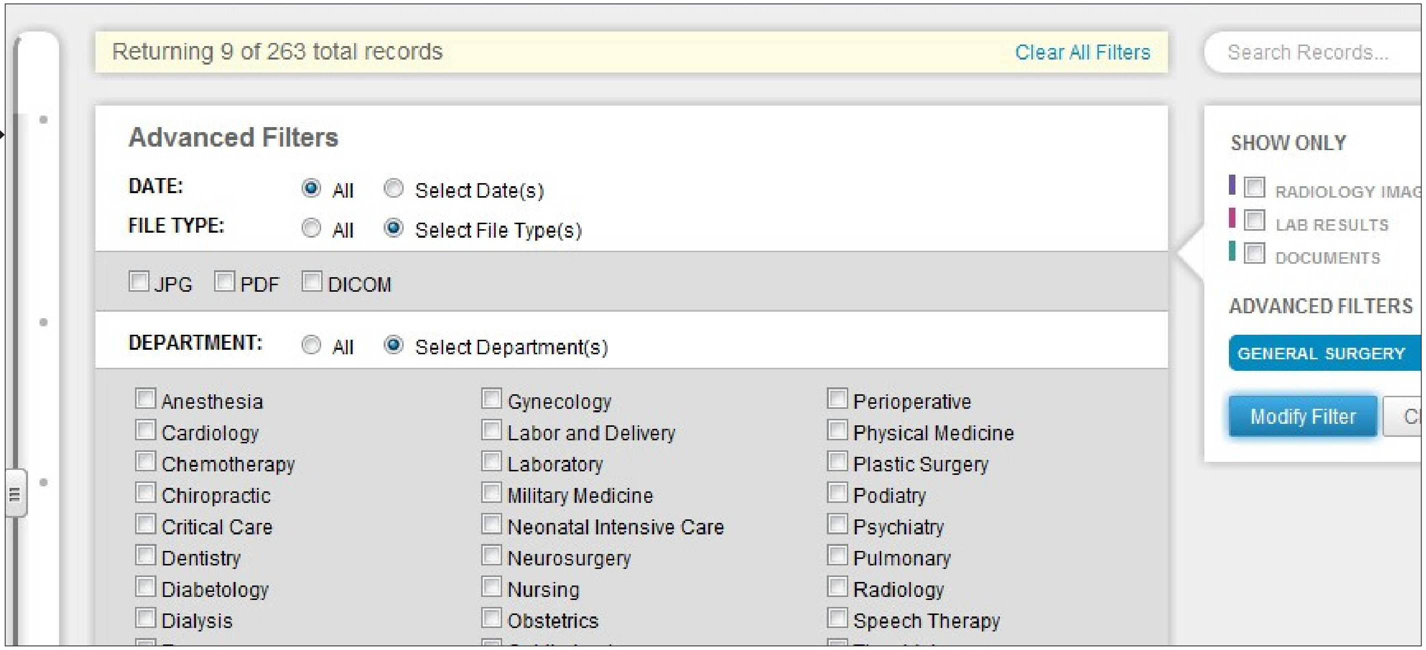
THE PIV IN PRACTICE

Using filters and search to narrow down the record

Now that Dr. Johnson has reviewed some of Lucas' records she wants to go back to looking at his medical history.



1 Upon realizing how many encounters he has had, she decides to search for only records from the General Surgery department. Typing in the first few letters brings up auto-complete suggestions in a drop-down box. Clicking on the suggestion adds General Surgery as a filter in the advanced filters panel. The history view is updated immediately to show only encounters from General Surgery, and a bar appears above the history view to show the number of returned results.



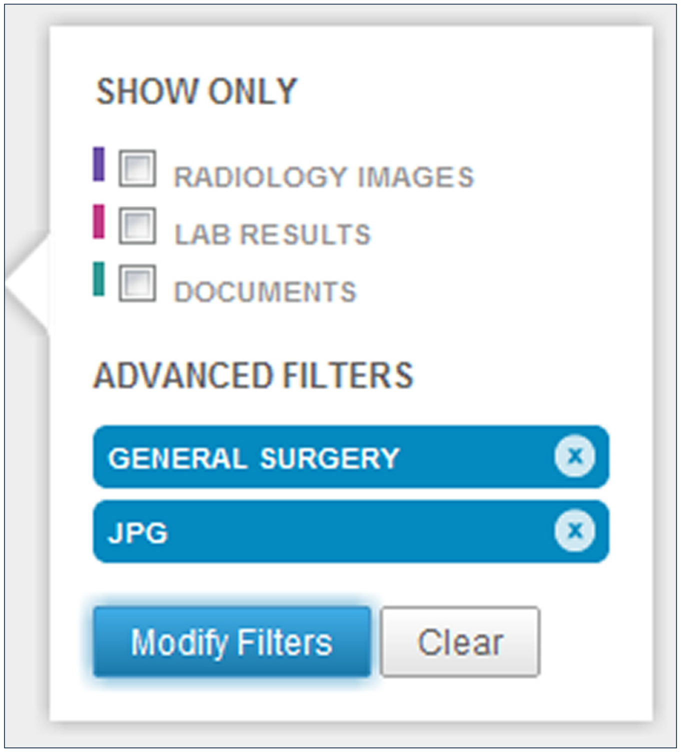
② Dr. Johnson decides that she wants to apply some more filters. By clicking on the Modify Filter button, she opens the advanced filters panel where she can select filters for Date, File Type and Department. These sections are expanded by toggling between the “All” option and the “Select Date/File Type/Department(s)” options.

THE PIV IN PRACTICE

Using filters and search to narrow down the record (continued)

③ Selecting the checkbox for JPG files also adds another indicator to the filters panel, showing that there are now two filters applied. The status bar above the history view also indicates how many records are being shown.

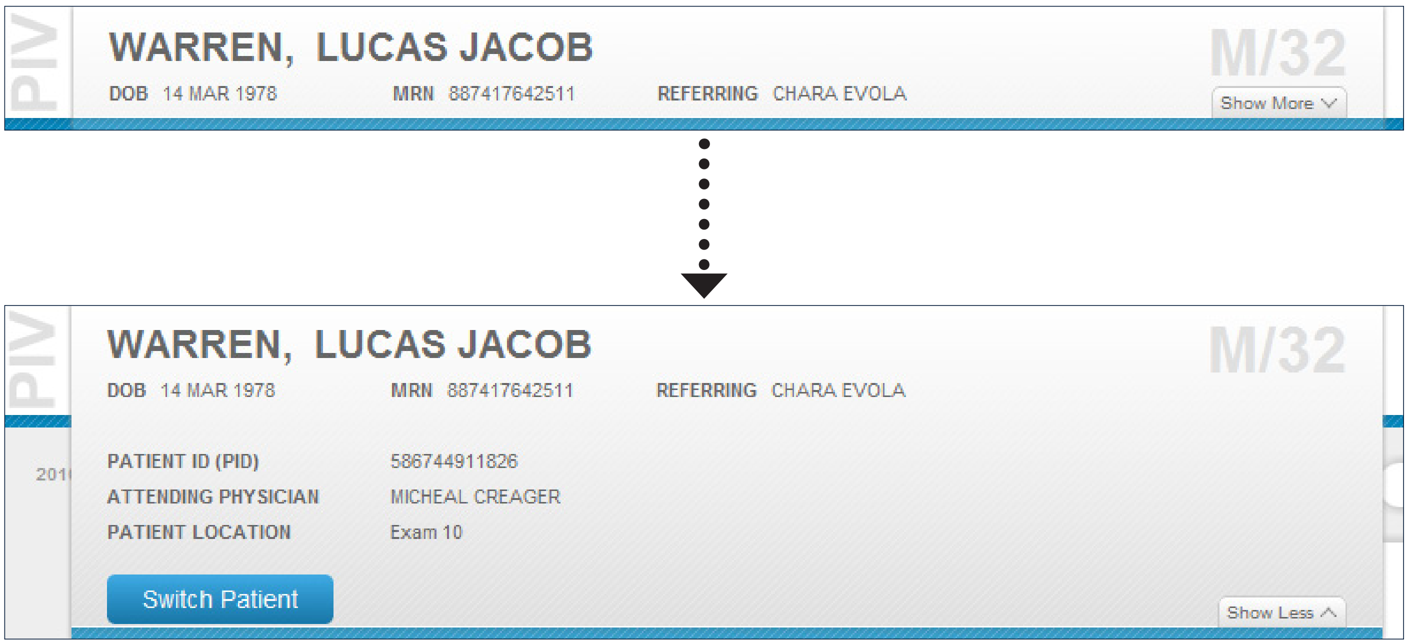
Dr. Johnson looks over Lucas' records of the JPG file type from the General Surgery department and decides that she needs to contact his attending physician to get further information about his health history.



THE PIV IN PRACTICE

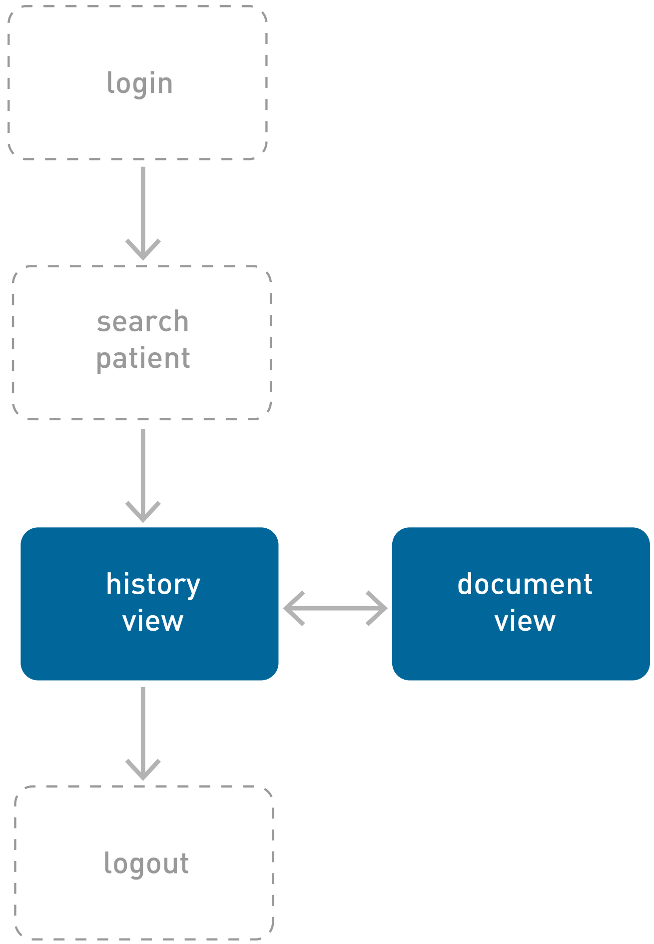
Viewing additional patient information

Having looked over Lucas' record and some of his documents, Dr. Johnson now wishes to contact his attending physician.



① While looking for the name of the attending physician, Dr. Johnson sees that general patient information is included in the header. Noticing the "Show More" button, she clicks on it and opens the full header. This expanded state contains additional information, which would otherwise add clutter to the main interface.

Interaction Diagram - Overview



Connections between different screens in the design, including the context of a full application with login and patient selection. The interactions on each of these screens are explained in further detail on the following pages.

INTERACTION DIAGRAM

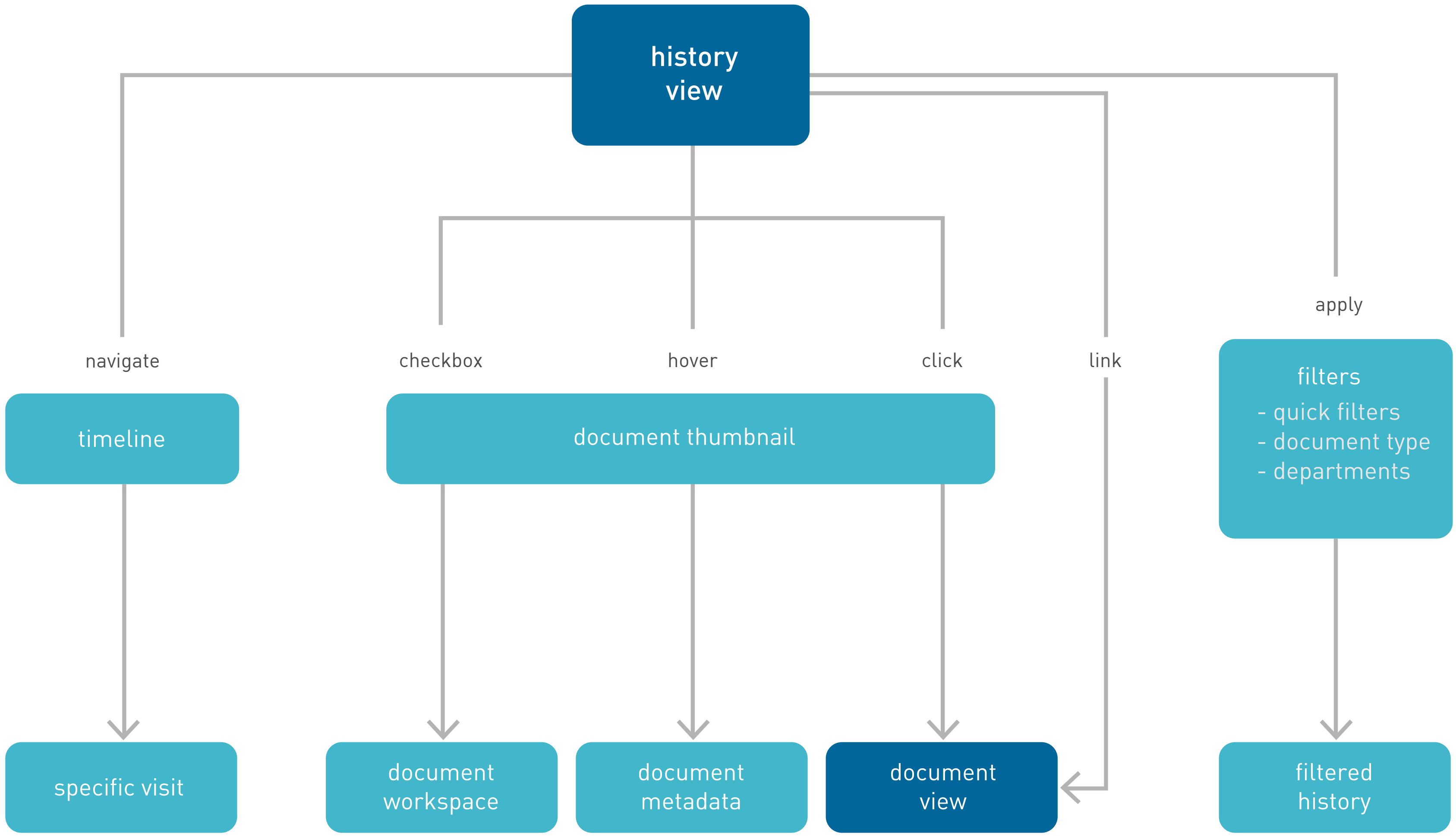
Interaction and navigation in the system

This system map illustrates the relationships between the different screens and features available in the deliverable design. Each diagram presents the possible interactions that can be performed in that view. In the history view, users can navigate visits and filter the patient records that are presented. The diagram also shows the ways in which a user can select one or multiple images. In the document view, users can change the arrangement of images, use tools to manipulate images, or simply navigate back to the history view.

KEY

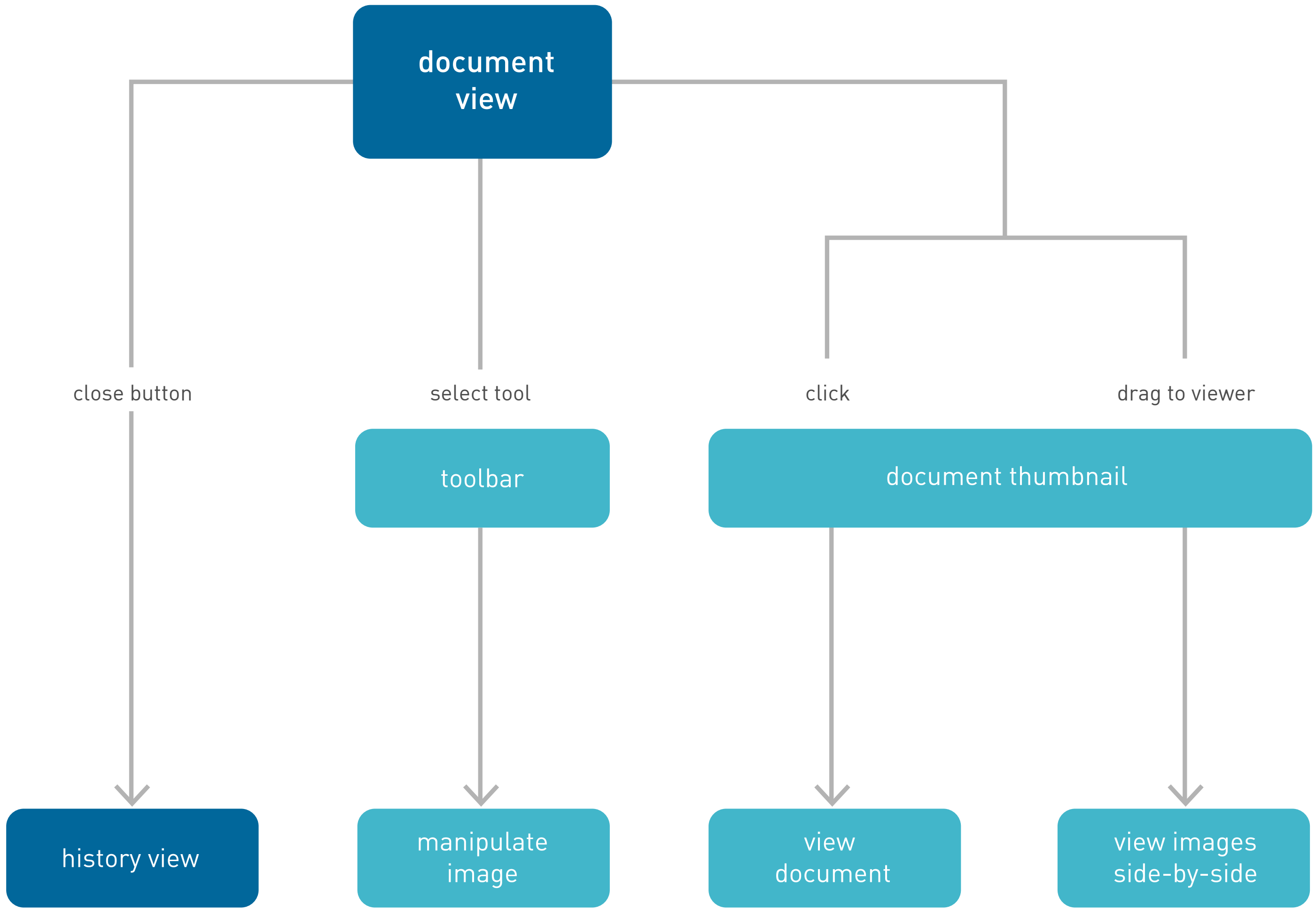
- Dark blue blocks are distinct screens in the interface
- Turquoise blocks are specific components or features

Interaction Diagram - History View



The history view can be changed using the timeline or filters, and documents can be selected in several different ways.

Interaction Diagram - Document View



The document view links back to the history view, and also provides ways to organize and manipulate images.

DESIGN GOALS

Clean, minimalist, easy and efficient

Developing the interface and aesthetic style for the PIV required the team to keep several design goals in mind. On a conceptual level, it is important to ensure that users do not feel overwhelmed by the interface. They should always feel confident and in control of the system.

In the design, this translated to a clean, minimalist look to make the system feel more open and less convoluted. In our research, it was not uncommon to see interfaces filling every pixel of the screen with content. Doctors, however, frequently made note of the fact that there was too much on the screen, and that much of it was extraneous. The final design avoids this style, aiming instead to provide information in a simple but effective design.

Beyond minimalism, we aimed to create a design that felt modern yet restrained, as the style should simply support the information rather than being the focal point itself. To accomplish this the design uses a color palate of white, greys and blues which to provide a modern feel without being loud or overbearing. Small, modernist design touches — such as the drop shadows employed to add depth — help draw the user's attention to certain elements, while still keeping the interface as simple as possible. In this way the design provides an aesthetically pleasing background to the information contained within.

Additionally, users should experience the system as efficient. Some of the ways that the design embodies this is the live filtering and auto-completing searches. Both of these components provide quick feedback to the user. Live updating in particular gives a feeling of speed in the interface. The design also aims to be as easy as possible to instill a feeling of confidence in the user. By providing multiple ways to complete the same task, a user's actions are more likely to have a successful outcome, which encourages continued use and exploration.

DESIGN SUMMARY

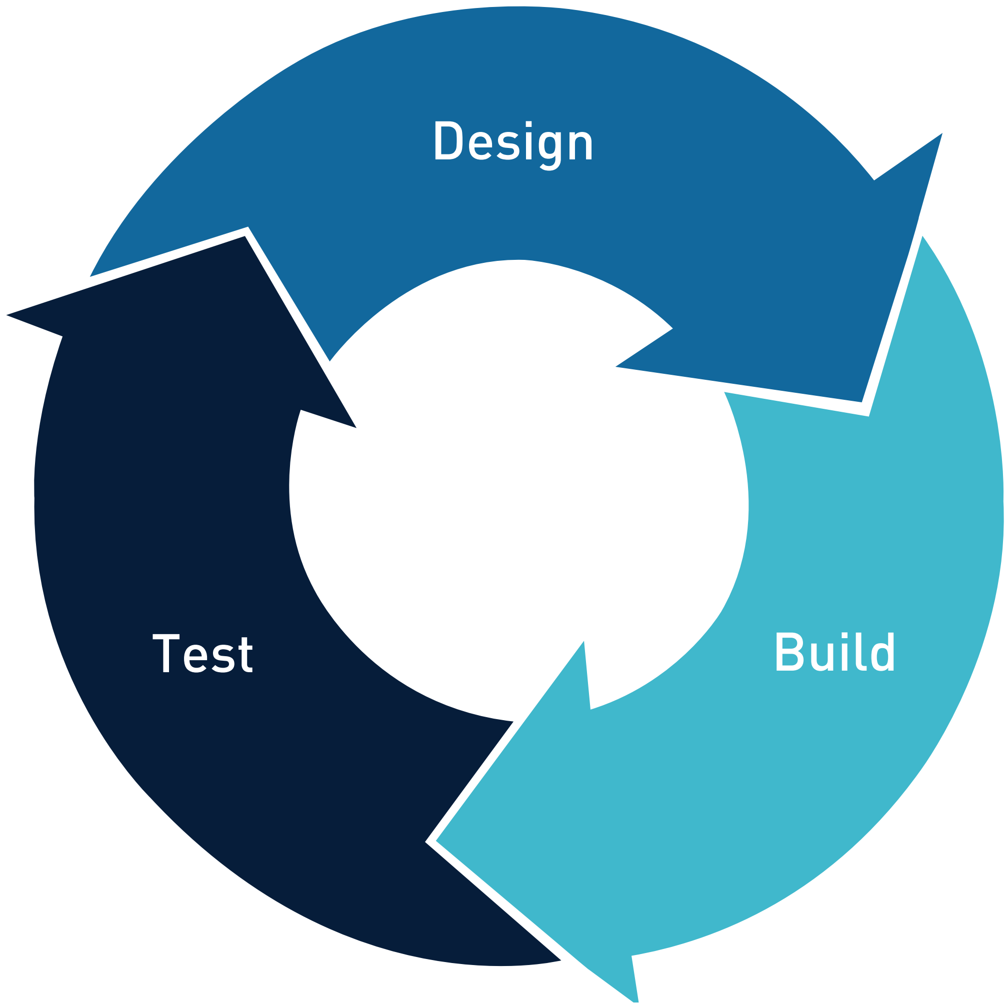
A better way to view patient information

The PIV allows doctors to quickly and effectively find the information they need. Whether using the timeline to navigate between dates or the filters to narrow the available data, the PIV provides intuitive, useful features to minimize the time needed to use the system and maximize the amount of relevant information provided. Doctors can view patient information from the header, providing not only greater safety through ensuring the data relates to the right patient, but also providing critical information a doctor would need about a patient. Patient information can be quickly found by navigating with the timeline when a date is known, by applying filters when relevant constraints are known, or by simply browsing through the available data. Once found, the information can be easily added to the workspace for later reference, or opened directly in the document view. If a doctor needs to reference two pieces of information at the same time, they can be opened side-by-side by simply dragging and dropping images into the document view.

This design is the product of significant research and testing, which provided a solid basis on which to develop the included features. Interactions were thoroughly vetted to ensure the greatest possible ease of use, while the information architecture was tested to confirm that doctors can find the data they need. As a whole, the PIV enables doctors to find information with greater ease than with current systems, allowing them to spend less time at the computer and more time with patients.

PROCESS

Iterative Process Diagram



The iterative design process we followed started with designs, which we then built, tested, and re-designed based on feedback.

ITERATIVE PROCESS

How we arrived at our design and vision

In order to develop the best possible design solution, the team followed an iterative design process. Using insights from the research phase, we began with very low fidelity sketches, in order to make sure that all ideas were captured. From there, a series of internal brainstorming activities and participatory design sessions with physicians helped shape the direction of the PIV.

With increasingly high-fidelity designs, we began a cycle of paper and click-through prototyping. Prototyping allowed for quick iterations and rapid improvements to the design. Once a new prototype was ready, it was immediately tested with users. The team then held internal discussions of the results in order to move forward with an updated prototype. In the high-fidelity implementation phase, an analogous iterative approach guided our process. This phase consisted of usability testing, internal review, and continued implementation.

