CREATING COMMUNICATION TECHNOLOGY FOR RADIOLOGY 2.0

Capstone Project Final Report

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