This rapid iterative process increased productivity and allowed the team to make continuous improvements very quickly. Constant user feedback also helped avoid the problem of becoming attached to ideas prematurely.

PIVOTAL team members brainstorm outside using the mind-mapping technique. By building off the ideas of others, the team can reach more creative insights and a shared understanding of the problem space.

BRAINSTORMING

Generating a wide variety of new ideas

Brainstorming is a tool for creatively generating a vast quantity and range of ideas. Some key rules for brainstorming are to refrain from criticism, welcome wild ideas, and to build upon and improve others' ideas. Due to its open nature, brainstorming allows the group to generate ideas without any boundaries or limitations. It allows groups to break free from traditional ways of thinking and allows them to look at the problem from fresh perspectives. At the start of the idea generation phase it is important to consider all ideas since pushing the envelope produces room for break-through ideas.

During our formal brainstorming sessions we utilized three different methods: interaction relabeling, extreme characterization, and mind-mapping.

Interaction Relabeling*

The first method, interaction relabeling, is a technique to trigger ideas about new ways to interact with a product. Participants take existing products and their characteristics and apply them to the primary problem at hand. Unrelated products help participants separate themselves from a typical interaction with the device they are designing for. By creating a mapping between products with different characteristics, the focus changes from function to different interaction possibilities.

Extreme Characterization*

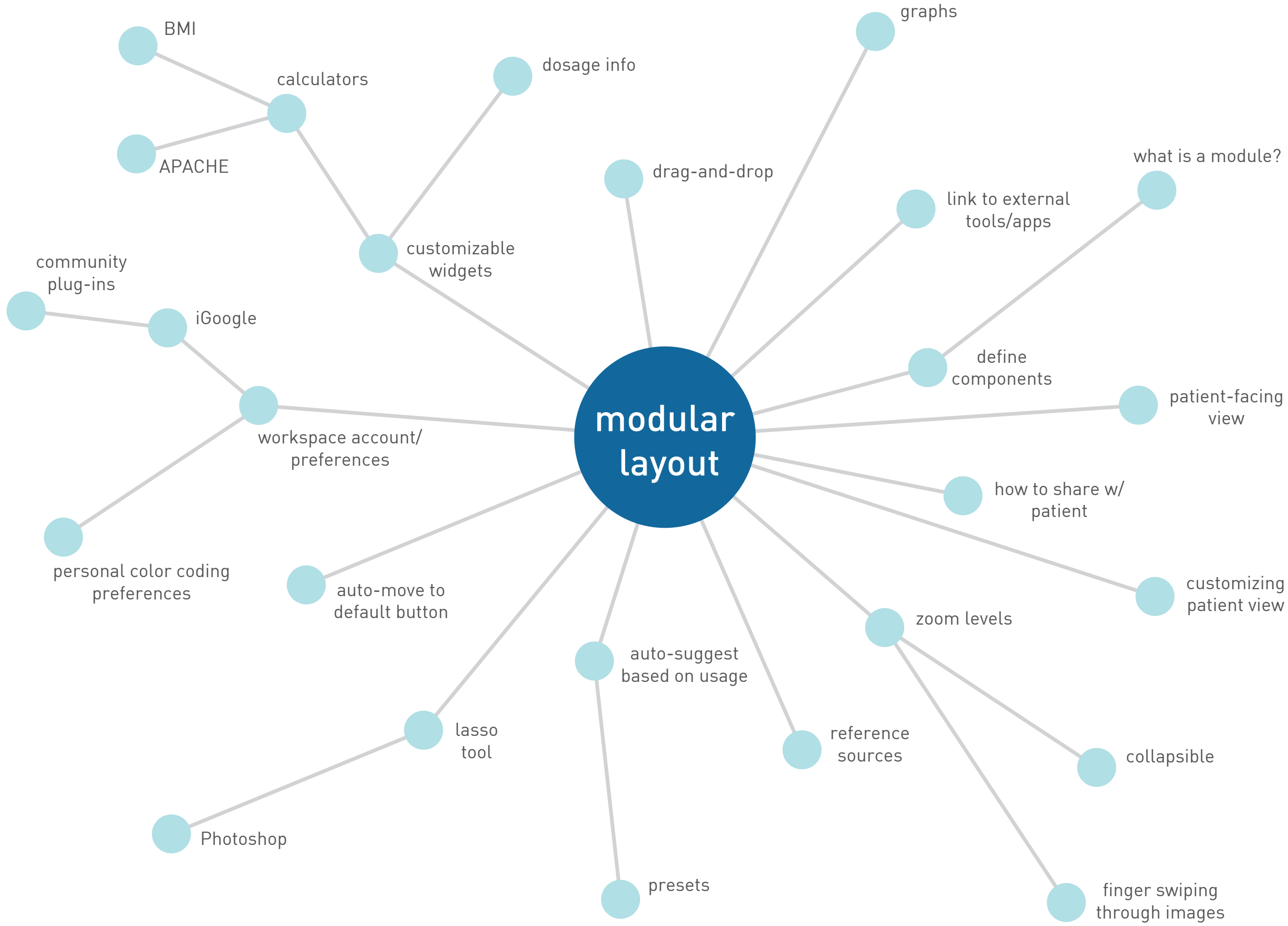
Extreme characterization is way to diverge from designing for the classic user or target group. This allows the group to think about about what kind of needs an unconventional user has for the product at hand. By designing for an extreme character, character traits and interactions can be exposed that may not have originally surfaced.

Mind-Mapping

The last method we used was mind-mapping, a collaborative process where participants work together to generate, visualize, and classify ideas in a radial manner. There is a central topic or question at hand and participants connect the main subtopics by using keywords, phrases, and sub-subtopics. Groups can choose one subtopic to expand at a time or brainstorm freely by adding ideas to whichever subtopic they choose. Collaboration and brainstorming off of others' ideas are encouraged.

*J. P. Djajadiningrat , W. W. Gaver , J. W. Fres, Interaction relabelling and extreme characters: methods for exploring aesthetic interactions, Proceedings of the conference on Designing interactive systems: processes, practices, methods, and techniques, p.66-71, August 17-19, 2000, New York City, New York, United States

Mind-Mapping Diagram



This mind-map was created during one of our brainstorming sessions on the topic of providing a modular layout, wherein content is broken into customizable clusters.

IDEAS FROM BRAINSTORMING

Innovative interaction styles, status indicators, and customizable components

Brainstorming exercises benefited the team by providing an expression for crazy design ideas. Due to sheer quantity, most of these ideas were not used in the final design. Nonetheless, brainstorming facilitated a shared understanding in the team and provided an opportunity to discuss the direction of the project more openly. A selection of some of the more intriguing ideas are described here.

Interaction Relabeling

Our interaction relabeling session involved generating ideas for different ways to present relevant information. We generated ideas by considering a clarinet, GPS, and stethoscope as ways to view patient information. The clarinet served as a metaphor where pressing different valves changed the results that the doctor would see. A GPS would know the doctor's location in the hospital and automatically present relevant patient information based on proximity to certain rooms or people. A stethoscope could provide relevant audio information while the chest piece could double as a dictation mouthpiece.

Extreme Characterization

During our extreme characterization session we considered the requirements of an information display for a bartender. We chose a bartender because their responsibilities include tracking tabs and balancing the needsseveral customers at the same time. We felt that this was analogous to some of the roles of a physician, while also being sufficiently different to allow us to brainstorm freely. Through the brainstorm we came up with several ideas that could be relevant to the Patient Information View. First, we decided that a status indicator is needed to facilitate communication. Second, the interface needs to allow for glanceable tab tracking. We also discussed different views depending on the fullness of the bar and a way to track the identity of patrons.

Mind-Mapping

We conducted a mind-mapping session on the topic of a modular layout. Some features involved customizable widgets for dosage information, as well as BMI and APACHE calculators. Based on our brainstorming, we briefly considered customization of the entire interface. A workspace account such as an iGoogle interface could involve personal color-coding preferences and community plug-ins. However, due to the constraints on the project, we decided to focus on presenting relevant information and moved away from our modular layout ideas.

PARTICIPATORY DESIGN

Involving users in the design process

Participatory design is the practice of bringing potential users into the design process by cooperatively designing and building systems with them. This takes advantage of the expert knowledge of the user population in order to make something more directly suited to their needs and desires. By interacting with tangible items and experiencing the design process, users begin to see the problem space in a new light and can provide new insights which are more concrete and objective than those normally acquired in straight-forward interviews.

Card Sorting

In our task, participants were given cards with different types of patient information. They were asked to organize the cards and discuss their thought process. They could organize in any way that seemed logical to them, by importance, sequence, or related information.

OUR PARTICIPATORY DESIGNERS

- 2 physicians, neurology
- 1 physician, emergency medicine
- 2 residents, neurology
- 1 resident, emergency medicine
- 1 medical student

These sessions helped to validate our findings from field research. Many of the results from these sessions mapped closely to those of previous research, while a few unique findings did arise (described in the following pages). Our participants ranged from a young medical student to an experienced attending physician, and included doctors from highly specific specialties such as neurology. With this breadth of participants it was particularly interesting to see the overlap of what was considered to be important or related information.

Sketching

As part of our participatory design phase, we also tried to engage physicians in a sketching activity. We thought that this would allow them to imagine an ideal interface, which could in turn help inspire our design ideas. Instead we found that they merely redrew the systems that they were accustomed to using. Based on our contextual research, we knew that these systems were flawed. In use, physicians had complained of problems with the very same systems that they then reproduced in sketches. Because the sketching activity did not provide new insights, we decided to focus fully on the card sorting activity.

Results of a card sorting session with two residents currently doing a rotation in neurology. They specifically highlighted the importance of including allergies, vital signs, and medications.

FINDINGS FROM CARD SORTING

Understanding the hierarchy of patient information

Primary Care Physician (PCP) Information

While our attending physician greatly emphasized the importance of knowing a patient's PCP, we found that most of our other participants placed that card as very low priority or cast it aside entirely. This is most likely because the attending physician has such vast experience in his hospital system that he personally knows many other physicians, PCPs in particular. For him, knowing the name of a patient's PCP provides many clues about the kind of care a patient usually receives, and sometimes even about a patient's existing health problems. This information was very valuable to him because of the tacit knowledge he had about other physicians.

For the other doctors we spoke with, who were all much younger, this information was not as important. One participant did mention that knowing what kind of doctor a patient had as their PCP could be valuable. We took this as a sign that it is actually very helpful to be aware of a patient's PCP, but that many doctors lack the experience and knowledge to know that a specific doctor's name implies a certain kind of patient care.

RECOMMENDATION

Provide information about PCP while making sure to include their area of specialization

Patient Status

Several of our participants stated that patient status was a vague and highly subjective category. It would not provide much useful information to them. They stated that the only department that would find status information useful was the emergency department. One participant said that status was "just your judgment" so it could vary widely from doctor to doctor and patient to patient. This was confirmed by another participant who said that it was unimportant, particularly outside the context of emergency care.

RECOMMENDATION

Patient status is not critical information

Most Critical Pieces of Information

Of all the different types of information, the participants consistently grouped allergies, vital signs, current medications, and past medications as the most useful information to quickly understand a patient's health status.

RECOMMENDATION

Emphasize allergies, vital signs and medications

Card Sorting Results Diagram

This diagram shows the result of one of our participatory design card-sorting sessions. This is the organization of cards created by one physician, with descriptions for the groupings.

FINDINGS FROM CARD SORTING (continued)

Understanding the hierarchy of patient information

Department-specific Information

In several situations, participants made reference to department-specific information. Neurologists that we spoke with said that they would like a section for neurologic history so they could distinguish the most relevant information from other visits. Some residents that we spoke with said that they wanted a specific way to access surgical history because this could be important to the task at hand. It was apparent that departments were mostly interested in seeing information relevant to their area of expertise.

RECOMMENDATION

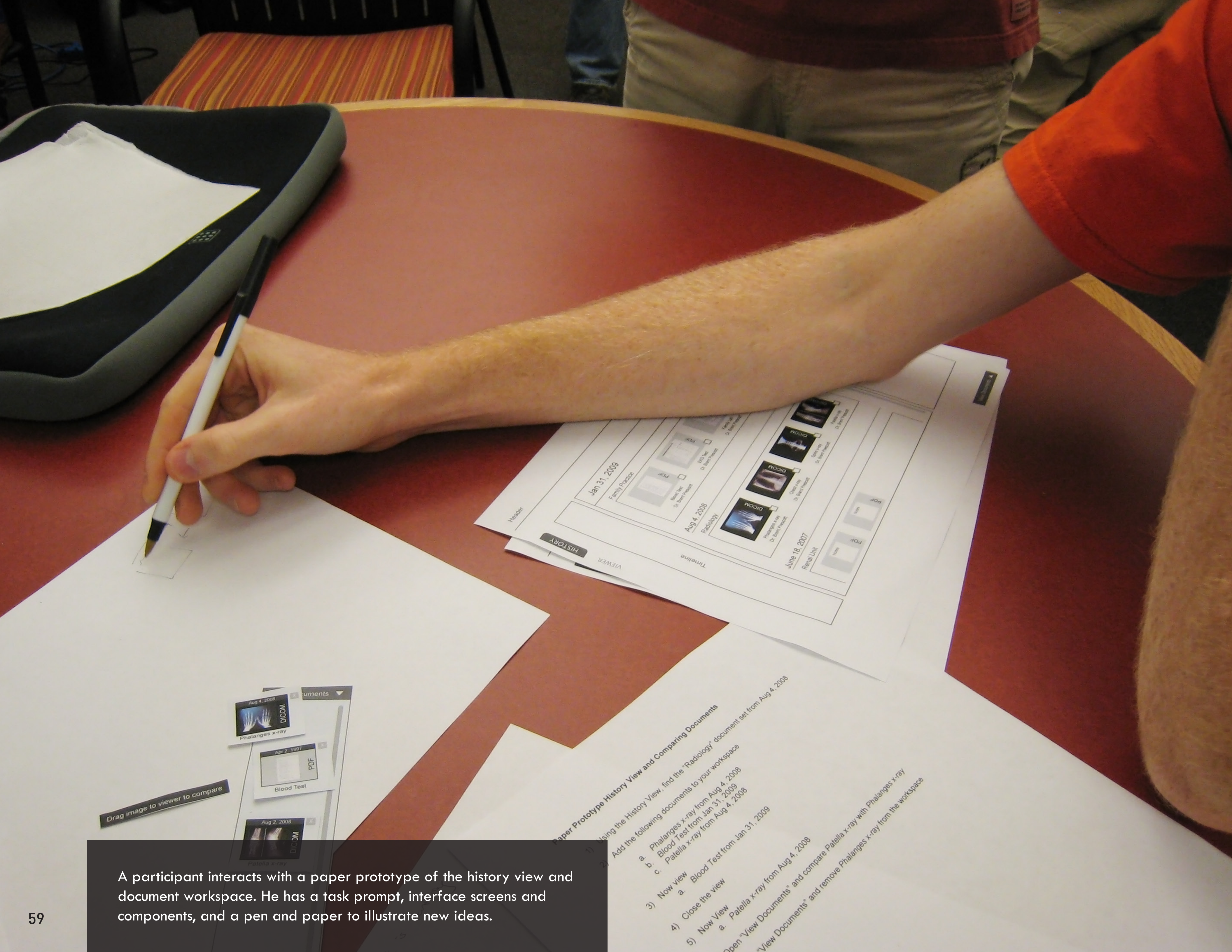
Group patient history by department

Less Important Information

Participants identified certain pieces of information as extraneous. These included insurance information, vaccines, and patient contact information. Patient contact information was cited by some participants as being useful because it would allow them to contact a patient's family members if the patient's condition worsened suddenly.

RECOMMENDATION

These types of information must be available but need not be featured prominently



A participant interacts with a paper prototype of the history view and document workspace. He has a task prompt, interface screens and components, and a pen and paper to illustrate new ideas.

PAPER PROTOTYPING

Early testing of low-fidelity designs

Paper prototyping is a method for quickly eliciting user feedback about an interface. It allows the design team to perform rapid iterations before committing to a visual style or high-fidelity implementation. The cost of creating new paper prototypes is very low, making it easy to discard designs that don't work and move on to improved versions. Also, because the team has not invested a large amount of time or effort to make the prototypes, they are more inclined to experiment with new ideas.

Process

In our paper prototyping phase, we created screens by sketching on paper or by making very simple wireframes (basic interface outlines) on the computer. We printed out these wireframes and cut out interactive components so that they could easily be moved around to simulate the changing interface. In order to run a successful paper prototyping session, the facilitator had to be well prepared to switch out components as the user performed their interactions. During the task, participants were provided with a task prompt to provide context for the interaction. They were then asked to think aloud about what they were seeing and doing.

Learning

While paper prototyping provides an excellent way to get quick feedback early in the design phase, we learned that it has some limitations. For example, interactions which are time-sensitive or require very smooth feedback (such as drag-and-drop) are almost impossible to test convincingly. In addition, some elements require a particular, styled appearance. A button may not look interactive when it is simply a hand-drawn rectangle, meaning that users may not realize that it is clickable.

Outcomes

Results and insights from paper prototyping are discussed in the Evaluation section of this report.

A click-through prototyping participant completes a timeline task. This prototype, created in Adobe Flash Catalyst, allowed the team to evaluate the effectiveness of showing metadata on hover.

CLICK-THROUGH PROTOTYPING

Testing higher-fidelity designs and interactive elements

Click-through prototypes consist of simple wireframes, usually lacking much aesthetic style, which has some basic interactivity applied to it. Typically, these prototypes are in no way fully functional, but are instead hard-coded just enough to allow for testing of particular interactions - e.g. nothing on a page may work aside from the one button which is being tested. Often this step directly follows paper prototyping of an interface idea, so the click-through prototyping is meant primarily as a more technically accurate validation of the ideas, though in some cases where paper prototyping cannot be used, click-through prototyping serves as the first level of concept validation.

Process

We used a variety of technologies to build these prototypes, including Adobe Fireworks and Adobe Illustrator for the layout of the wireframe and Adobe Flash Catalyst and HTML for providing interactivity. For simple interactions, Catalyst was used to extend wireframes to allow for state-based interaction - e.g. different interactions would cause the system to change to a different, pre-determined state. For more complex interactions, such those requiring more dynamic state changes, HTML proved a more suitable tool for prototyping. Click-through prototypes built in HTML on occasion also served as a proof-of-concept design for any components we felt could be technologically difficult to implement, such as the timeline.

Learning

Click-through prototypes have the advantage of exploring the interaction in a context closer to the actual implementation, and can also be quicker to test than paper prototypes (as less proctoring is needed). Additionally, the feedback from click-through prototypes can often be of greater quality than paper prototypes as users have an easier time imagining how the system will actually work. The downside of this type of prototyping is that it can take longer than lower fidelity prototypes and may still lack the full context of the interaction.

Outcomes

Results and insights from click-through prototyping are discussed in the Evaluation section of this report.

FINAL IMPLEMENTATION TESTING

Usability testing to ensure the most effective design solution

As part of our agile prototyping process, we incorporated usability testing to quickly receive feedback from physicians. This allowed us to immediately fix usability problems and iterate on the design. The goals of general usability testing are to determine the performance of the system. Some metrics include: how often users express confusion or frustration, the number of mistakes made while using the system, and whether the user feels the task was completed.

Process

In our version of usability testing, we used the think-aloud protocol to observe physicians using the system while they verbalized their thought process. Having participants say what they're thinking helps illustrate where the interface successfully or unsuccessfully matches expectations. To make the most of our limited time and run as many iterations as possible, we conducted rapid usability tests in the cafeteria at a local hospital. This gave us access to a large number of physicians from a variety of different departments. Each test conducted was about ten minutes in length and users were given a script with five tasks to complete. We used Clearleft Silverback usability testing software to record the user's screen activity, voice, and video of their face.

Learning

While usability testing has proved to be a very effective tool for discovering problems, it does come with some inherent trade-offs. In order to meet the quick turn-around time of agile development, usability testing is often performed in quick spurts. This typically meant that each round involved about five users, which had the potential to introduce bias due to the small sample size. Because usability testing involves a high-fidelity, fully-designed prototype, users may fixate on small design details. To overcome these drawbacks, we internally discussed all feedback and carefully scrutinized any changes.

Outcomes

Results and insights from usability testing the final implementation are discussed in the Evaluation section of this report.

USING WEB TECHNOLOGIES

Implementing in a universal language well-suited for easy prototyping

The PIVOTAL team decided to implement our final prototype using web technologies, mainly HTML5, JavaScript, and CSS3. Additionally, the powerful JavaScript library jQuery allows us to quickly create highly-dynamic webpages. Finally, we are also utilizing PHP5 as a simple template engine and XML for data files. Our decision to use these technologies was based on many criteria, with prior experience being particularly important. The iterative nature of this project, along with the short development cycle, meant that we had little time to ramp up on proprietary programming languages and systems. Furthermore, every PIVOTAL team member has had significant experience with these technologies.

Our web strategy has proven to be a great choice in that our iterations have been quick and easy to deploy. Additionally, finding resources online is simple, and debugging has not been difficult. We have chosen the Google Chrome browser (and its underlying rendering engine WebKit) to serve as our base case for development purposes. Chrome has proven to be a fast and stable cross-platform browser, and WebKit has quickly and steadily adopted many of the requisite HTML5 technologies. Since the PIV application is developed in open web languages, translating the interface in the future to a mobile device, like a tablet, would be trivial and require only minimal HTML and CSS changes.

PROTOTYPING TOOLS

- HTML5 and CSS3
- jQuery JavaScript library, and custom-written JavaScript for widgets and controls
- XML files of test patient information

PROCESS SUMMARY

An effective process for quickly developing and testing our design

By utilizing numerous methods of testing and rapidly iterating throughout the process, the team was able to quickly test ideas, develop components, and ensure that the system is extremely usable. Starting with paper prototypes, ideas were quickly sketched on paper and then tested to validate the underlying concepts and basic interaction details. From there, validated ideas were made into clickable prototypes using tools like Adobe Flash Catalyst and HTML. These prototypes provided a more realistic representation of the idea and allowed for greater feedback about interaction details and design layout. Finally, the ideas which passed these phases of testing - now having been iterated upon numerous times - were built into a high fidelity HTML prototype.

This prototype fully represents the basic functionality of the system and, in particular, the information organization and interaction techniques designed for the PIV. This prototype underwent numerous rounds of usability testing with both target users and participants outside of healthcare. This testing ensured that every detail was as polished and usable as possible, and validated fundamental design concepts which were difficult to illustrate in lower fidelity prototypes.

EVALUATION

A PIVOTAL team member leads a workshop discussion of the filters interface. By breaking the interface into smaller components, we could iterate thoroughly on each piece.

ITERATIVE COMPONENT-BASED PROTOTYPING

Quick iterations on small, but significant, details of each component

This section describes the development of the PIV interface. We broke the interface into smaller components in the early phases of development. Each of these components was sufficiently separable that it could be perfected individually before combining it with others. This was largely possible because there were a number of different views that needed very distinct interactions.

With each component (header, timeline, history view, filters, and document view) we prototyped, usability tested, and critiqued our designs. This made it possible to work through the intricacies of each piece. This attention to detail would have been impossible in a test of the overall system.

To avoid designing an inconsistent system, all component-specific prototyping was performed at low levels of fidelity. With each component vetted by paper and click-through prototyping, the final design could be implemented by bringing all of the components together. This section describes the component-specific design decisions and usability testing results that eventually led to our final design and vision.

Header Information Comparison Diagram

	Name	Age	Date of Birth	Sex	Medical Record Number	Phone Number	Allergies	PCP	Address	Next Appointment	Photo	Encounter Date	Current Provider
Cerner EMR	●	●	●	●	●	●	●	●	●				
Cerner FirstNet	●	●	●	●	●		●						
eClinicalWorks	●	●	●	●	●	●		●	●			●	●
Eclipsys	●	●	●	●		●							
e-MDs	●	●	●	●							●		
McKesson Medisoft	●	●	●	●	●					●			
McKesson Practice Partner	●	●	●	●	●					●	●		
NextGen EMR	●	●	●	●								●	●

Based on a review of several EMR systems, the most commonly featured patient header information is name, age, date of birth, and sex.

ABOUT THE HEADER

A glanceable format for viewing a patient's demographic information

Although the header may seem like a small part of the overall interface, the information it contains plays a critical role. It is very important for a physician to easily be able to identify what patient they are currently looking at and extract any necessary demographic information. Many other systems that we have observed have overly cluttered headers. Their cluttered appearance is usually the result of overloading the header with unnecessary information, or having an unclear visual hierarchy of information. The goal of our design is to provide the necessary and useful information in a view that is both easily accessible and quickly comprehensible.

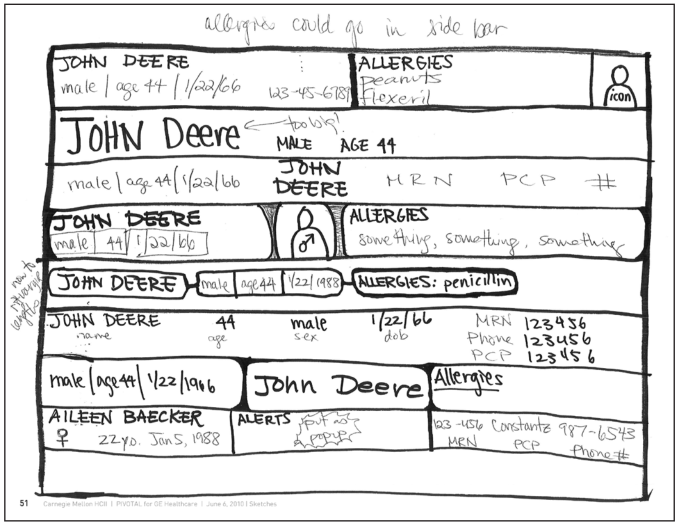
Our research has shown that doctors are usually not interested in seeing all of a patient's demographic information. Instead, doctors are most interested in the patient's name, date of birth (and age) and referring physician. In some departments, there may be other critical information (like weight for pediatrics). Our research also indicates that excess data on the screen overwhelms the user, and is another reason why we are trying to hide extraneous or less-pertinent data.

We looked at a number of existing EMR systems to determine the most commonly displayed pieces of information (see diagram, left). Only four pieces of information appeared in every interface that we looked at: name, age, date of birth, and sex. These key pieces of information are significant because they allow the physician to quickly identify the patient. Other information was placed in the expanded portion of the header, as discussed in this section. Finally, some information was excluded due to the constraints of the data available to us.

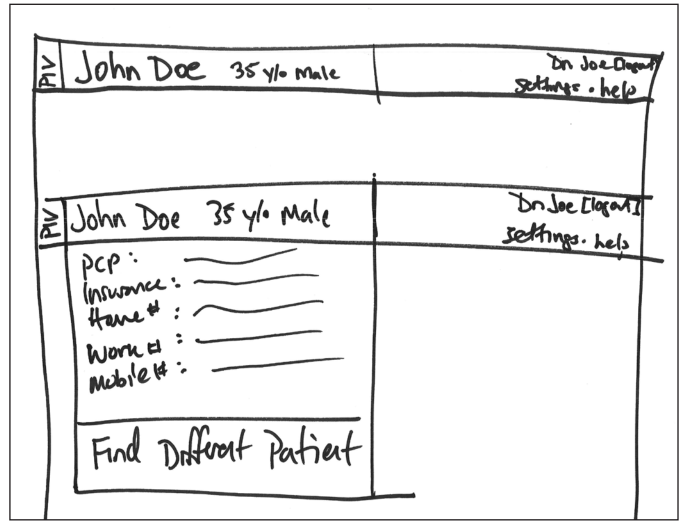
HEADER

DESIGNING AND TESTING THE HEADER

Primary patient information is always viewable while secondary information is collapsed from view



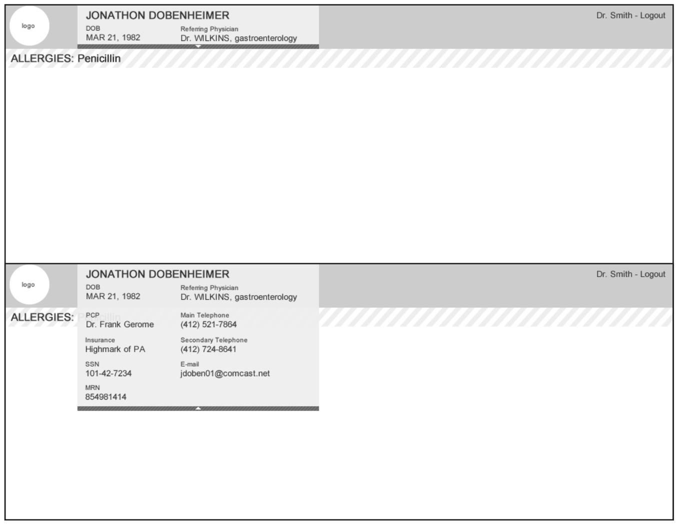
Quick sketches of early header design ideas



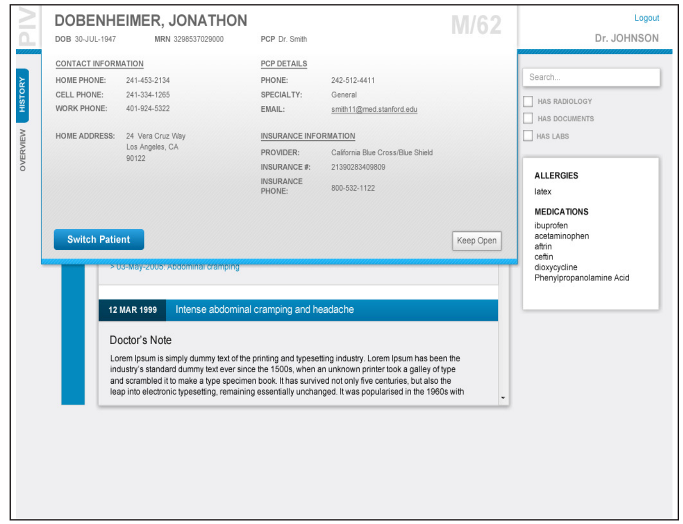
Paper prototype (closed and open state)

These early sketches include different brainstorming ideas for identifying a patient and differentiating one record from another. One area of concern was that physicians might look at the wrong record and mistakenly diagnose a patient based on another patient's information. In these sketches we considered the idea of using iconography and typography to make a patient's identity more obvious. These sketches also explored what types of information need to be present and how they could best be organized.

One of the distinguishing characteristics of our header is that only the most important patient data is displayed by default. To access the secondary information the user must mouse over to the header "shelf" area. At this point the shelf extends downward displaying the full set of patient demographic information. This early sketch demonstrates the origins of this idea.



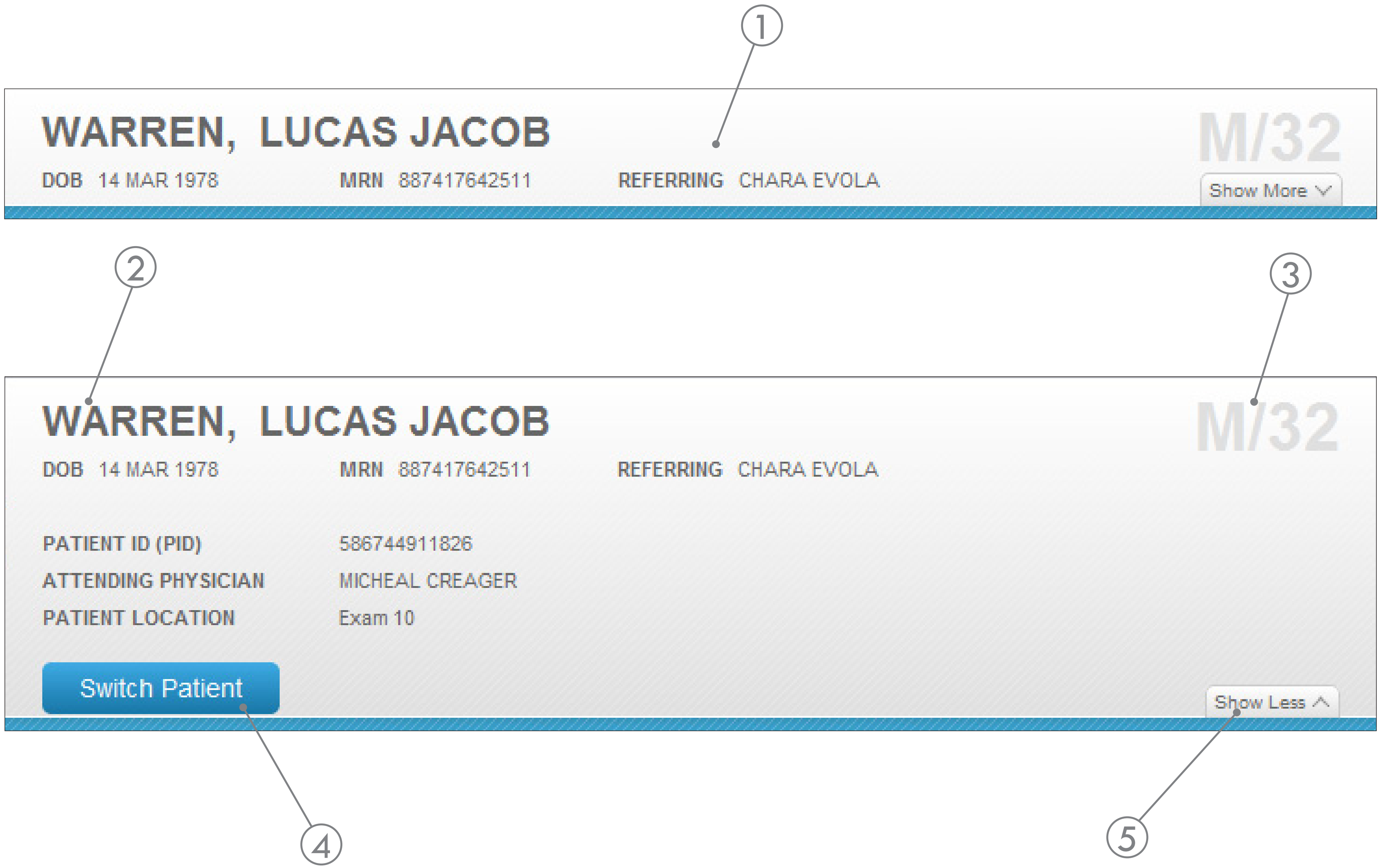
Click-through prototype in Adobe Flash Catalyst (closed and open state)



Early iteration of final prototype (open state)

One of our click-through prototype tests focused on the idea that secondary patient information would be hidden until explicitly requested by the user. The secondary patient information would be accessed by mousing over the primary information. Our usability test showed that users were able to intuitively access the secondary patient information without much difficulty. However, a later usability test found that the hover effect caused the header to open too frequently, and the design was updated so that the header only opened when a user clicked.

Our header is also characterized by clean, easy-to-read fonts and high contrast colors. We also exploit typographical cues to make certain text stand out, like the patient's last name. Furthermore, our header is prudent in its use of vertical space so as to obscure as little of the main section as possible when closed.


1
WARREN, LUCAS JACOB
M/32
DOB 14 MAR 1978
MRN 887417642511
REFERRING CHARA EVOLA
Show More
2
3
WARREN, LUCAS JACOB
M/32
DOB 14 MAR 1978
MRN 887417642511
REFERRING CHARA EVOLA
PATIENT ID (PID)
586744911826
ATTENDING PHYSICIAN
MICHEAL CREAGER
PATIENT LOCATION
Exam 10
Switch Patient
Show Less
4
5

FINAL HEADER DESIGN

A glanceable format for viewing a patient's demographic information

1. A collapsed view shows only the most important information, saving space.

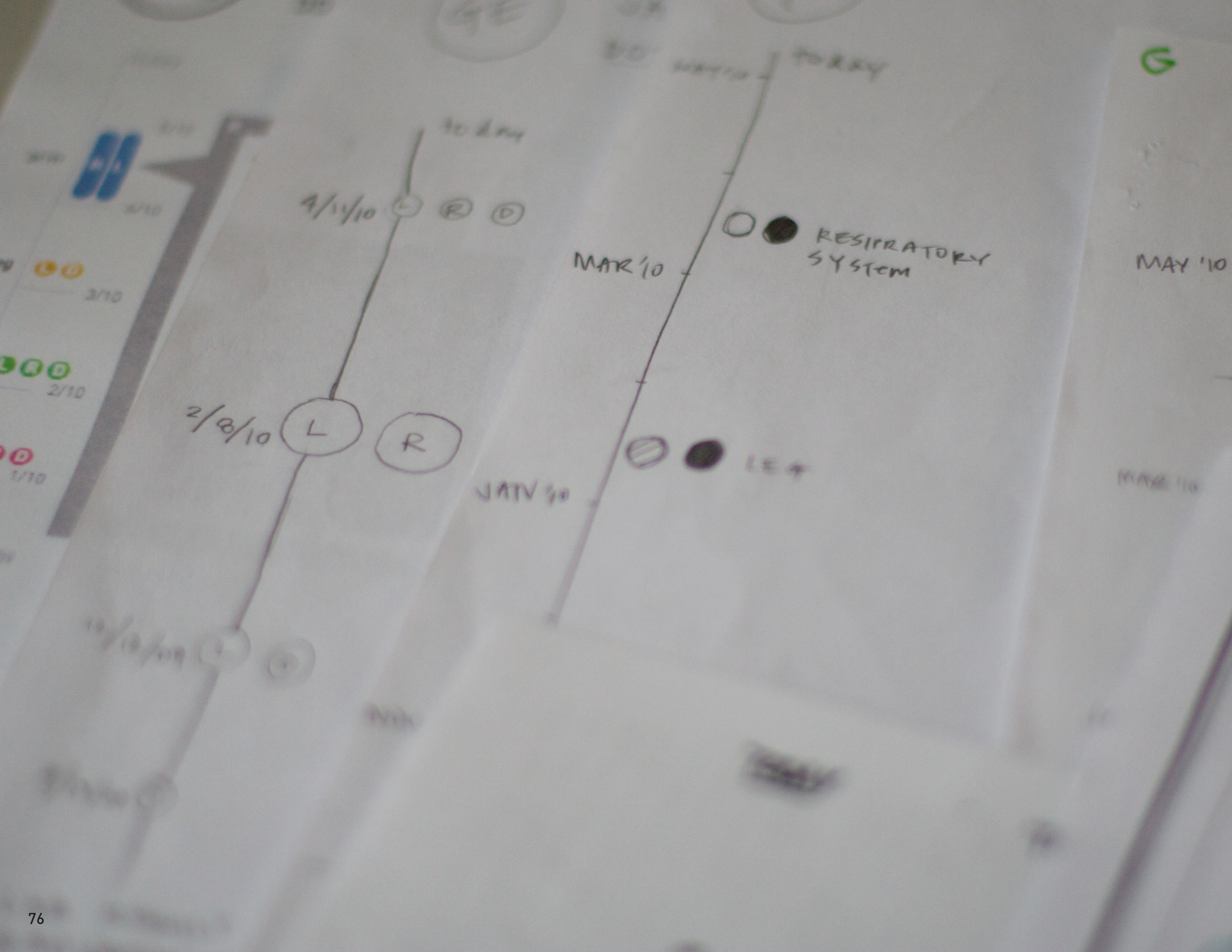
2. Typography draws attention to the patient name, helping to avoid mix-ups of patient information.

3. Though subtle, this indicator of sex and age provides quick glanceable demographic information about the patient and increases safety by allowing the user to verify that they're looking at the correct patient's information.

4. This button would take the user to a patient selection screen (not developed for this prototype).

5. This button — analogous to the "Show More" button in the collapsed header — helps keep the header area free of clutter and unnecessary information. Clicking anywhere outside of the header will also cause it to auto-collapse, since it would otherwise obscure parts of the timeline and history views.

   Also, if users need access to additional information when they are in the collapsed state, it is always one click away.


4/11/10
2/8/10
L
R
MAR '10
RESPIRATORY SYSTEM
MAY '10

TIMELINE

ABOUT THE TIMELINE

A longitudinal visualization of a patient's record

The timeline component is the primary navigational tool of the PIV interface. By displaying a longitudinal view of a patient's visits, the timeline provides a way to get a sense of a patient's entire health history. A user can also select a visit from this view to access the documents and images associated with it. The usability goals for this component include easy navigation to specific events, ease in finding a specific date or document, and easily glanceable data, allowing doctors to skim through years of medical history at a high-level of detail.

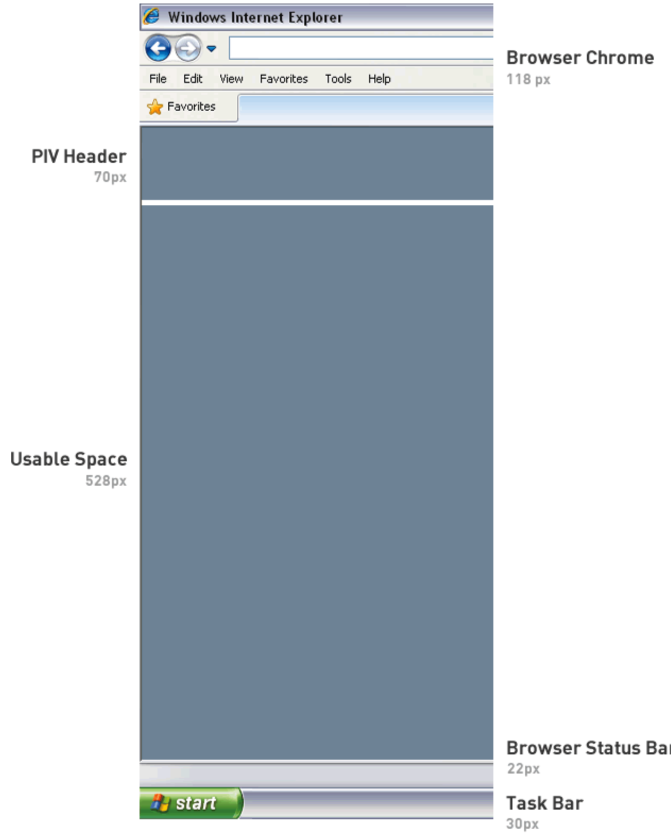
The timeline proved to be a particularly challenging design problem for a number of reasons. First, the timeline needed to fit into the overall interface without losing too much usable information space. This was resolved by creating a vertical timeline (pg. 79) which took advantage of the fact that most computer screens are wider than they are tall. Making the timeline glanceable and understandable as a visualization of a patient's health entailed many information design challenges (pg. 80). We also encountered some patient data sets that were difficult to incorporate because they were so large. We began by discussing this problem internally and hosting a design workshop on the topic of timeline design (pg. 81). Finally, we determined that a two timeline view was the best solution to the problem (pg. 82). This design has one timeline on the left which shows the entire patient record, and another for navigation of the history view.

WHY VERTICAL?

Dealing with the limitations of screen real-estate

Our research has indicated that most doctors work on older computer equipment, and do not have the luxury of working with large monitors. Since the aspect ratio of most screens is 4:3, a typical screen affords more horizontal real estate than vertical. To make things worse, valuable vertical space is used by the browser chrome and other operating system components. Additionally, application toolbars and header bars further reduce the amount of available space. In practice, a typical web application may have as few as 600 pixels of usable vertical body space. By contrast, the usable horizontal space is nearly double that.

To avoid taking up additional vertical space with a traditional horizontal timeline, we explored ways of showing time on a vertical timeline. Some of the issues we encountered include how to: represent recent vs. old events, show detail for tightly clustered events vs. sparsely distributed ones, and show key information in a glanceable fashion, all while remaining user friendly.



Due to the vertical space lost to browser and operating system components, the available space on a typical 1024 by 768 monitor is actually only 598 pixels. Of this, we are devoting 70 pixels to the PIV header.

INFORMATION DESIGN CHALLENGES

Handling data sets of different sizes and lengths

Designing the timeline view faced a number of challenges, mostly due to variation in patient data. Some patients may have such long and complex medical histories that data points would be crowded, making it difficult to select one visit. Trying to fit a fifty-year patient history into the 528 pixels of available vertical space would make the timeline useless as a navigation tool, even if it still provides an effective visualization. We took this into consideration in our design, and included a way to view an expanded portion of the timeline. We also experimented with whether the timeline needed to be displayed on an absolute scale, or whether merely seeing sequence was the most useful. We decided in the end that we could accomplish both by scaling the left timeline but not the right. In this way users can see clusters of events on the left, and can easily navigate dates on the unscaled right portion of the timeline.

We also encountered several other design challenges. First of all, labeling and iconography pose a problem. Fitting this additional information on the timeline takes up a considerable amount of space, which we dealt with by making most of this information visible on mouse-over. Another problem is that some visits may be much more important or severe than others. Whether or not this should be part of the timeline visualization was questioned, but could not be implemented based on the available data.

Furthermore, we unearthed several interaction design difficulties through implementation. We quickly discovered the complexity of displaying independently-scaled units of time between the two halves of the timeline. The design rationale behind this was that timeline information should remain both glanceable and easily accessible. We also discovered the difficulty in conveying which parts of the timeline could be manipulated (i.e. the slider thumb vs. slider indicator). Several tweaks to the timeline were made during the prototype phase.

DESIGN WORKSHOP

Eliciting outside perspectives to help tackle our design challenges

We held a design forum with our colleagues where we discussed the design of the timeline. We encouraged the participants to sketch and discuss ideas they had, as well as talk about examples of well-implemented timelines. This session was great for discovering a whole new set of ideas with which to experiment. We ended up taking some of the best pieces from several different designs and started our new timeline design from that point.

One of the ideas that stuck, was the notion of having side-by-side timelines. An example given was that of Google Finance (google.com/finance), in which the user can control the zoom on the main view by using a secondary control. We brainstormed this idea further to arrive at our big design breakthrough of having a segmented timeline.

This diagram shows the double timelines used by Google Finance to allow users to select a range for detailed viewing.

TIMELINE

TWO HALVES ARE BETTER THAN ONE

Providing an overview timeline for glanceability and a detailed timeline for navigation

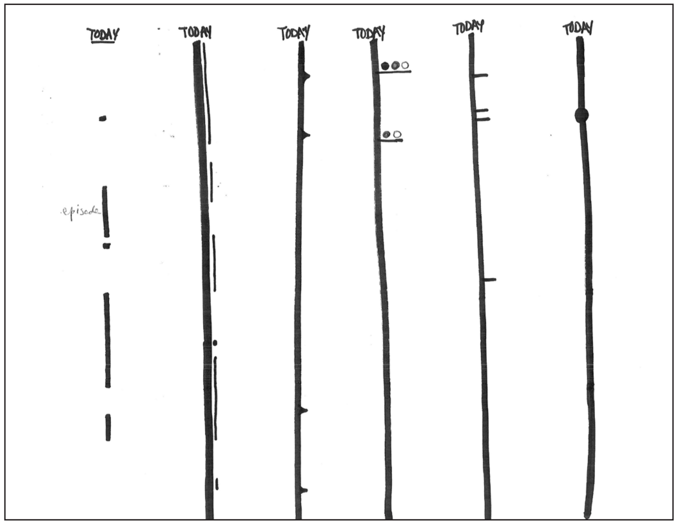
We designed our timeline to utilize two halves — one half is dedicated to showing the entire overview of the patient's medical record, and the other serves as a zoomed-in view. The overview half contains a draggable slider that controls which segment of the overall timeline is viewed on the right-hand side. The slider has an indicated range that stretches depending on the length of time which is dynamically being shown. This approach is beneficial over a traditional range selector because it saves the user valuable time of setting the range. In our design, the temporal range of the right half is a function of the maximum number of items that can be displayed from the patient record on the right side at a given time. If there are many items in a short period of time, the range will be small. Conversely, the range will be longer if there are fewer items to display.

The right-hand side is also where the user can see specific details of an entry in the timeline. Each row contains the date of the items, the departments they are from, and the number of items by content type (radiology images, documents and lab results). Clicking on a row will scroll the main history view directly to the corresponding entry.

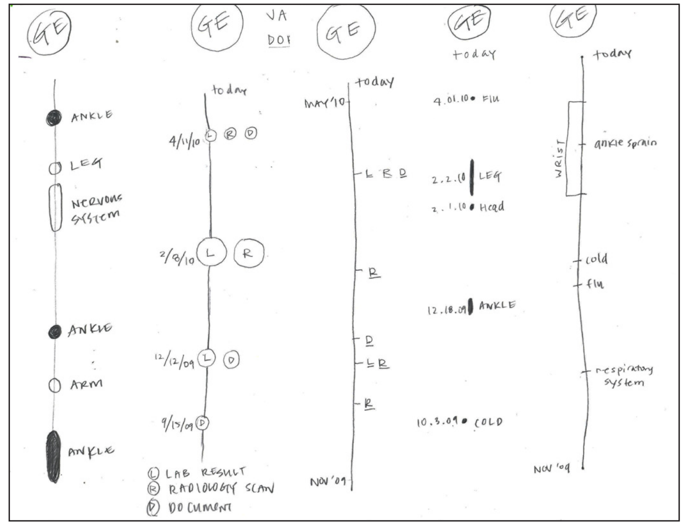
Based on testing results, the timeline was redesigned so that only the left half is shown when inactive. Since the left half has year labels that are positioned along the side, it reinforces the affordance of being a timeline. Furthermore, showing only the left-side while inactive serves to simplify the experience, minimize clutter, and maximize screen real-estate. When a user interacts with the timeline, it instantly springs to life, changing colors from gray to blue and expanding to its full size to show both halves. Moving the mouse away reverts the timeline to its default state after a momentary delay.

DESIGNING AND ITERATING THE TIMELINE

Validating the vertical design concept



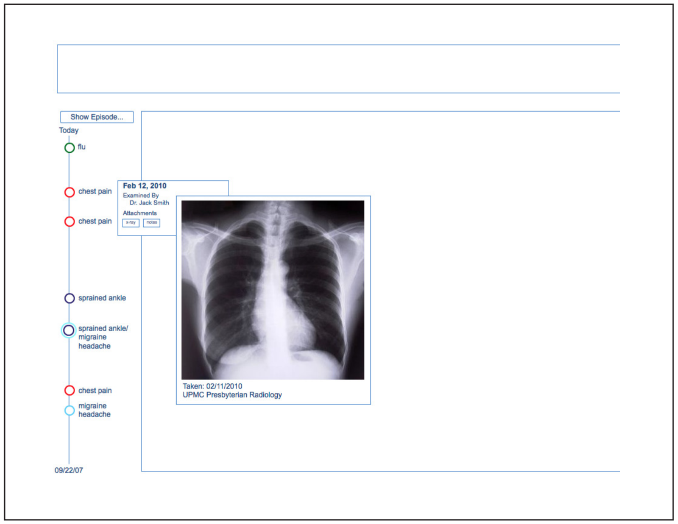
Early sketches of different aesthetics and symbol types



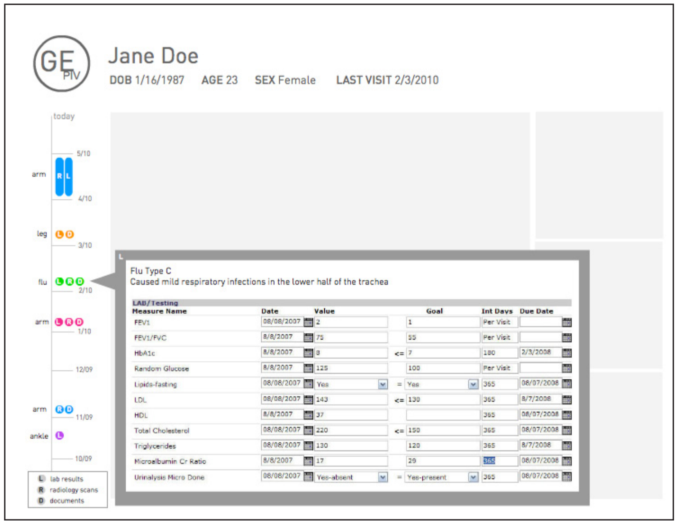
Early sketches of labels and icons

In the earliest test of our timeline, participants looked at sketches and described which they liked or disliked the most. We were primarily interested in seeing if participants understood a vertical timeline. Initially, there was some confusion about whether the oldest record should be at the top or bottom of the line, but participants felt that it could go either way and that labeling would resolve their confusion.

Participants also shared feedback about several aspects of the timeline's aesthetic, including how well it communicated content, what labels might be needed, and what types of iconography to use. Overall, most participants felt that the timelines were too minimalist and required more detailed date labels.



Mockup experimenting with color-coding



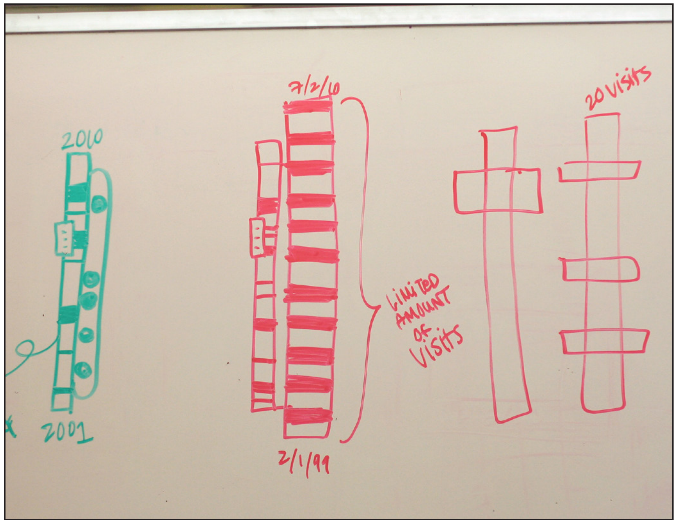
Mockup indicating related episodes

The goals of testing the higher fidelity timeline component were to understand if users would intuitively know how to use a vertical timeline, test the usability of viewing document summary information, and validate the component as a navigational tool. Throughout our testing, users had no problems understanding the vertical orientation of the timeline. Many times the question was asked in academic settings of why it was not horizontal, but no confusion was expressed. Additionally, viewing summary information in pop-ups when over a point on the timeline was easily understood and well received.

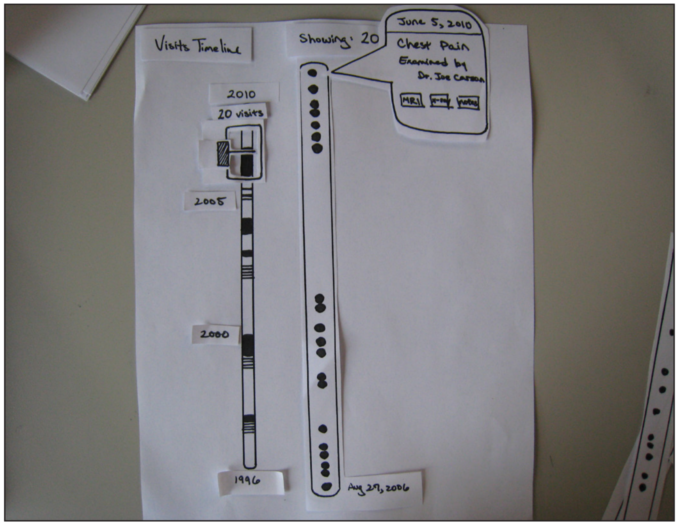
In one of our timeline iterations, episodic categorization of patient symptoms was integrated with the timeline. Through the use of a drop-down list, the user was able to select a specific episode to view. The timeline then filtered to show only visits pertaining to the selected episode. All participants understood the use of this feature immediately.

DESIGNING AND ITERATING THE TIMELINE (continued)

Testing the split timeline component



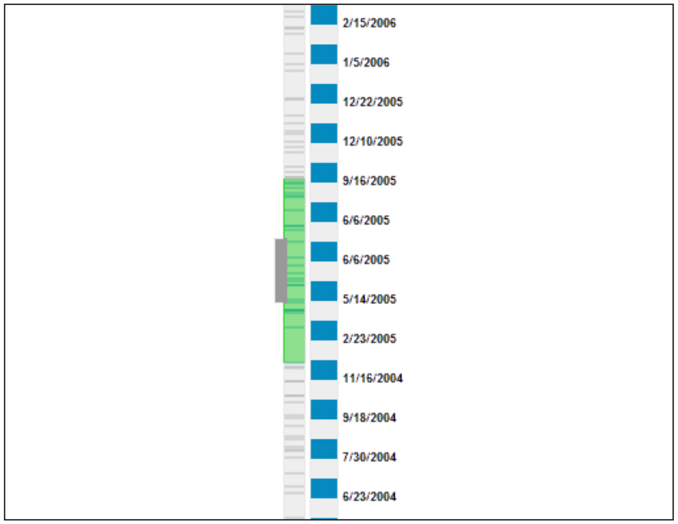
Early whiteboard sketches of the two-timeline view



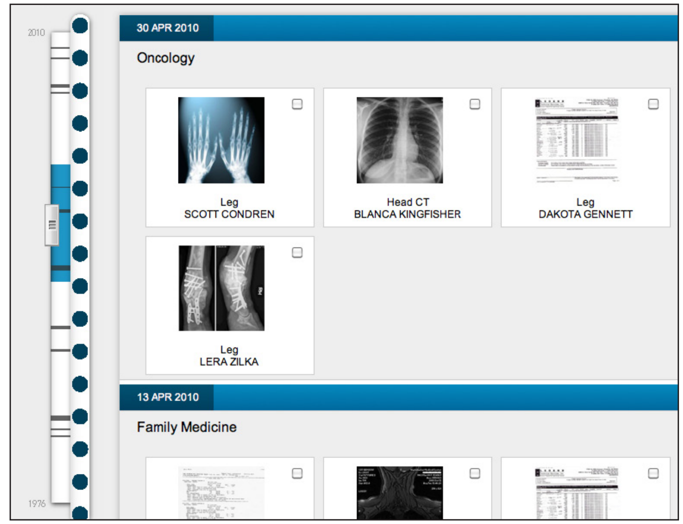
Testing kit for the two-timeline paper prototype

To test the usability of the two-timeline view (pg. 82), we created a paper prototype to see if users could quickly recognize that one timeline is an overview of a patient's entire medical record and the other timeline is a zoomed-in subset of the overview timeline. Users were asked to find a record of a specific date on the paper prototype where they would physically move the selection slider on the overview timeline to that date. Concurrently, a PIVOTAL team member would replace the zoomed-in timeline view that corresponds with the selection from the slider.

Testing showed that users quickly grasped the concept of the two-timeline view, intuitively understanding that the second timeline represented the zoomed-in view of the overview timeline. One issue was whether the transition of the zoomed-in timeline would be distinguishable from the previous selection. Although, it could not be demonstrated in paper prototyping, the transition of the zoomed-in view selection will be a fluid scrolling effect so users can track the transition from one selection to another. Aside from the transition issue, users had no problems understanding the concept of the two-timeline view.



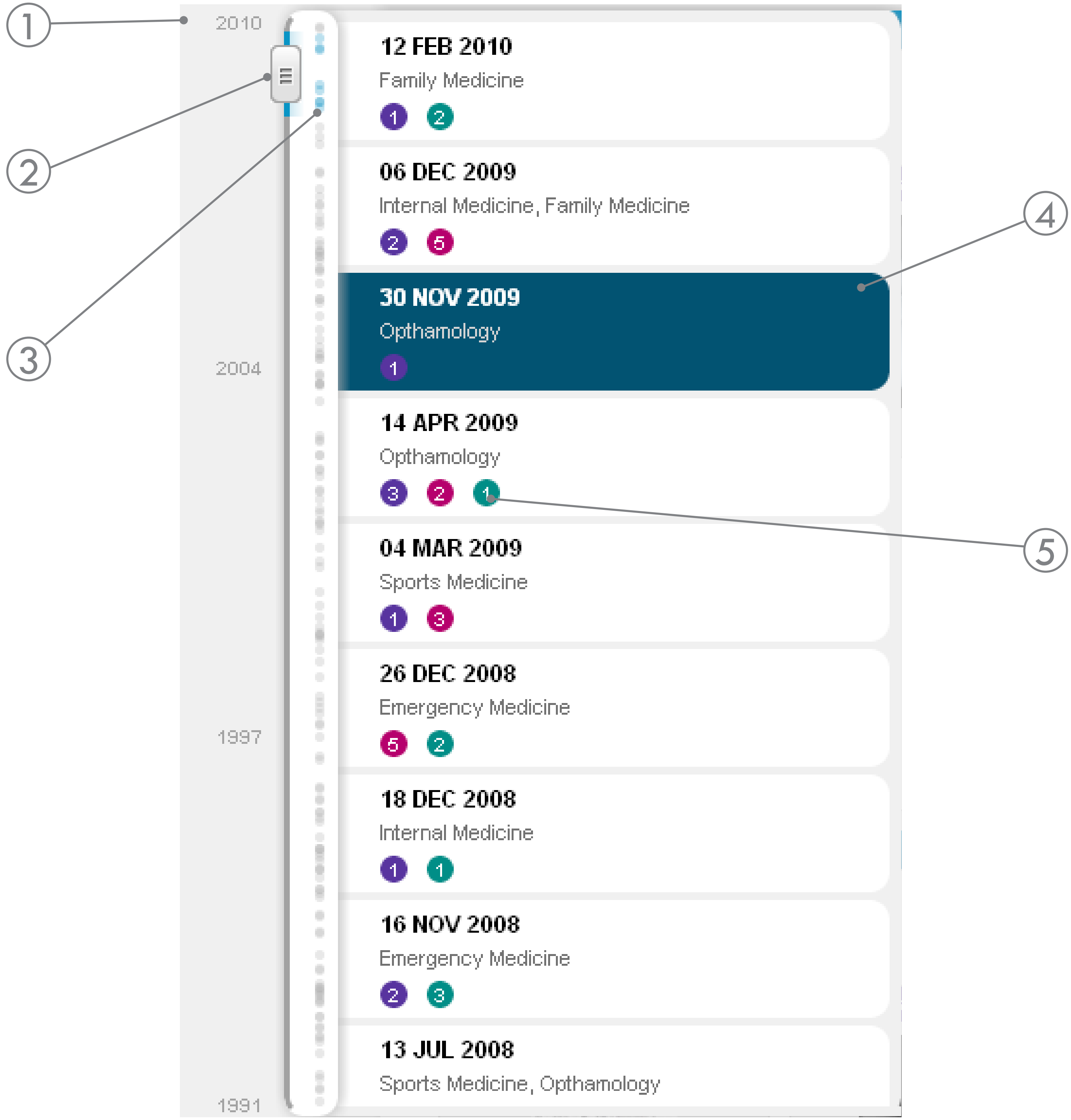
Click-through prototype in JavaScript



Styled high fidelity timeline

To better understand the functionality of the timeline, and to allow for more realistic testing, we created a medium-fidelity click-through prototype in JavaScript and HTML. Building a prototype for the timeline proved challenging, but was extremely useful in bringing to light issues surrounding high volumes of events in a full dataset. Additionally, the high fidelity prototype was built to be usable in the smallest supported screen resolution. The combination of the high volume of events and realistic sizing quickly showed that some of our assumptions about the layout of the timeline needed adjustment.

When there were many events (up to 300 days), the timeline quickly became full. This was especially apparent when events spanned a large period of time, a very likely possibility in the actual implementation of PIV. When a patient had multiple records in nearby dates, the indicators on the "zoomed-out" timeline would often overlap. A patient who sees a doctor and then has labwork done could have a doctor's note from the first day, as well as additional documents from a day or two later. In order to show multiple instances in the same space, we made the indicators semi-opaque, so that layering them on top of each other created a darker appearance.



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2010
2004
1997
1991
12 FEB 2010
Family Medicine
1 2
06 DEC 2009
Internal Medicine, Family Medicine
2 5
30 NOV 2009
Opthamology
1
14 APR 2009
Opthamology
3 2 1
04 MAR 2009
Sports Medicine
1 3
26 DEC 2008
Emergency Medicine
5 2
18 DEC 2008
Internal Medicine
1 1
16 NOV 2008
Emergency Medicine
2 3
13 JUL 2008
Sports Medicine, Opthamology

FINAL TIMELINE DESIGN

A longitudinal visualization of a patient's record

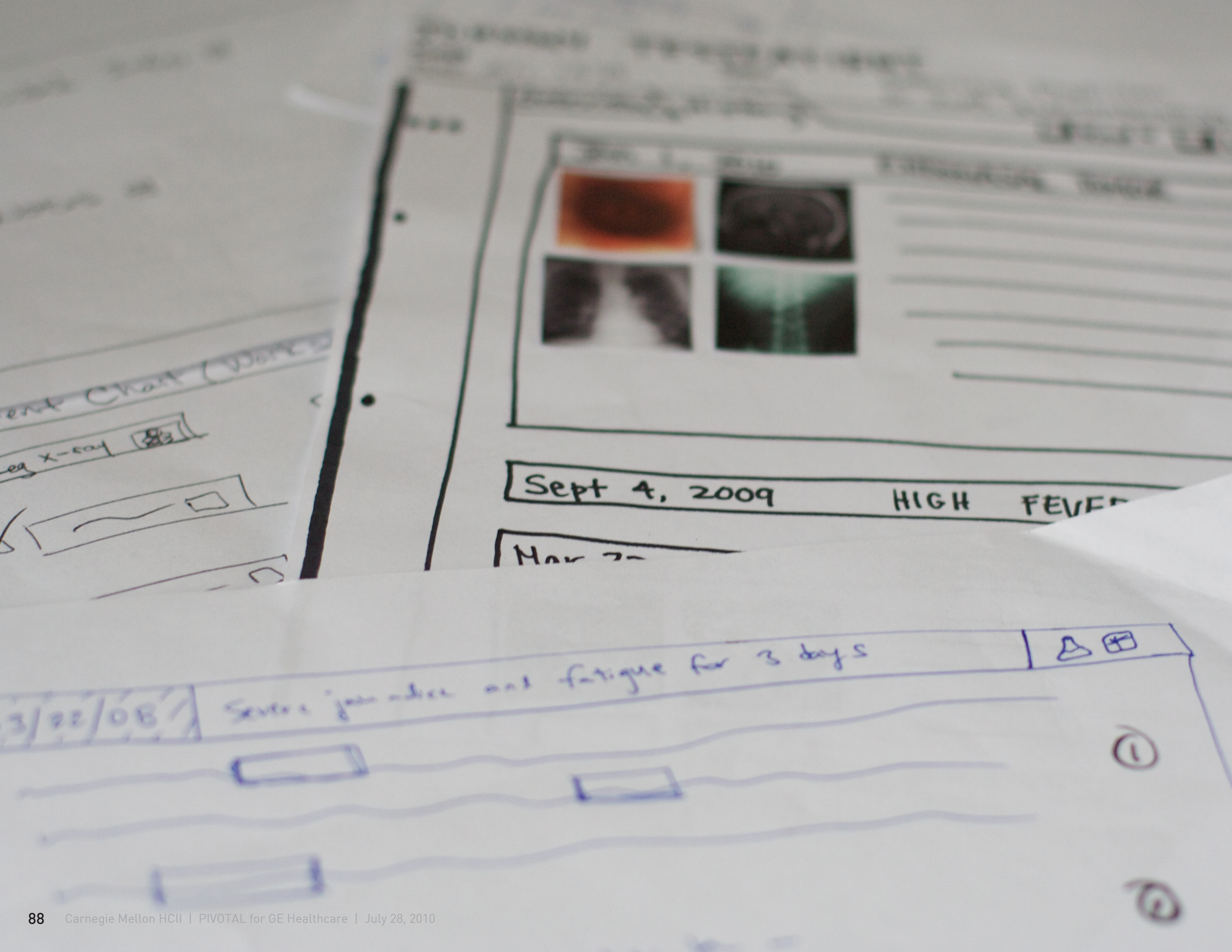
1. The left side of the timeline displays an overview of all the activity in a patient record. Year labels run along the left side and small semi-transparent circles mark individual events inside the bar. Any time a user hovers over this main timeline, the right side detail pane will slide into view.

2. The thumb controls the selected timeline area by scrolling it up and down. In addition to moving the thumb, the user can also click or scroll with the mouse-wheel to move the selected area. Moving the thumb will change what indicators are marked in blue, as well as the detailed view on the right.

3. The selected area is marked by the blue line and gradient when in use (gray when inactive). The selected area is dynamically determined based on the clustering of events, and will always show the maximum displayable amount on the right side.

4. The details view slides out from the timeline date bar and shows a "zoomed-in" table view of the patient record. Clicking on a row will scroll the history view to the selected record.

5. Each entry in the details view shows the event date, departments, and item count by document type. The format for the date was deliberately selected because it is unambiguous, and avoids internationalization problems. The color-coding of the item count markers is consistent throughout the application — including the labels on document thumbnails and in the filters.


Sept 4, 2009
HIGH

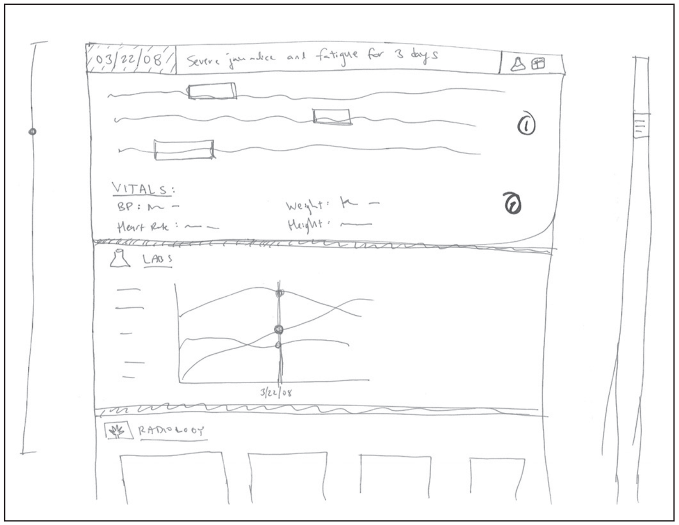
ABOUT THE HISTORY VIEW

A chronological view of all patient encounters and documents

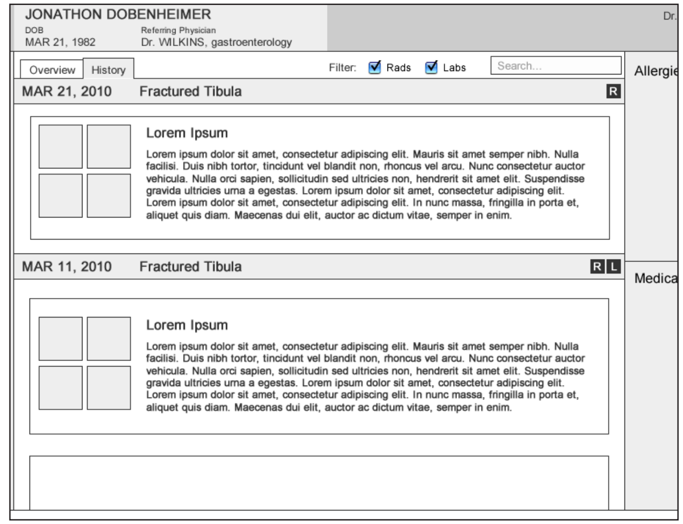
The history view constitutes one of the most prominent features of our design, by showing the actual content from an encounter. Our goals with this component were to ensure that all the content was easy to find, easy to read and that there were shortcuts available for finding the most relevant content. The basic layout of the history view utilizes a modular take on encounters — each encounter is displayed as a self-contained module which includes titles and thumbnails for each document. In order to tie it to the timeline, the history view is organized chronologically, with the most recent visit listed first.

DESIGNING AND ITERATING THE HISTORY VIEW

Evaluating concepts for the display of visits and document thumbnails



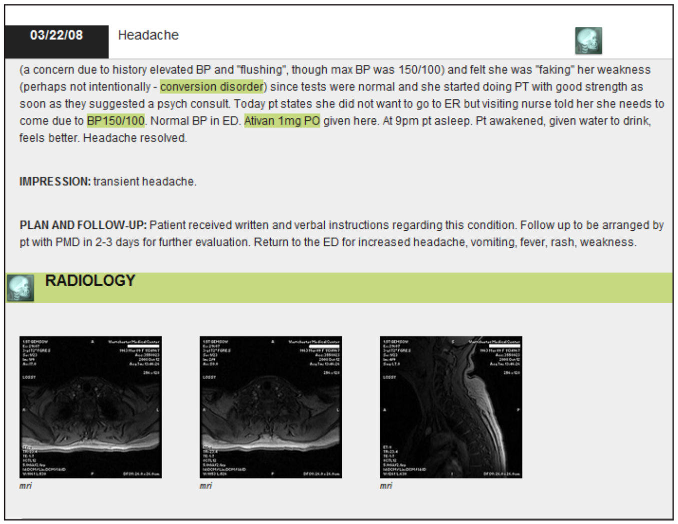
Early sketch of scrolling history view



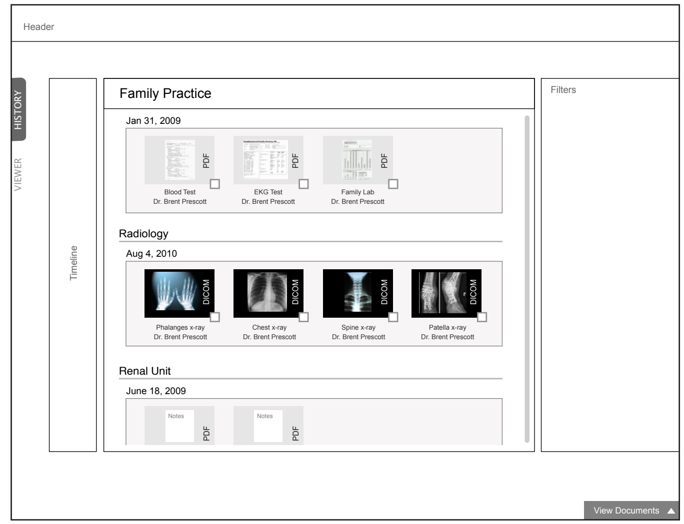
Digitized wireframe

Some initial sketches explored different ways to view a patient visit. To make the information easier to digest, we also discussed the use of keyword highlighting. This would make important clinical terms, such as a diagnosis or prescription drug name, more visible and allow for the data to be quickly skimmed. We also wanted to use thumbnails to provide glanceable access to images and documents.

Users have numerous ways of accessing different encounters, starting with a scroll bar to the right of the history view. In addition, the user has the ability to select an encounter from the timeline, allowing quick access when looking for a specific date. A static header at the top of the history view shows the date, complaint, and available media types for the currently viewed encounter. Clicking on the icons for the available media types takes the user directly to the listing for that document in the encounter.



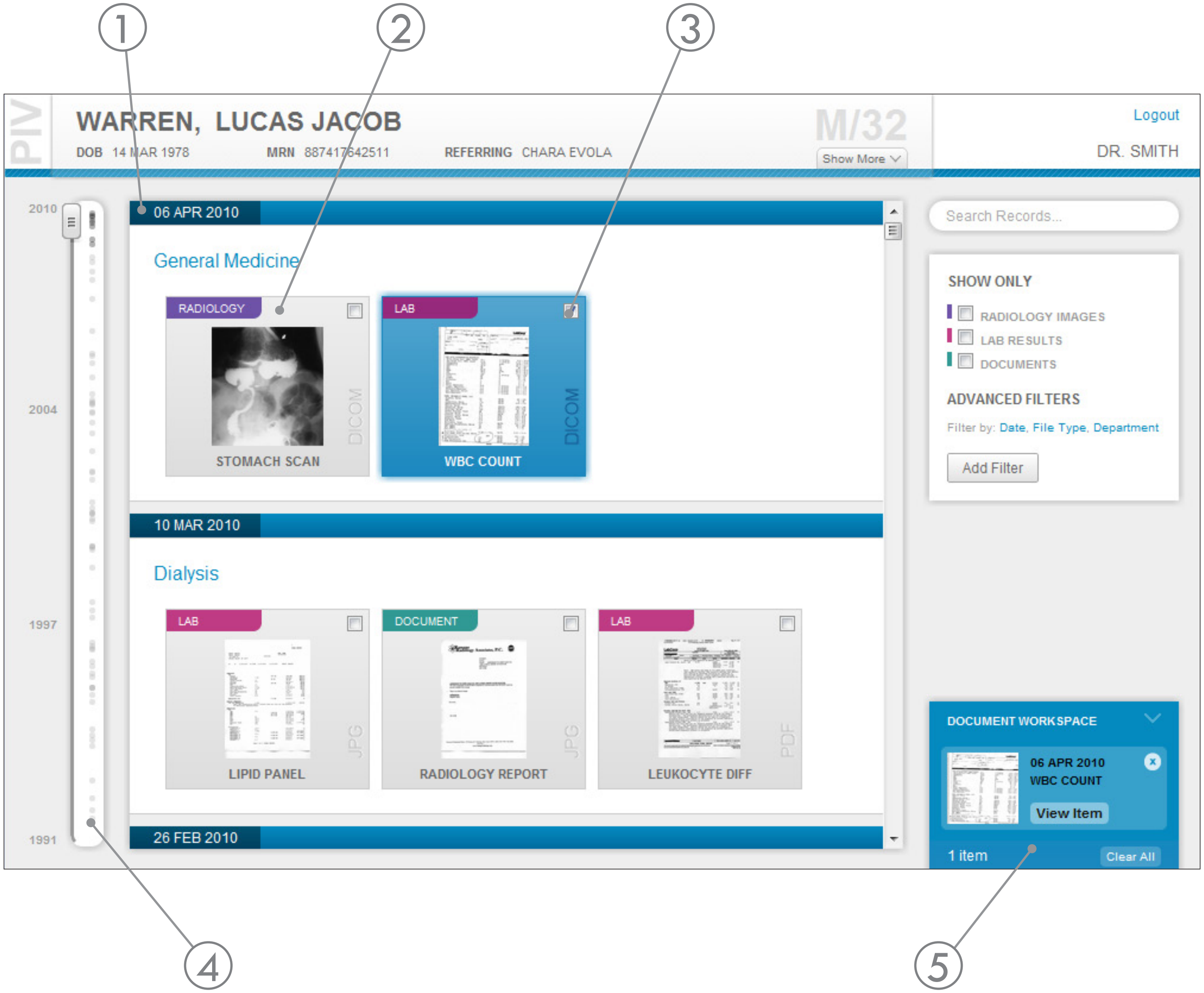
HTML/JavaScript prototype with static header



High fidelity mock-up and paper prototype

Initial testing of the history view showed that users had no trouble understanding the layout or how to navigate using the scrolling mechanism. Timeline integration was not included in this round of testing. The static header, updated based on scroll position, was generally well received though some feedback was provided about the timing of the change being a bit early. As a result the prototype was modified so that the static header would update after getting further into a new record.

Upon realizing that we would not have access to any structured data for the PIV, we developed a new visual design for the history view which would incorporate only images and the minimal data associated with them. This view has much less text, and our design ideas for text treatment have been moved to the vision, instead of the deliverable. Additionally, because each visit now contains a smaller amount of data, the static header became unnecessary as the full set of information could typically be viewed without scrolling.



1
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PIV
WARREN, LUCAS JACOB
DOB 14 MAR 1978
MRN 887417642511
REFERRING CHARA EVOLA
M/32
Show More
Logout
DR. SMITH
2010
2004
1997
1991
06 APR 2010
General Medicine
RADIOLOGY
STOMACH SCAN
DICOM
LAB
WBC COUNT
DICOM
10 MAR 2010
Dialysis
LAB
LIPID PANEL
JPG
DOCUMENT
RADIOLOGY REPORT
JPG
LAB
LEUKOCYTE DIFF
PDF
26 FEB 2010
Search Records...
SHOW ONLY
RADIOLOGY IMAGES
LAB RESULTS
DOCUMENTS
ADVANCED FILTERS
Filter by: Date, File Type, Department
Add Filter
DOCUMENT WORKSPACE
06 APR 2010
WBC COUNT
View Item
1 item
Clear All

FINAL HISTORY DESIGN

A chronological view of all patient encounters and documents

1. This concept presents encounters in a modular view, where documents are represented as thumbnails to provide a preview for physicians. To make documents easier to find, they are organized by the date of the encounter first and then sorted by their originating departments. This organization was influenced by participatory design sessions with physicians. The chronological organization also maintains the navigational relationship with the timeline.

2. The only information associated with a thumbnail is its clinical document type (such as ultrasound report, discharge summary, etc.), file type and content type (radiology image, document, or lab result). The design included only this information to allow a presentation of minimal but relevant text.

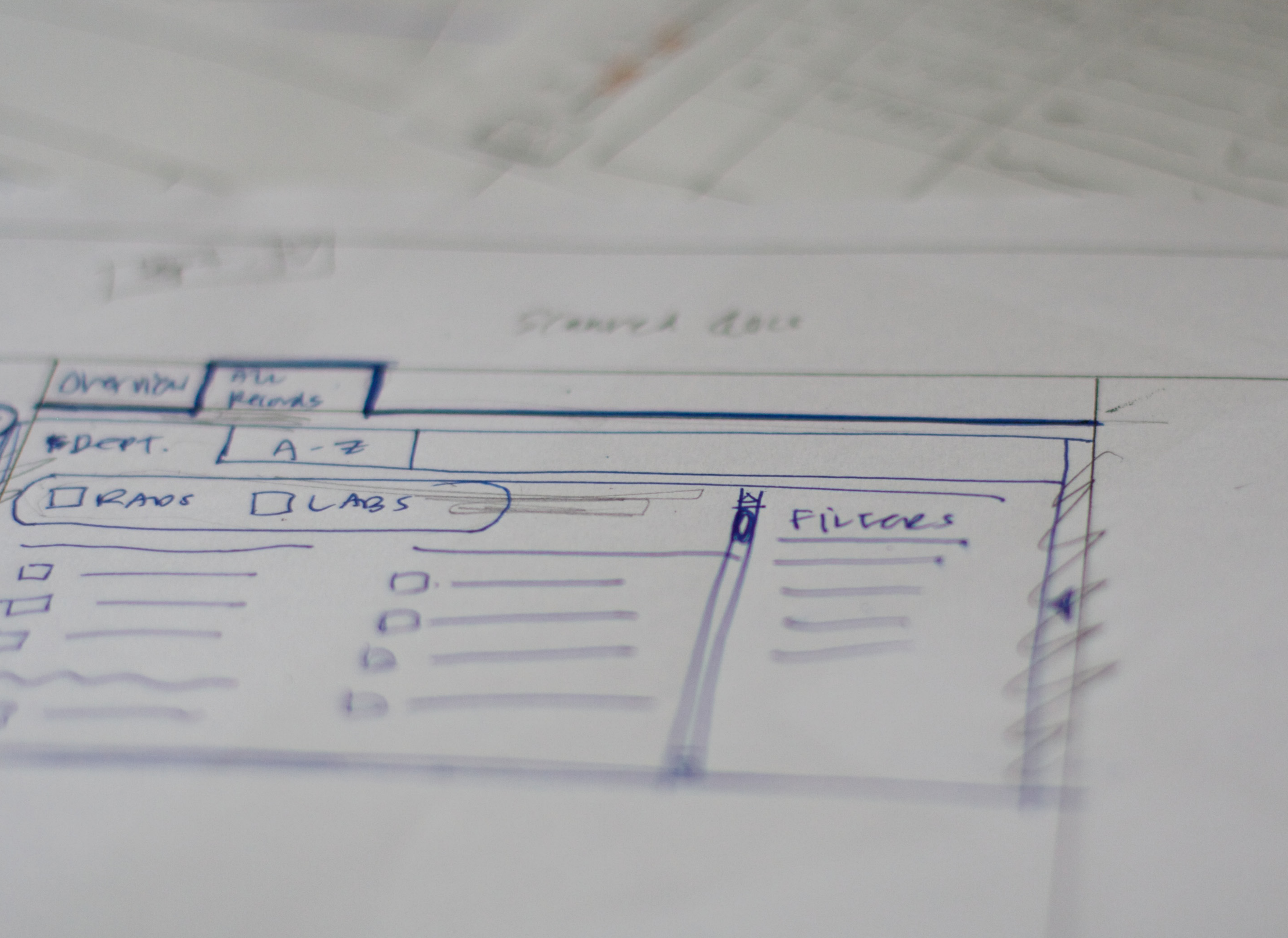
   Other glanceable visual indicators such as a strip of color on the document thumbnail help physicians to immediately distinguish whether the document is one of three content types: radiology image, lab report, or general document.

   Clicking on the thumbnail will allow physicians to see the document in its full view through the document view. Additionally, document thumbnails are highlighted to visually indicate that they have been added to the document workspace. This feature reminds physicians what documents in the history view are currently in their workspace.

3. A checkbox on each thumbnail provides a way to add documents to the document workspace (5). Even though this interaction follows conventions, it may not be immediately obvious to a user, especially a novice. To help make this more clear, the checkbox shows a tooltip on hover to help users understand its functionality.

4. To quickly find the relevant encounters, physicians can use the timeline to browse the encounter dates along with the types of content in each, which are shown with visual icons. Furthermore, by clicking on a specific date in the timeline, the history view will automatically scroll to that encounter.

5. The document workspace allows the user to select a number of images for more efficient navigation. Documents and images are added to the workspace by using the checkbox on the thumbnails. More information about the document workspace can be found on pg. 105.


Overview
DEPT.
A - Z
RADS
LABS
Filters

ABOUT THE FILTERS

A straightforward way to find the most relevant or necessary information

Filtering is a crucial feature of presenting relevant information to doctors. Doctors should have the ability to filter data by department, type of document, and related episodes. In our research, we found that doctors were frequently overwhelmed by the amount of information available to them. Several people we spoke to complained that important and relevant information was buried among trivial documents about colds or routine check-ups. They often know what they are looking for in the record, but have no effective way to locate it. By filtering this information along a number of dimensions, doctors will be able to locate documents more quickly, especially for patients with long or complicated medical histories.

In building the filters interface we encountered a few challenges. FIrst of all, users need to have a correct understanding and mental model of how the different filters interact with one another. This meant that the system needed an intuitive way to show how filters were related, without introducing a large amount of additional text or visual clutter (pg. 97). Based on user feedback, the filters interface is also accompanied by a search bar, to provide fast access to filters (pg. 98). After internal discussion, the team decided to use the search as a way to add filters quickly, especially for expert users.

THE AND/OR PROBLEM

Providing a clear indication of the relationships between filters

The filter status box displays information about which content (lab results, radiology scans, other documents), file type, or department the history is being filtered by. Within each of these filter categories, the logic of the filter is OR, meaning that the filter will return results that contain any of the selected items in that category. Between categories the filter's logic is AND. For example, if a user selects a PDF document-type and the Cardiology department, the results will have to meet both of those criteria.

Several internal and external discussions centered on how to visualize this relationship between items. We wanted to ensure that users had the correct mental model to avoid confusion about whether the content, type, and department were being filtered all together, some together, or all independently of each other. When we were trying to show that discrepancy in the filter box the interface started to become very cluttered and messy with a series of "and's" and "or's" next to each department and episode.

We looked at how other advanced filters were designed and decided that instead of having tabbed search options, we would create a filter view that takes up the main body portion of the interface. This displays all the filter options in one straightforward view, with everything visible at once. The filter categories are divided by horizontal lines, illustrating that the file type, department, and date ranges are all "and's" which makes it more clear that the checkboxes within each category are "or's".

FILTERS

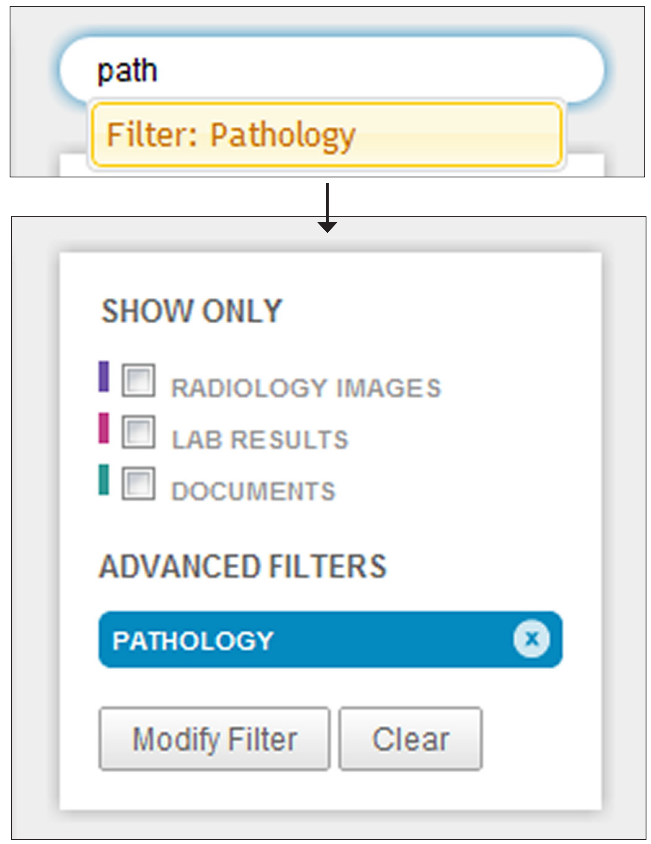
INCORPORATING SEARCH

Moving towards search — a new mechanism for filtering

In many of our early usability tests of filters, we found that participants frequently asked if they could just search for key terms instead of having to navigate through the filter options. We received comments that filtering took too long and required too much clicking. In the age of search engines and frequent web searches, filters have become increasingly outmoded, and users find them cumbersome and confusing.

Users frequently have very high expectations for search. They expect auto-completion and spelling suggestions. Some participants also said that they expect to see live searches that are highly responsive. However, we also received feedback that live searches on slower systems can be frustrating as the lag makes it difficult to tell what has been applied.

Incorporating search with filtering has also required some careful decision-making. Based on feedback from design workshops and internal discussion, we have decided that the search will function as a way to create filters. This means that if a user types “Pathology”, this will appear as a filter in the list of selected filters. This is useful because it allows users to quickly search by a number of different keywords without having to learn specific search syntax.

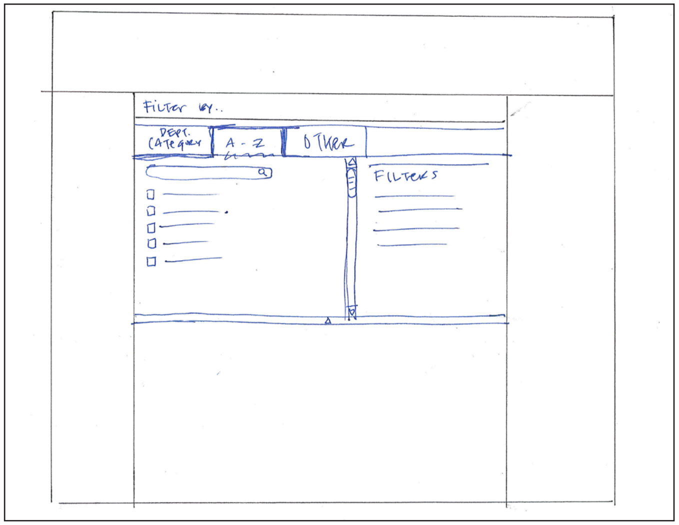


This diagram shows the flow from search to suggested auto-complete, and finally the creation of a filter.

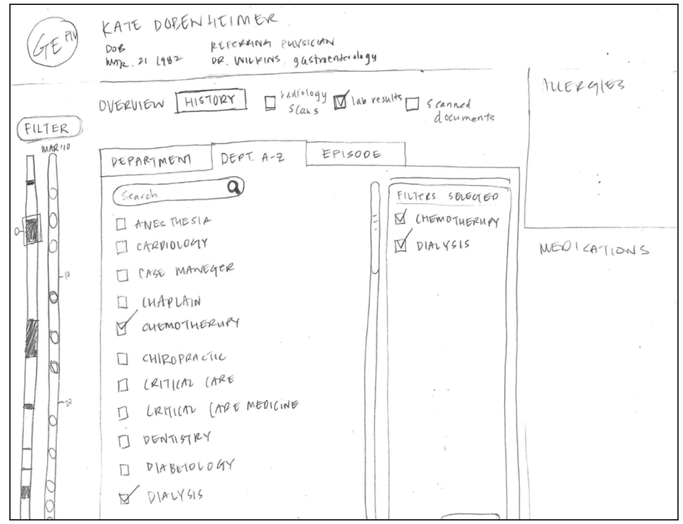
EVALUATION

DESIGNING AND ITERATING FILTERS

Organizing filters by type and providing feedback for selected filters



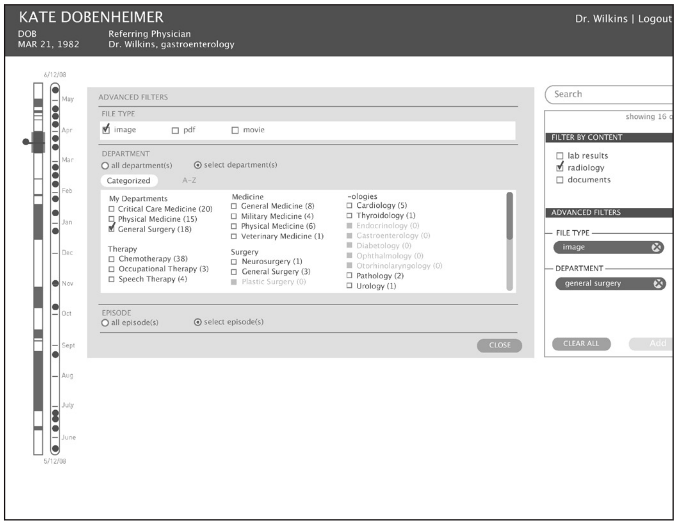
Rough sketch of tabbed filter window



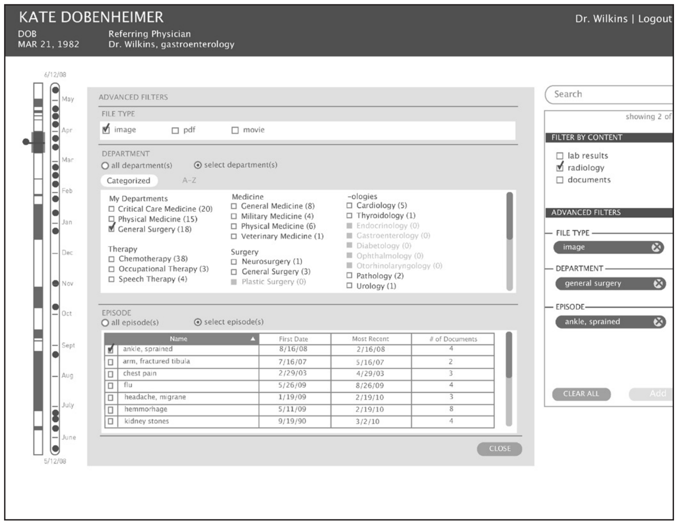
Paper prototype shows the selected filters panel

Testing was initially performed with a low-fidelity paper prototype. Since the filter feature has several options for searching by department and episode, the tasks focused on understanding if participants could easily navigate through these options. We also wanted to see if participants understood that they were able to apply more than one filter at a time using the main filter options that are not within the advanced search tabs: radiology, lab results, and documents.

There was a slight learning curve for selecting the main filter options (radiology, lab results, and documents) in addition to the advanced search tabbed options. After figuring out that the differently located filters function in parallel it was easy for participants to understand it the second time around. The separate location of the main filters is crucial since users can use them without having to open the advanced filters view. Users also immediately understood that whichever filters they chose would appear in the “Filters Selected” panel.



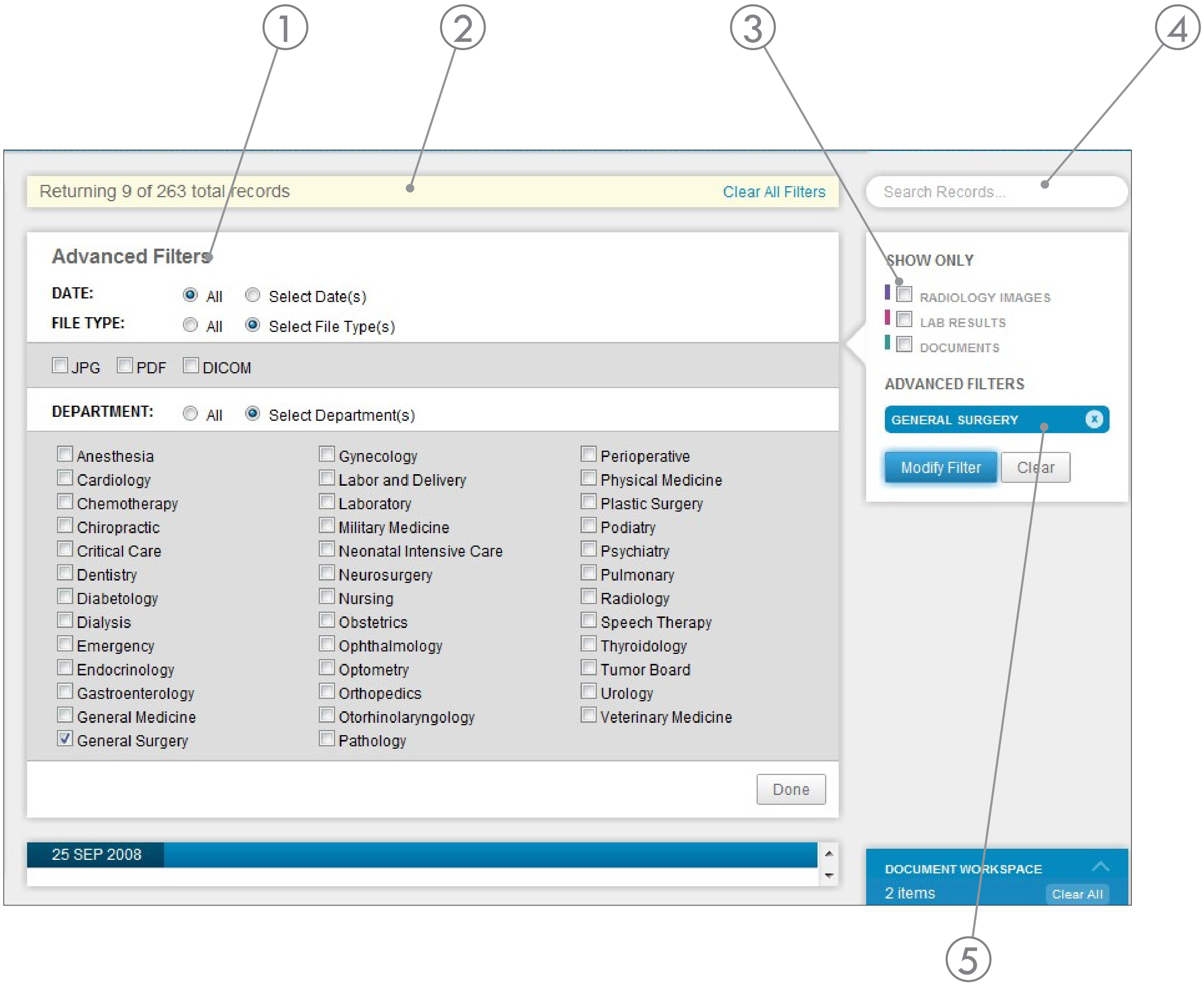
Medium-fidelity mock-up of Advanced Filter window



Medium-fidelity mock-up showing options for different filters

We removed the modal window that displays the tabbed filter options of department and episode and replaced that with a filter page that takes up the body of the interface. The filter status box is always visible in the right-hand column of the screen and once the "add" button (located at the bottom right-hand corner of the filter box) is selected, the filter page appears above the history view. There is also a "clear all" button to quickly clear all the filters. To maintain the filters and return to the history screen the close button on the bottom right-hand corner of the advanced filters view should be selected.

The file type, department, and episode categories will have two radio buttons: "view all" and "select specific file types/ departments/episodes". The filter screen will display all the respective checkboxes once the corresponding "select" radiobutton is chosen. The content (lab results, radiology scans, other documents) checkboxes remain only on the filter status box since those are quick filters that should be easily accessible when the user is in the history view.



1
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5
Returning 9 of 263 total records
Clear All Filters
Search Records...
Advanced Filters
DATE: All Select Date(s)
FILE TYPE: All Select File Type(s)
JPG PDF DICOM
DEPARTMENT: All Select Department(s)
Anesthesia
Cardiology
Chemotherapy
Chiropractic
Critical Care
Dentistry
Diabetology
Dialysis
Emergency
Endocrinology
Gastroenterology
General Medicine
General Surgery
Gynecology
Labor and Delivery
Laboratory
Military Medicine
Neonatal Intensive Care
Neurosurgery
Nursing
Obstetrics
Ophthalmology
Optometry
Orthopedics
Otorhinolaryngology
Pathology
Perioperative
Physical Medicine
Plastic Surgery
Podiatry
Psychiatry
Pulmonary
Radiology
Speech Therapy
Thyroidology
Tumor Board
Urology
Veterinary Medicine
Done
SHOW ONLY
RADIOLOGY IMAGES
LAB RESULTS
DOCUMENTS
ADVANCED FILTERS
GENERAL SURGERY
Modify Filter
Clear
25 SEP 2008
DOCUMENT WORKSPACE
2 items
Clear All

FINAL FILTERS DESIGN

A straightforward way to find the most relevant or necessary information

1. The advanced filters window allows users to specify filters for dates, file types, and departments. In each of these categories the default view has the "All" radio button selected, and the gray area is collapsed. However, if a user wishes to use a particular filter, they select the corresponding radio button, which expands the possible filters (as shown, left), and then use the checkbox to select the correct filters. Dates are selected using a calendar-style widget.

2. The filter status bar shows the number of results being returned based on the filter criteria. This flashes every time a new filter is added to draw the user's attention. It also provides an indication that the user is only seeing a subset of an entire patient record. There is a link for removing all of the currently applied filters.

3. These checkboxes allow for quick filtering. Based on our research, documents could be categorized into radiology images, lab results, and general scanned documents. These checkboxes are always visible and do not require the user to open an additional window, because we believe that these will be the most commonly used filters.

4. The search bar uses auto-complete suggestions to make it easier for users to find what they need. The search also allows users to create filters if their query is one of the existing filters, such as a department name or file type.

5. Whenever a user selects a filter, an indicator appears in the filter panel to the right of the history view. This helps the user keep track of what filters they have applied. The 'X' button also provides an easy way to remove a filter. Filters can also be removed with the clear button.

ABOUT COMPARING DOCUMENTS

A viewer for single or side-by-side document comparisons

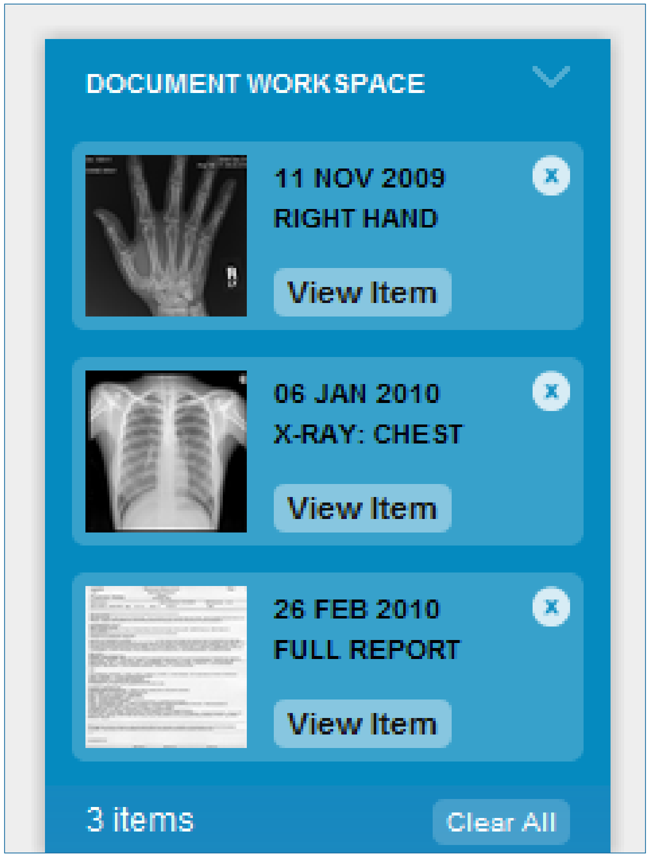
One of the primary goals of the patient information viewer is to provide an improved way to view images and documents. In order to do so, the system has an efficient way to select an image (or multiple images) for viewing (pg. 105). Document and image selection should be possible directly from the patient's history page. In addition to this, users need a way to compare different types of documents in order to form a better diagnosis. We wanted to ensure that this viewing and comparison mode took advantage of available screen real estate effectively, while still providing the necessary tools and features (pg. 106).

DOCUMENT WORKSPACE

Simplifying the process of selecting and navigating documents

In order to select and navigate documents, the system incorporates a document workspace which will provide a bridge from the history view to the document view. This workspace is located in the bottom-right corner of the interface and is collapsed when not in use. While viewing the patient record, a user can select several documents by clicking on the checkbox associated with each thumbnail. This will add a thumbnail of each document to the workspace, and also cause the workspace to pop up so that users have clear feedback that their selection has been added.

To move to the document view from the document workspace, the user clicks on the "View item" button (alternately, the document view can be accessed by directly clicking a thumbnail in the history view). Even though the overall view changes, the document workspace persists to provide consistency between the two views. In the document view, clicking on a thumbnail will show that document full-scale. Dragging an image from the workspace into the viewer will place it alongside the current image, allowing for a two-up comparison view. The workspace provides a consistent document navigation metaphor across the PIV interface and an easy way to view many images very quickly.



The document workspace shows thumbnails and metadata for every selected image and helps bridge interactions between the history and document views.

DOCUMENT VIEW TOOLBAR

Offering simple tools for document and image manipulation

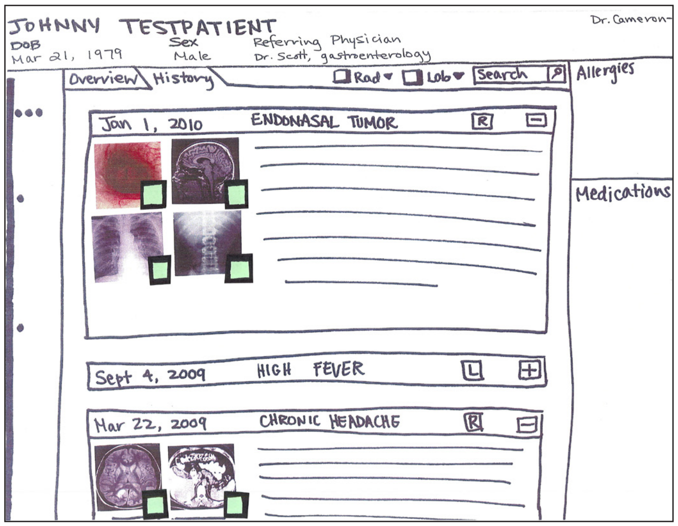
In the document view, there are also a number of tools for viewing and manipulating images. However, due to limitations of scope these tools are not being developed in our design. Our contribution is the selection of tools, styling, and interactions required for document manipulation.

By looking at PACS viewers, and speaking with a user who has experience with several PACS systems, we arrived at a selection of tools that we felt would be appropriate for the PIV. We initially considered an expansive toolset including annotation and color manipulation tools. However, upon considering the true needs of the users, we decided to provide simpler functionality than a traditional PACS viewer, since an attending physician does not need nearly as many tools as a radiologist. These simple functionalities include the ability to rotate, flip, zoom, measure, and reset the size of documents. In addition, the PIV can be a launching point to an external application which has more powerful document manipulation functionality, such as a dedicated PACS viewer. The styling of the toolbox and tool icons follows design conventions for toolbars and is both simple and easily understandable.

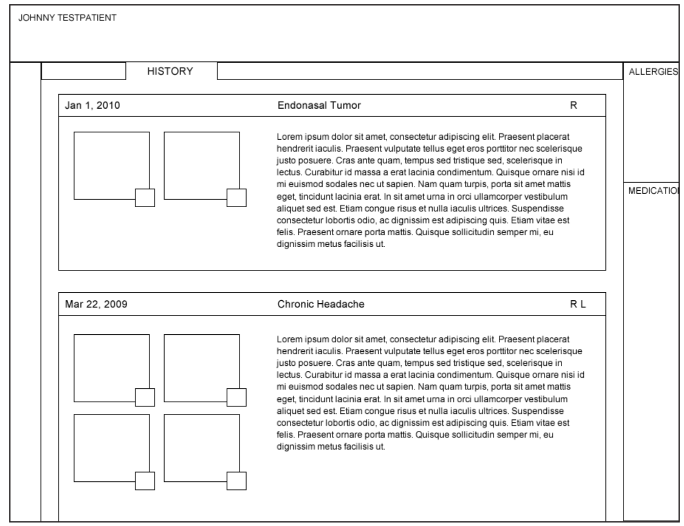
The document view contains a toolbar, which allows for simple image manipulations. The toolbar also enables users to launch an external application to access additional tools.

DESIGNING AND ITERATING DOCUMENT SELECTION

Using checkboxes and a document workspace to facilitate document selection



Paper prototype of checkbox interaction

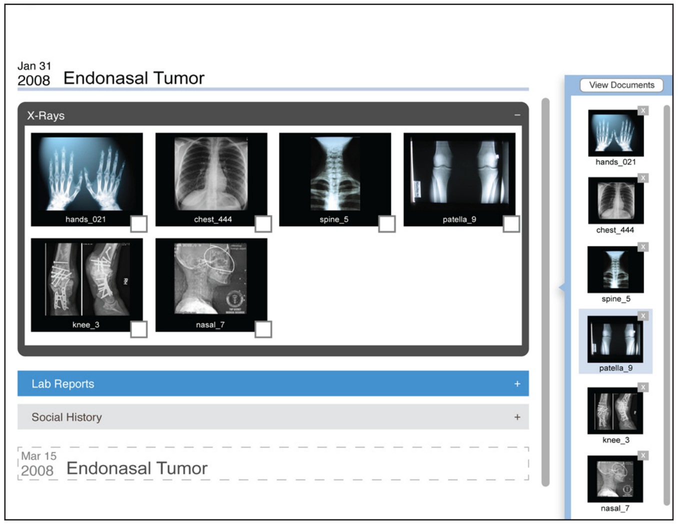


Wireframe of checkbox interaction in history view

In the first round of paper prototyping, the team experimented with different interactions for image selection. These included: pulling up a contextual menu after selecting an image, selecting images using checkboxes, and a preview for arranging selected images. The use of the contextual menu was discarded because it required too much clicking when the user only wanted to view one image. The preview for arranging the selected images was also found to be unnecessary. With these changes, the design progressed with the checkbox interaction, which testers found useful in the paper prototype.

The checkbox interaction allows users to select any number of images, by marking their checkbox, and then move to the image viewing page to view them further. If a user needs to arrange multiple images, they can do so in the image viewer portion itself. Internal team discussions also led to the inclusion of a panel to show the selected images. In this panel we wanted to provide a thumbnail, image caption, and date, in addition to easy ways to remove images from selection. This panel also exists in the history view to provide consistency in our layout.

High fidelity mock-up of document workspace



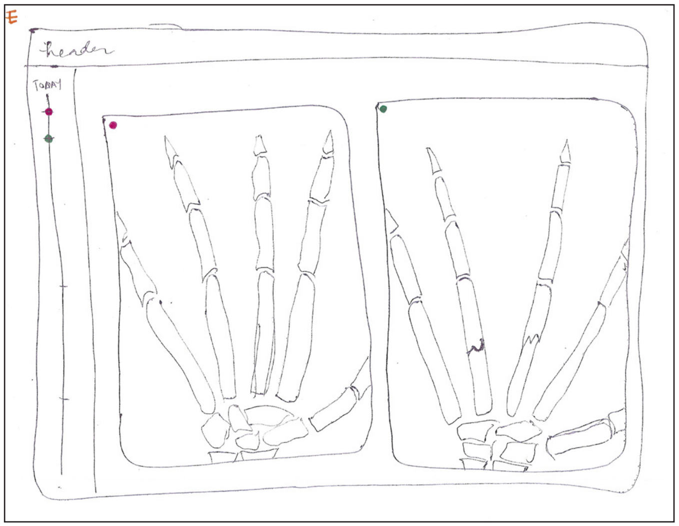
High fidelity mock-up of checkboxes and workspace

Testing this version as a click-through prototype on a computer found that users understood the checkbox interaction. While some did not initially notice the appearance of the preview panel, they soon understood what to do and quickly completed the task. Users also understood that they could remove images from the panel using the "x" button associated with each thumbnail.

The panel that contains the selected documents acts as a workspace for physicians to easily access selected documents. When an image is selected through its checkbox in the history view, the workspace panel will update to show the added image. This concise view only shows the thumbnail of the recently added document as well as a link to expand the workspace to its full size. This allows users to browse the entire selection of documents. The physician can also minimize the fully expanded view back to its concise view.

DESIGNING AND ITERATING DOCUMENT VIEWING

Experimenting with several different interactions: timeline, workspace, and drag-and-drop

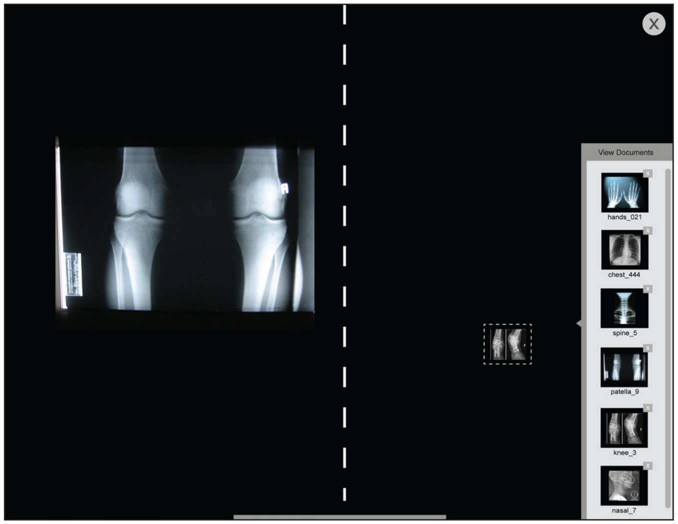


Early sketch of document comparison

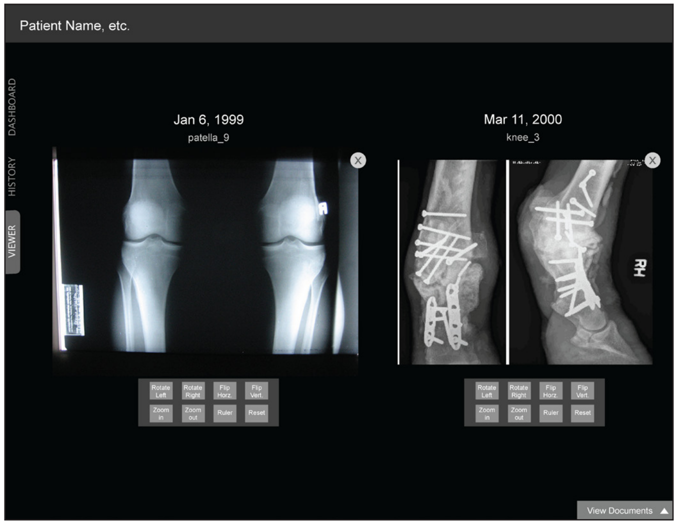
Low fidelity click-through prototype in Adobe Flash Catalyst

In early sketches, we determined that viewing images or documents side-by-side would be a useful feature. This would allow for easy comparisons between before and after pictures, or a document and its associated image. We also considered how to make it intuitive and obvious which image is most recent when the images are viewed simultaneously. One way of showing this is with color-coding to relate each image to the timeline.

The document workspace will provide the primary way for physicians to navigate and view the selected images. In order to change the image being viewed, users would just have to select a new image from the panel. In this view they can also close images or remove them from the workspace. In this early iteration we did not include any tools but acknowledged that a small toolset would be necessary.



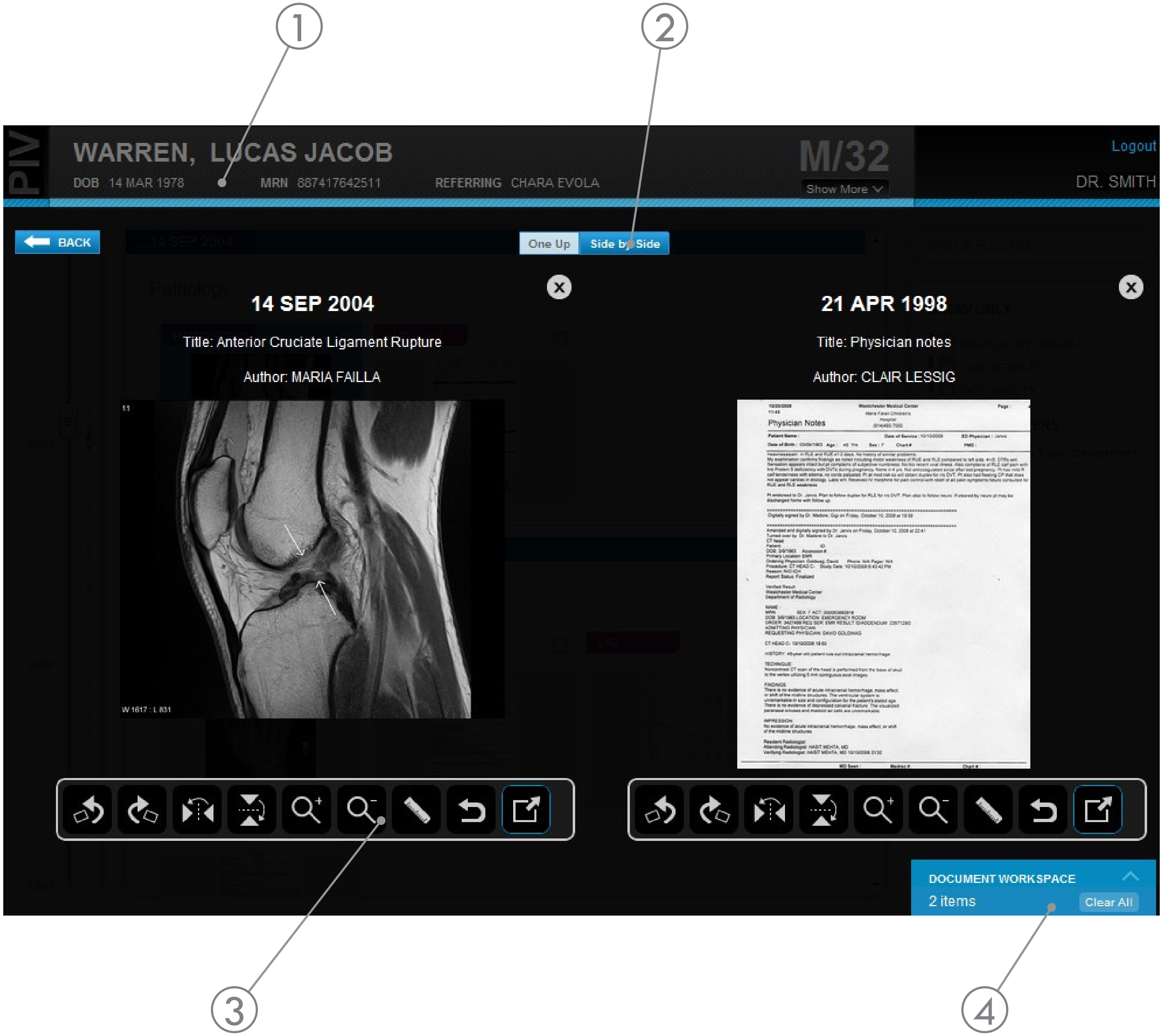
Medium fidelity mock-up of drag-and-drop interaction



Medium fidelity mock-up of comparison view and toolsets

In this medium fidelity mock-up we show the interactions for viewing multiple images simultaneously. If a user wants to compare documents in a side-by-side view, they can drag the second image thumbnail into the viewer area. However, the challenge was to provide an affordance to drag-and-drop the thumbnails. One way this was solved was to show an outline for where the image should be placed in the viewer. We also added a label that states "Drag image to viewer to compare" when the panel is opened.

The abilities to rotate, flip, zoom, measure, and reset images are available through a toolbox that appears when the physician hovers over the image in the viewer and disappears after a couple seconds when the mouse rolls out. The reason for this interaction is to create a less cluttered interface when the toolbox is not needed. In addition, when comparing two images, each image will have its own toolbox for a more distinct and direct interaction for manipulating multiple images.



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Author: MARIA FAILLA
21 APR 1998
Title: Physician notes
Author: CLAIR LESSIG
DOCUMENT WORKSPACE
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FINAL DOCUMENT VIEW DESIGN

A viewer for single or side-by-side document comparisons

1. Most of the UI is in darker colors to present a minimalist aesthetic and prevent visual distraction when viewing documents. The header information adapts to the darker color scheme to allow physicians continual access to the patient's information and as a reminder of whose document they are viewing.

2. The document view allows for viewing images side-by-side. This facilitates comparisons between images, as well as viewing an image alongside its corresponding radiology report. In order to view images two-up, users must drag them in from the document workspace. The drag-and-drop feature of the compared document from the workspace to the document view provides an intuitive interaction that is easy to learn and use.

3. The toolbar allows for standard image manipulation functionality for physicians. This functionality includes the ability to rotate, flip, zoom, measure, reset, and launch an external PACS viewer application for more manipulation capabilities. Styling of the tool icons is simple and easily understandable while also being supported by a tool-tip description. These tools are not implemented in the prototype.

4. The document workspace persists from the history view to the document view to provide a consist navigation metaphor between the two screens.

The first prototype of the PIV was tested by recruiting doctors at a hospital cafeteria. These doctors often did not notice features, resulting in less effective system usage.

ROUND 1: FIXING VISIBILITY PROBLEMS

Participants overlooked important components such as the timeline and filters

The first round of usability testing, conducted with three doctors and five everyday users, revealed a number of important problems. Participants struggled to find some of the interface elements, especially the timeline and filters. The search and document view were not yet implemented at this time, and were not tested.

Header

In this iteration the header did not have a button to show expanded information, as it would expand every time that a user hovered over it. Because there were no buttons on the header, users did not initially know how to interact with it until they accidentally hovered over it. Eventually, this annoyed many users as they would inadvertently open the header while they were trying to navigate to other elements or merely trying to explore the interface. This problem was exacerbated by the fact that the hit-area for the header was very large.

Timeline

Users frequently did not understand how to interact with the timeline. They did not notice the thumb and instead tried to click or drag the entire timeline. It also became evident that they did not understand the relationship between the two timelines. The idea that the selected region on the left timeline corresponded to the right timeline was completely overlooked. Several thought that the selected area on the left timeline represented the history view, not the right timeline. In order to deal with this, the styling of the timeline needed to be changed. We also dealt with some smaller concerns such as the format of the dates, providing metadata about each entry, and making timeline dates clickable.

History

The styling of the thumbnails in the history view did not provide sufficient information to users. They were frequently confused by the names listed under each thumbnail, thinking that these might be from different patients. We needed to add an indicator that this was the author of the document. Additionally thumbnails needed better indication of the document type, which was added in a later style iteration.

Filter

Several users in this round overlooked the filters panel on the right side. We solved this problem by changing the link “Add Filters” to a button, to provide more visual prominence. Because they could not find the filters panel, users frequently tried to use the department names in the history view to create filters. This mechanism was implemented for the next iteration, where users found it useful and intuitive.

A physician participates in a usability test of the PIV. PIVOTAL team members facilitate the usability test by providing background about the interface and guiding the participant through tasks.

ROUND 2: A MORE INTUITIVE INTERFACE

Participants were confused by the functionality of certain features

Round two of usability testing included a number of updates and changes based on the results from round one. This iteration also included several newly implemented features such as search, document selection, and document viewing. Usability tests were performed on five healthcare practitioners including three physicians, a pharmacist, and one medical student.

Timeline

Because we had not yet had an opportunity to make changes to the timeline style, findings for the timeline were similar to those in round one. Participants again overlooked the timeline, preferring instead to scroll through the history view to find the results they needed. Users may have overlooked the timeline because it lacked labeling, particularly to show the year span. Simple hints like labeling could provide users with a subtle indicator of how to use the component. Upon eventually finding the timeline (or having it pointed out to them) participants wanted the hover to include more information, particularly the department of origin. With this knowledge, a new style was developed for the timeline.

Filters

In this iteration, participants were quicker to find the filters panel, but still did not know how to interact with it. The task asked them to filter by a specific department, and they did not think to look under advanced filters. Providing a label of available filters was seen as a solution to this problem, so that users would not need to open the filter window.

Upon figuring out how to create a filter, participants were still unsure of whether it had actually been applied or not. They did not notice the indicator in the right panel, or the yellow counter along the top of the history view. We added an animated flashing effect to these elements in order to make the feedback more apparent.

Document Workspace

In order to add images (from the history view) to the document workspace, users needed to click on the checkbox in the respective thumbnail. Many users did not notice the checkboxes or understand what they were for. Providing clues about the functionality of the checkboxes could be implemented as a hover tool-tip. Once users had added several documents to the workspace, they were unsure of how to move to the document view. They did not notice the view button in the bottom corner of the workspace, or click on the thumbnails.

Document View

The document workspace was highly successful. Most users figured out how to drag a second image into the workspace, and all users enjoyed and appreciated this feature once they had tried it. The only problematic issue in the document view was how to close it, as users did not notice the “Close” button in the top right corner.

ROUND 3: AN EFFECTIVE SYSTEM

Participants were able to complete tasks quickly, even expressing delight at some features

The third and final round of usability testing served as affirmation of many of the changes we had made throughout the iteration process. Doctors we tested the system on completed tasks quickly and easily, and said they really liked the system. As a whole, we saw a great improvement in the usability of the system from previous rounds, as evidenced both in the speed of task completion and also in the reactions of users of the system. In particular, participants liked features such as the drop-down header, the timeline, and the drag-and-drop functionality of the document view, often enthusiastically telling us that these features were cool or useful.

Document View

At the beginning of this round, participants encountered some difficulty in figuring out how to view two images side by side. While the task was still completed, we added a toggle to switch between viewing one and viewing two images at a time in order to make this feature more obvious. Testing later in this round saw this task completed with greater ease, and every participant was able to complete the task.

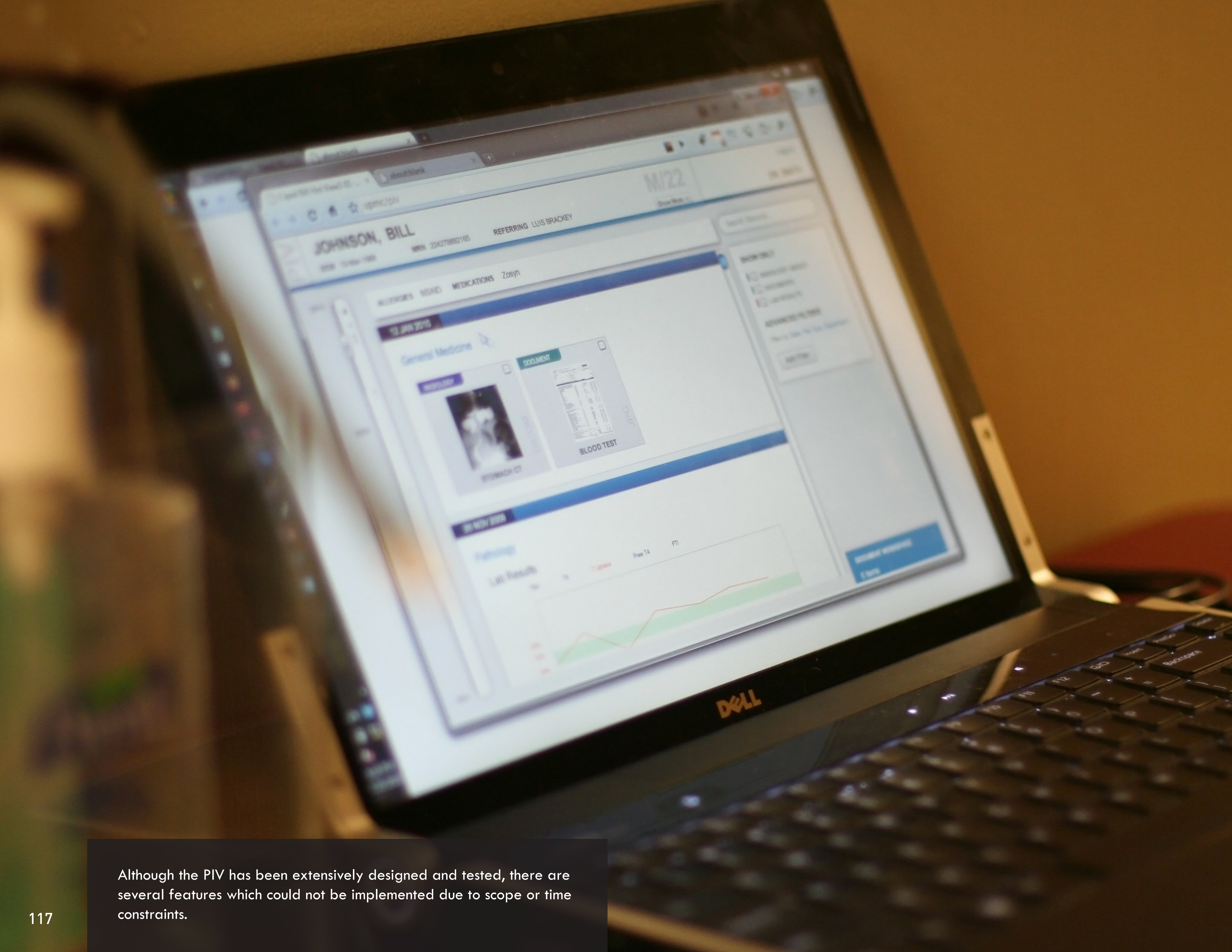
PARTICIPANT COMMENTS:

"I think it's great. It's pretty exciting."

"It's very intuitive... [the] click and drag and pull."

"I like it. The side-by-side view is helpful."

"Ooo is this a timeline here? Interesting. I like that!"



Although the PIV has been extensively designed and tested, there are several features which could not be implemented due to scope or time constraints.

FEATURES NOT PROTOTYPED

Ideated, but not implemented

Because of time and technological limitations, some features were not implemented in the final prototype. Some of these features are described here.

Filter Hinting
To help users choose filters, the number of results that would be returned should be shown next to each label (e.g. "Family Medicine (33)"). While this feature was omitted for technical difficulty, it should be easier to implement when a full database is used.

Recency Filters
While the timeline and date-specific filters provide numerous ways in which doctors can navigate data over time, adding the ability to filter by recency would further enhance their usefulness. This filter would allow doctors to quickly see only encounters from the past month, past six months, past year, or past three years.

Full Search
While search should include auto-complete for filters, as is currently implemented, it should go beyond this to also search any text associated with a record. While not tested with users, our belief is that all XDS metadata, including dates, should be searchable.

Theming
To accommodate different contexts of use, the PIV should have different interface themes available. These themes would include options for dark settings, such as the rooms typically used by radiologists. Additionally, themes for grayscale monitors would allow for color coding to be replaced with something more usable in those situations.

Enhanced Document View
The current implement of the document view includes only a bare-bones set of placeholder "tools". Ideally, the document view would be much more advanced, and in particular, would have tool sets defined by the type of document being viewed.

Multiple Document Comparison
Currently, the PIV allows comparison of a maximum of two documents. Ideally the system will scale to the particular user's needs, allowing them to view more than two documents if needed.

Document View Navigation
The document workspace provides a quick, effective way for doctors to look through numerous documents in a row. To further build on this feature, key navigation should be added, such as the ability to navigate through selected documents using the up and down keys.

OUR VISION

ABSTRACT

INTEGRATION

All Systems Integrated
One fluid system

PRESENTING RELEVANT INFORMATION

Search
Quick search by different keywords without learning specific search syntax

Header
Necessary & useful information; quickly comprehensible

Timeline
Longitudinal view of patient's visits; serves as navigational tool

History View
All content from encounters; easy to find and read; shortcuts for most relevant content

Viewer
Improved way to view & compare images & documents

Filters
Quickly filter by content, department, file type, and episode

Dashboard
Glanceable patient overview; today's & most recent visit, radiology imgs, & lab results

Specialized Tools
Calculators: ABG, APACHE, dosage, and other reference guides facilitate workflow

Allergies & Medication List
Most crucial information; immediately impacts treatment and diagnosis

CUSTOMIZATION

Modular Layout
Accomodate doctors' work preferences & specializations

Customizable Settings
Preserve time by saving state for filters and searches

PATIENT INTERACTION

Portable / Mobile Device
Facilitate doctor workflow

Patient-facing Content
Bring patient into the technology experience

CONCRETE FEATURES

Deliverables

Additional Ideas for Vision

VISION OVERVIEW

An ideal future vision for the PIV

Throughout our research we found many improvements and opportunities that could become part of the PIV. Many of these, however, went beyond the current scope of the application or simply raised questions of technical feasibility. Thus, we separated these features from the deliverable version of our design, and created a distinct vision design which represents the ideal future state of patient information viewing.

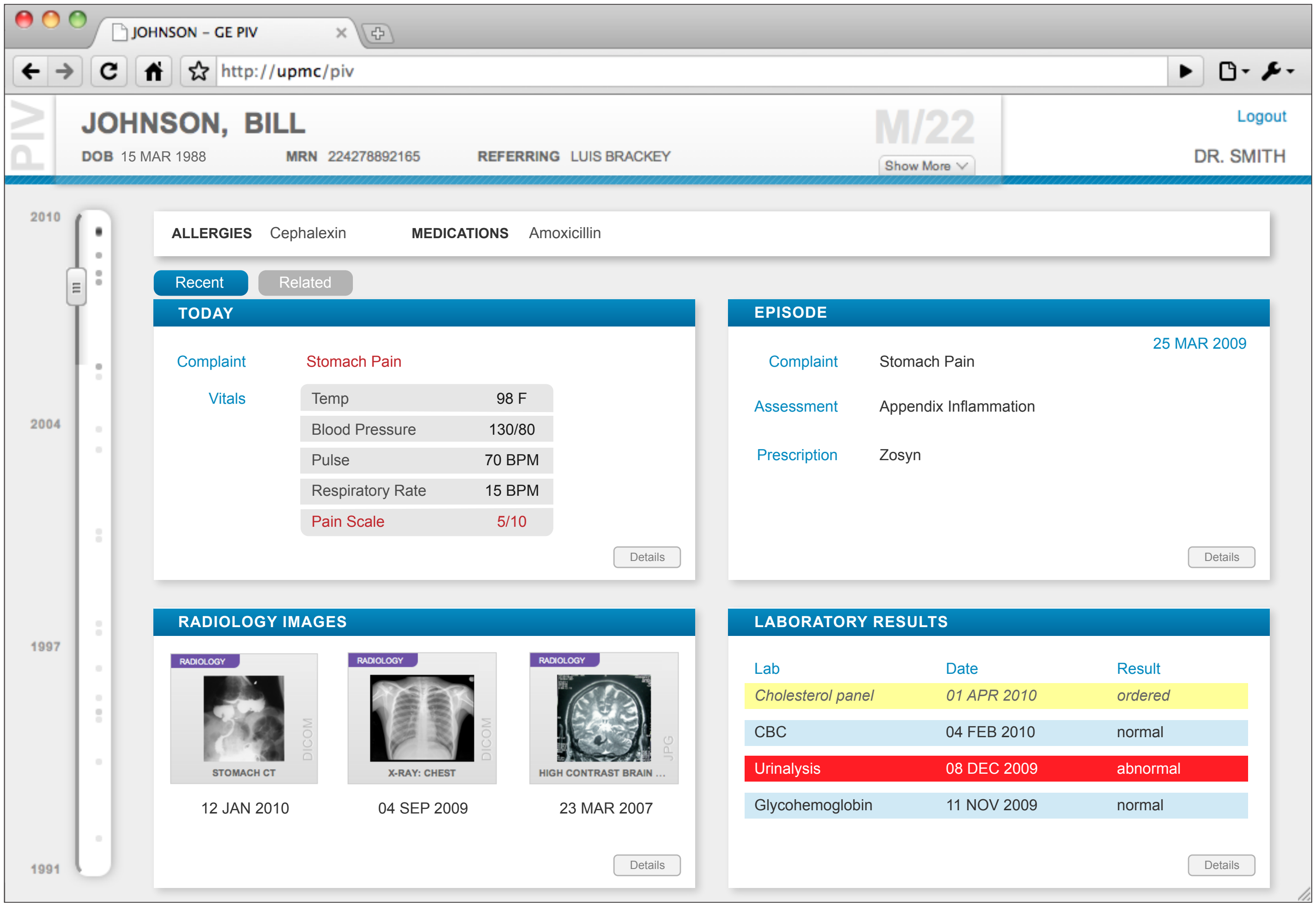
Our vision sees the PIV expanded into a fully featured healthcare application, bringing in features currently separated into EMR, PACS, and other medical software. The goal of the PIV shifts to being the primary, and ideally sole, application used by a physician. To achieve this, the PIV will include features such as full patient records in text form (including discrete data) and a quick dashboard for getting patient status. Further, the vision for the PIV includes a tablet version, allowing doctors to take the application with them to the patient bedside. Our research showed that doctors valued close patient interaction very highly, and felt that current technology got in the way of the best possible interaction. An ideal system would also include options for customization and use of external tools and resources. While the ideal future state would incorporate entering data into the system, this is not included in this design, since our research focused only on viewing patient information.

Due to time constraints our vision design did not undergo the same degree of usability testing as our deliverable design, however all of the design decisions are based on our research on hospital culture and work practice. Further details of this research can be found in our Spring Research Report*.

ABOUT THE VISION

- Integrated systems
- Structured, discrete data
- Portable form factors and new interaction styles

** Designing a Better Way to View Patient Information: Spring Research Report, May 11, 2010*



The dashbaord view provides a snapshot of the patient's current health.

DASHBOARD

A first glance overview and launch screen for the PIV

In order to provide quick access to glanceable patient information, we present an overview screen in the interface to serve as a dashboard. This screen will be visible when a physician first pulls up a patient's record and includes important elements such as the header, timeline, allergies and medications. The dashboard is included in the vision because it has an important role in giving a doctor a quick overview of a patient's information.

The research shows that the most important elements to include are: today's visit, most recent visit, radiology images, and laboratory results. The layout of this information is placed in a two-by-two display, so that each element feels like a separate module.

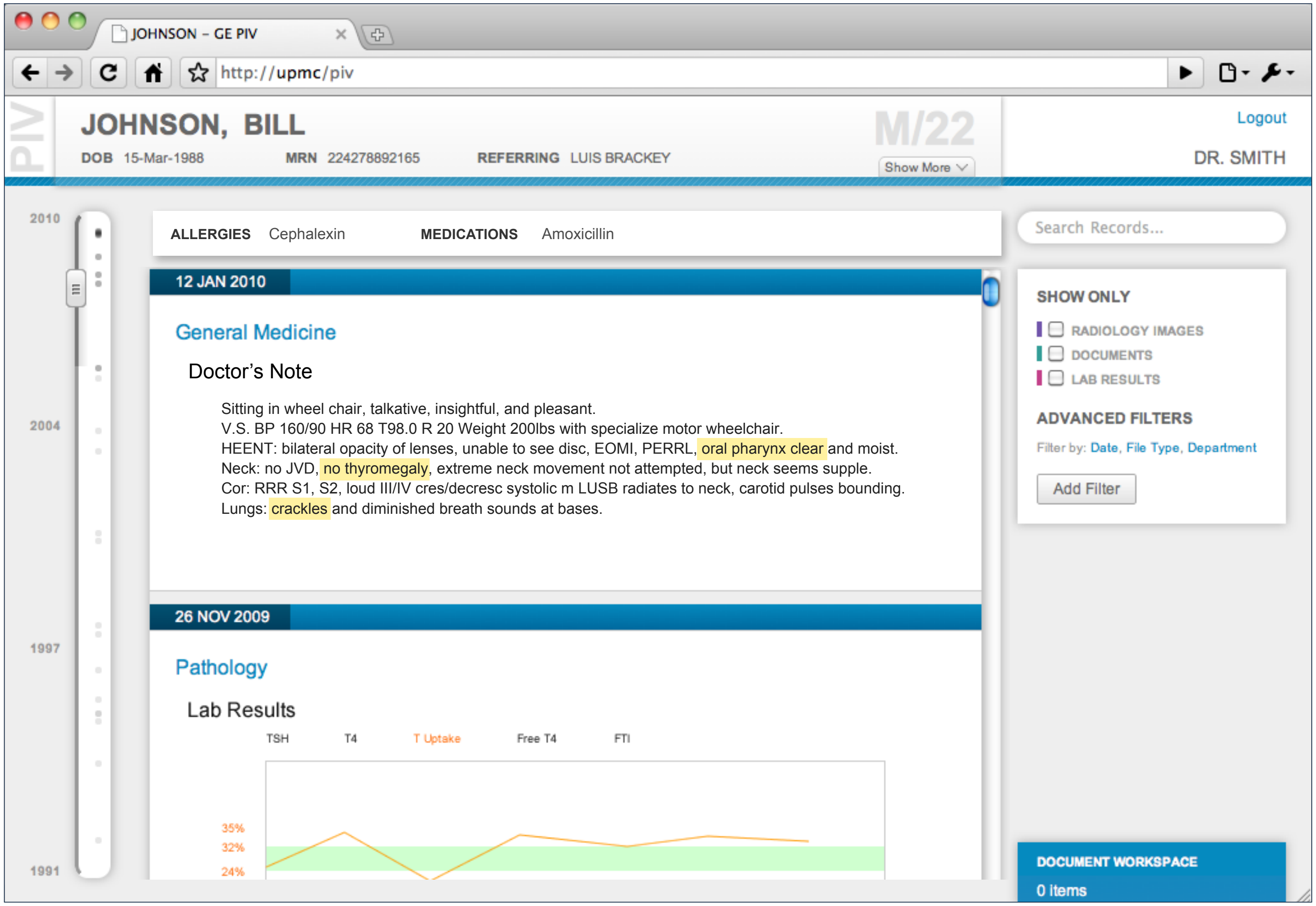
The Today's Visit section includes quick overview information about the current visit, such as complaint and vital signs. This is information that is usually entered at registration or by a nurse, prior to the doctor seeing the patient. Participatory design sessions indicated that patient complaint and vital signs were critical to know at the beginning of a patient encounter. These pieces of information can fundamentally change the course of a visit, diagnosis, and treatment plan.

The Most Recent Visit field provides a quick overview of the last visit, including the complaint and how it was resolved, including prescriptions and possible treatment plans. The purpose of the Radiology Images and Laboratory Results section is primarily to provide quick access to the newest results, and function as links to images or parts of the patient record.

The dashboard uses text highlighting to call attention to the most important information on the page (such as patient complaint and abnormal vital signs). In addition to this, users can filter recent and relevant information in order to easily access both the most recent images and labs, and those that are most relevant to the current visit.

Customization options in the dashboard view were also discussed. Because the design of the dashboard is modular, we feel that it is logical to allow doctors to place the boxes in any configuration that makes sense to them, given their specialization and individual workflow.

Advanced History View



By incorporating labs, text and other information all in-line, and by adding intelligent highlighting and graphing, doctors are able to more quickly analyze information.

ADVANCED HISTORY VIEW

A history view with full-text reports and structured data

As part of our future vision, the PIV will use the same structured data that EMR systems currently have access to. This includes records related to a patient's allergies, medication history, physician notes, contact, insurance, and primary care information. By integrating the PIV in this manner, patient records will be grouped and organized by the visit date of their complaint, instead of being organized by the document creation date. If more than one visit stemmed from the same complaint this would be considered an episode, and those visits would be grouped accordingly. We envision that physicians can more easily locate relevant information by filtering records by episode. As a result, the timeline and the history view will update to show information of the filtered episode while others are collapsed in view.

In our participatory design phase, we performed card sorting activities with physicians to better understand what types of information they want to see, and how they want them organized. Based on those results we have broken up the interface into subsets and organized the patient information accordingly. Allergies and medications are among the most crucial types of information that physicians look at. They are often viewed first because they have an immediate impact on diagnosis and treatment. Because of this crucial role, allergies and medications are placed in a top bar that is always shown.

In the history view panel, patient complaint and patient provided information are provided first, since most physicians use this data to quickly understand the patient's health problem. When necessary, physicians can further investigate by reading the patient's family, social, past medical, and department-specific history. Finally, lab reports, radiology images, graphs, and test results are provided to give physicians more information about the patient's condition as needed.

We have also included text highlighting of key medical information such as prescriptions, symptoms, and important keywords such as "critical". The purpose of this is to allow physicians to quickly glance through large amounts of text information in paragraph form and extract the most essential information.

CUSTOMIZATION OPTIONS

Allowing users to create personal or department-specific settings

In our research phase, we consistently found that specific departments and specialties have different workflows and patient information needs. Physicians within a particular department are often most interested in seeing results that are relevant to their work. This is particularly true in cases where a specialist frequently receives referrals for the same types of problems.

While finding department-specific results is possible by using a filter or search, customization and adjustable modules would allow users to save settings and arrange their PIV workspace according to their needs. Preserving customizable settings will save users time, as they will not have to continuously reapply the same filters or searches. In addition, some physicians access radiology images more than others, so they may want this featured more prominently in their interface. The types of metadata displayed could also vary based on a physician's personal preferences.

Due to time constraints and limitations on the scope of the project, we did not fully prototype or test customization options. In spite of this, we feel that customization is an important piece of the ideal vision for PIV. As users become savvy and technologically-aware, forward-looking technologies are increasingly providing customization options. In keeping with the innovative ideas contained in the vision, we feel that allowing for customization is critical.

SUPPLEMENTAL TOOLS AND RESOURCES

Integrating tools, calculators, and external reference tools

During our research phase, we discovered that many doctors have different sets of external tools that they utilize throughout their work. Certain specialties have specific tools like the Harriet Lane Handbook, which is a manual for pediatric physicians. Other tools such as medications and dosage information, are much more general in their use. Although not implemented in our system, due to limitations of scope, external tools are a powerful add-on for the ideal vision of the PIV system.

External tools will assist doctors in accessing information, which will in turn expedite and strengthen their diagnosing process. We saw several examples from different locations that support this recommendation. At Johns Hopkins, an anesthesiologist acknowledged that it would make his work a lot easier if there was an ABG or APACHE II calculator built into the medical record for quick references, as he currently uses applications that he has downloaded to his Android phone. He even conveyed surprise that something so fast and convenient did not already exist in medical software.

Immediate access to medication and dosage information is also an important component that would be integrated into the system, since this information is constantly referenced by doctors when they write prescriptions for their patients. Some doctors currently use their iPhones to retrieve this information quickly.

These tools are fundamental to the needs of a doctor and while they may be able to locate these tools outside of the EMR, it is preferable that they are incorporated in the system to avoid workflow disruptions. In the ideal patient information system, each department would have tools customized for their specialty. In accordance with the customization recommendation, these tools could even be tailored to the specific doctor within a certain specialty. We envision this customized toolbar to live at the bottom left of the interface where its default setting would be a collapsed button. This button would expand into a horizontal toolbar when selected.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Radiology Images
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Ankle, Sprained
Carpal Tunnel
Chest Pain
Headache
Knee Fracture
Neck Pain
PIV

MOBILE VISION

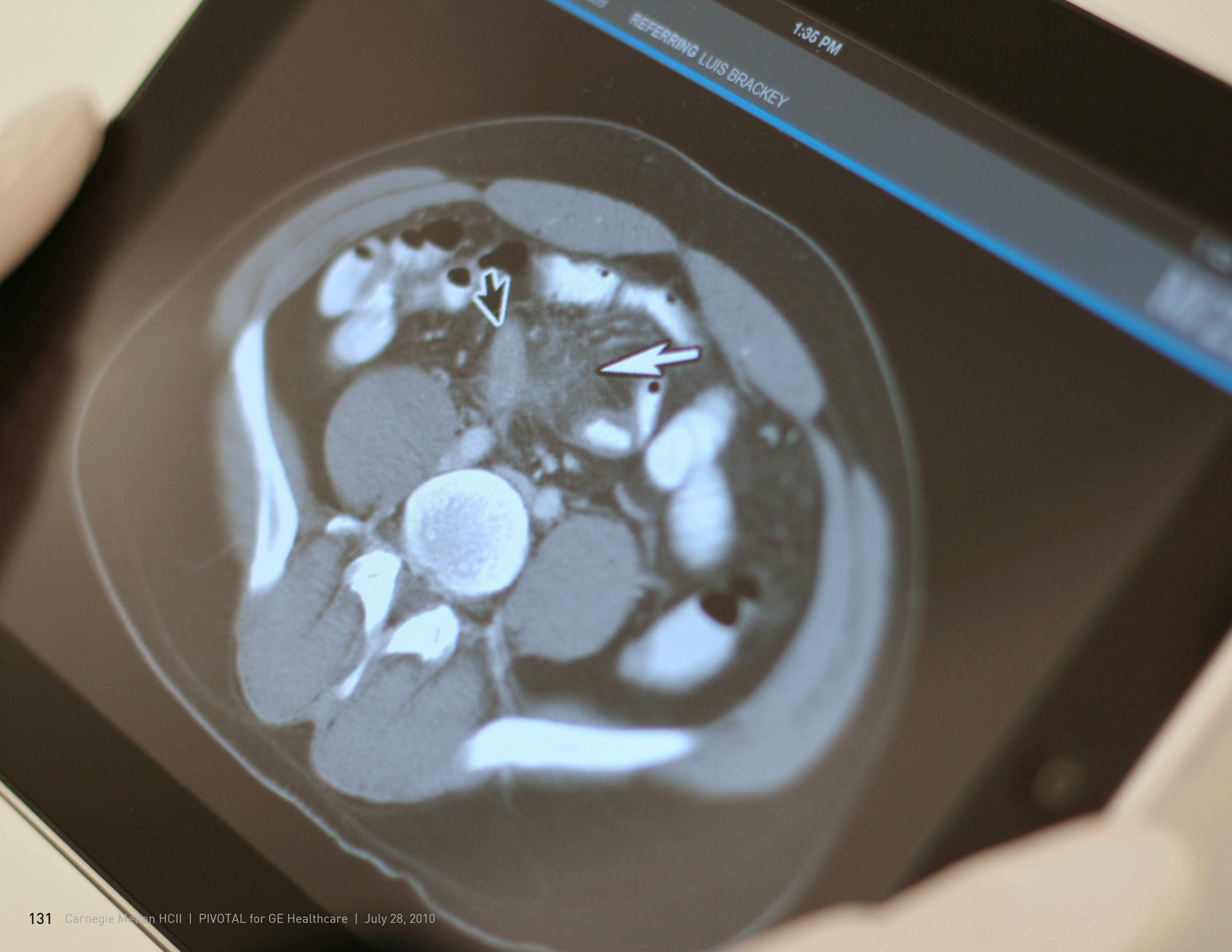
Bringing PIV to the bedside

In our research phase, we repeatedly noticed that doctors have highly mobile and unpredictable workflows. They are constantly moving between patients, computer stations and sometimes even hospitals. For many doctors being on the go is simply a part of the job description. As such, we noticed the growing tension over common resources, like COWs (computer on wheels). These stations were often over-crowded or ill-placed, and ultimately slowed doctors down while they were trying to provide patient care. Since the COWs were shared, they had many issues common to shared computers: improper maintenance, sanitary issues, and security concerns such as previous patient data left on-screen.

We did however notice a growing trend, the smartphone. It was commonplace for doctors to own and use Apple iPhones or Google Android devices. In fact, doctors would often pull out their smartphones and say "Why can't medical software be more like this?!" when they wanted to make a point about problems with current systems. Doctors desired not only the mobility of the device, but also the simplicity and ease of using it.

Doctors also liked the idea that they would have control, if not possession, of the device. By carrying your own device, you could avoid having to queue up at a shared station to access patient data. More importantly, it means that you can access the wealth of patient data anywhere in the hospital, including at the patient's bedside. This is an area where the current technology fails particularly badly.
Because of their size or placement, shared computing stations also prevent doctors from properly engaging with their patients. It is common for the computer to either obstruct the line of vision, or force the doctor to face entirely away from the patient. This is one of the areas where a mobile computing platform can have the biggest impact. Medical software running on a tablet or smartphone would allow for more direct doctor-patient interaction. It would also allow the doctor to stay connected to patient data throughout the entire day — even when not at the hospital, something that was desired depending on the health and treatment plan of the patient.

Mobile platforms can solve many of the current drawbacks of technology in a hospital. Of course though, they also come with a few drawbacks. A switch to mobile technology could potentially force doctors to carry around an extra (sometimes substantially-sized) device. Mobile platforms also introduce other issues, like the limitations of battery life and less screen real-estate. However, we feel that the benefits of using this type of technology certainly outweigh the potential drawbacks. Mobile computing is often heralded as the future of technology, and this certainly seems to apply to the medical domain as well.


REFERRING LUIS BRACKEY
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DESIGNING FOR THE IPAD

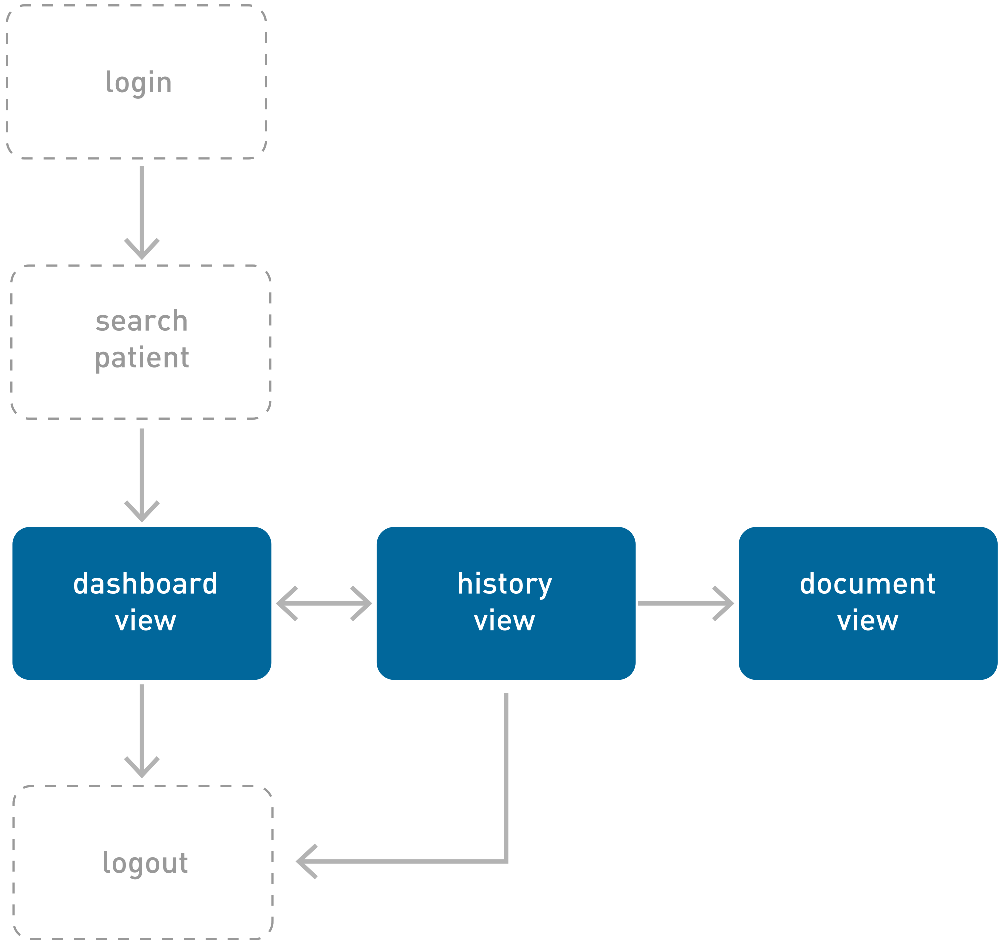
Design conflicts in building the PIV for the iPad

Any native application that is part of a suite, or collection of software, will need to strike a balance between matching the platform's native look and feel and the suite's branding and aesthetics. In this respect, our vision of the PIV iPad application is no different. Users should feel comfortable using the iPad-tailored PIV, which requires keeping the interface consistent with Apple's stringent iOS Human-Interface Guidelines.

To ensure consistency, we examined dozens of iPad applications that embodied the interaction style we desired. The final design leverages ideas and design metaphors from several different Apple-branded applications including the Photos and iPod applications. The iPad PIV features the familiar tab-bar along the bottom as well as pinch-able stacks of images. We also utilize familiar menus and layouts to reinforce consistency.

The PIV iPad application also balances the native application look with the design guidelines previously set for the PIV web application. The dropdown header is an instantly familiar element. Additionally, the same language and filter metaphors are carried across both modalities.

Interaction Diagram - Overview (Vision)



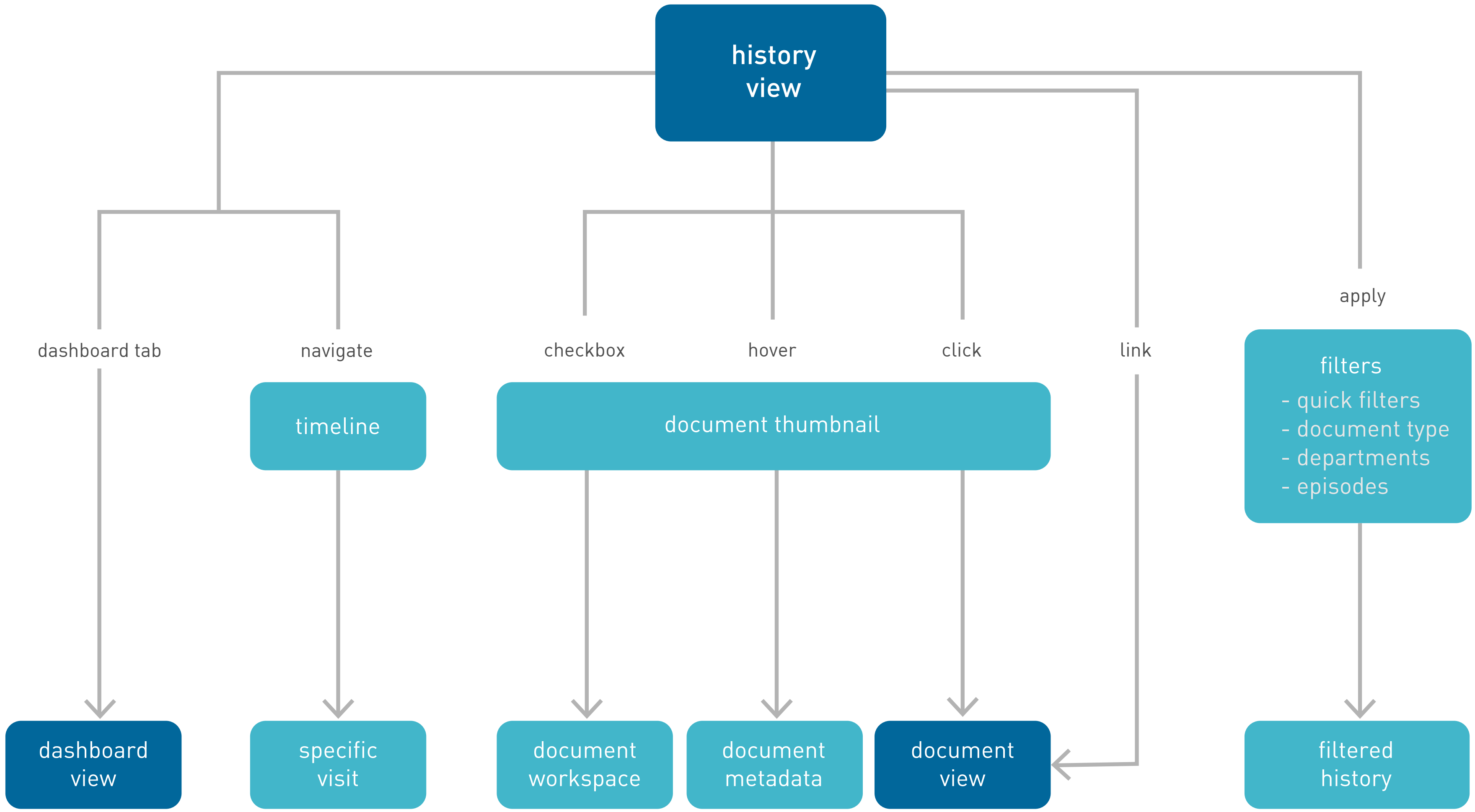
Connections between different screens in the design. The interactions on each of these screens are explained in further detail on the following pages.

INTERACTION DIAGRAM

Interaction and navigation in the system

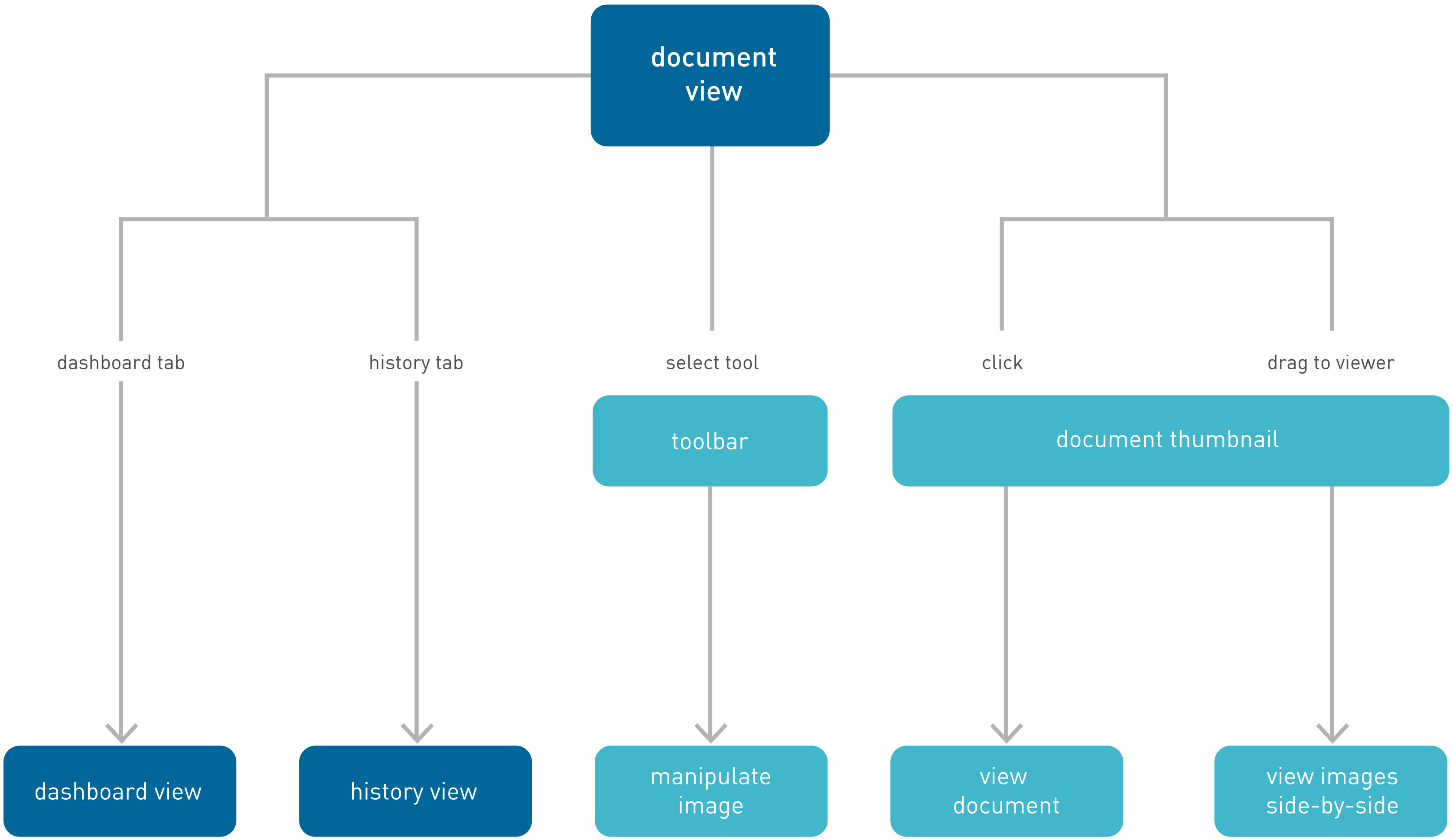
This system map illustrates the relationships between the different screens and features available in the vision. This builds on the system in the design piece by providing the dashboard which allows for a greater number of entry points to get to the history view. By including discrete data in the vision we are also able to provide more ways to navigate the patient record.

Interaction Diagram - History View (Vision)



The history view can be changed using the timeline or filters, and documents can be selected in several different ways.

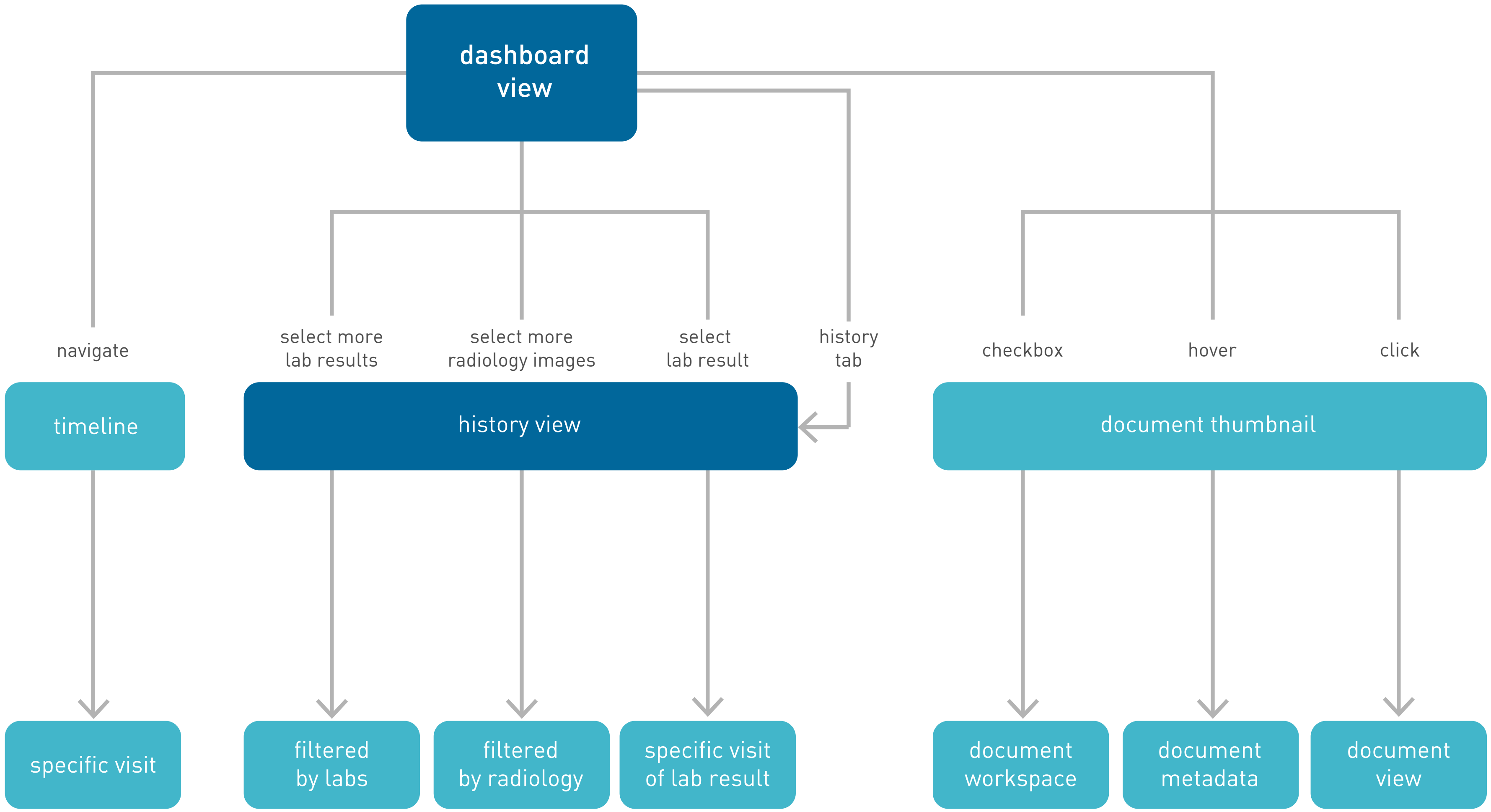
Interactin Diagram - Document View (Vision)



The document view has links back to both the dashboard and history views, as well as ways to organize or manipulate images.

OUR VISION

Interaction Diagram - Dashboard View (Vision)



The dashboard serves as a launching point to almost every part of the application, including the history view (filtered in a number of different ways) and the document view.

VISION SUMMARY

PIV as the primary application, supporting efficient doctor workflow and better patient care

By integrating more information, more features and greater sensemaking capabilities, we believe the PIV can serve as the primary application for use by doctors. Doctors' current frustrations in having to constantly switch between applications would be alleviated through this consolidation of features into the PIV.

A quick dashboard view would provide them with an at-a-glance look at a patient's health, and the fully integrated history would give them any information they will need about past medical events. Color-coding would make this information more easily glanceable, while breaking out the various components of each patient encounter (e.g. doctor note, radiology images) would make it especially quick and easy to find the most relevant information. Customization would allow each doctor to optimize the workflow to their unique needs, and ensure that the most relevant information is easily accessible. Including tools within the interface itself would save time and streamline work by allowing doctors to do everything they need all in one place. Finally, enabling doctors to use this application from a mobile device will allow them to easily take their information into patient rooms without detracting from their interaction with patients.

CONCLUSION

SUMMARY

Working towards healthcare systems that support better patient care

This summer has seen the PIV take shape, moving from research findings to a working prototype. By synthesizing concrete findings from our research with our brainstorming ideas and design directions, we began our work on the PIV. We refined the major components of the PIV interface through paper-prototyping, wireframing, and click-through prototyping. To fully evaluate the user interface, we conducted quick usability tests with physicians at a local hospital. This allowed us to iterate our design to ensure that our user interface is simple, minimal, and easy-to-use. After seven months of research, design, development and testing, team PIVOTAL, with the direction of GE Healthcare, presents a revolutionary way to view patient information.

We hope that our findings and insights will help the medical industry move towards more innovative software solutions to provide higher quality patient care.

NEXT STEPS

Further opportunity spaces include data entry, and full integration

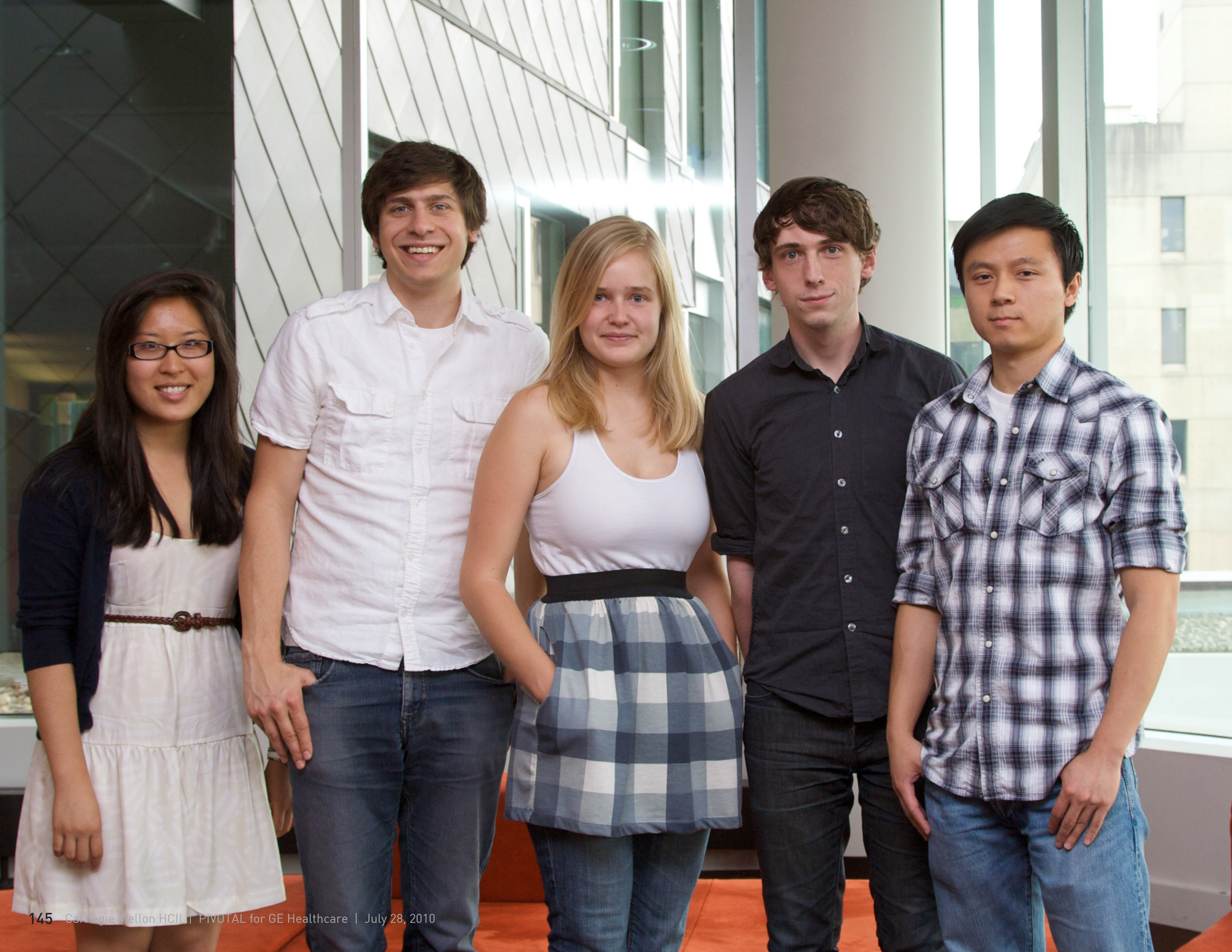
Due to time constraints, we focused on only a subset of what we think the ideal PIV could be. Further research, design and testing could take the PIV even further than the vision we have provided. In particular, there is room for more research to be done into how doctors and other hospital staff enter data. This research would provide groundwork for incorporating data entry into the PIV. This is an important feature since it will greatly enhance the PIV's ability to be the primary (and ideally only) application that a doctor uses.

Another area that can be researched is understanding the complete usability of different systems used by doctors for image viewing, patient scheduling, electronic communication, and accessing various patient records. Unfortunately, every patient record system we researched and observed had different behavior and appearance. Rather than having physicians recalling the different types of interactions in many systems, we envision that creating a single, consolidated patient application would allow consistent behavior and appearance to reduce physicians' cognitive load of remembering how to use all the systems. Furthermore, additional time required to load different systems would be reduced, thus allowing more time for patient interaction.

Having the ability to efficiently enter data, as well as quickly retrieve patient information, all in the same application, could provide significant improvements in doctor workflows, and in turn, patient care as a whole.

IDEAS FOR FUTURE RESEARCH

- How doctors and other hospital staff enter patient information
- Integrating all healthcare applications into one system



ABOUT THE TEAM

An interdisciplinary team of researchers, designers, and developers

Youna Yang | Design Lead
Youna is from Philadelphia and graduated with an undergraduate degree in Industrial Design from Carnegie Mellon. Youna has worked on projects involving families, elders, product brand identity, and interface design. Currently, Youna is pursuing a Masters in Human-Computer Interaction to learn more about user research and to better understand and design for people's needs.

Mike Sparandara | Project Lead
Hailing from New York, Mike attended Tufts University in Boston where he studied Computer Science and Engineering Psychology. After receiving his diploma, Mike transitioned to the West coast where he worked for various Bay Area start-ups doing user interface design work. Mike is now studying at Carnegie Mellon to further his development as a designer.

Anna Ostberg | Research Director
Anna is originally from the San Francisco Bay Area, and studied Cognitive Science with Specialization in Human-Computer Interaction at the University of California, San Diego. Anna has worked on research projects dealing with interaction in public spaces, personal information management, and using cell phones to control public displays.

Nick Leonard | Communications Director
Originally from St. Louis, Nick attended the University of Missouri where he studied journalism as well as information technology. Before coming to Carnegie Mellon, Nick worked for the University of Missouri School of Medicine and a medical technology start-up as a web application developer. Nick is emphasizing design in his graduate education.

Michael Lin | Chief Architect
Michael grew up in Illinois and Connecticut before attending the University of California, Irvine. He studied Information and Computer Science and worked as a software engineer at a major defense company in San Diego. Currently, Michael is pursuing a Masters in Human Computer Interaction at Carnegie Mellon to follow his interests in system usability.


MHCI Project Team: GE Patient Care
Nick Leonard
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Mike Sparandara
Youna Yang
Human-Computer Interaction Institute
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ABOUT THE HUMAN-COMPUTER INTERACTION INSTITUTE

Research and education in computer technology to support human activity and society

The mission of the Human-Computer Interaction Institute (HCII) at Carnegie Mellon University includes studying ways to understand the goals of the user through methods that analyze and evaluate human behavior. Interdisciplinary perspectives in design, computer science, and behavioral sciences inform an understanding of user needs. This guides design solutions that better support user tasks while also improving the overall user experience.

Within the HCII, the Masters of Human-Computer Interaction (MHCI) program is a full-time, twelve-month program that includes an eight-month long capstone project. Students from various academic backgrounds and work experiences collaborate in teams with an industry sponsor to create a working prototype through an end-to-end design and development cycle.


visualization
signal/
noise
Viewing
File
Types
User
Workflow
Data
Context
Different
Users
Patient
Context
XDS

THANK YOU!

Team PIVOTAL would like to thank all of the people who helped make this project possible. The insights from our research participants proved invaluable. Without the support of GE Healthcare and our faculty mentors at Carnegie Mellon, this project would not have been possible.

We hope the information and design ideas we've provided serve to inform and inspire future work.

If you have any questions about the project, or about the potential for future projects, please contact our advisor:

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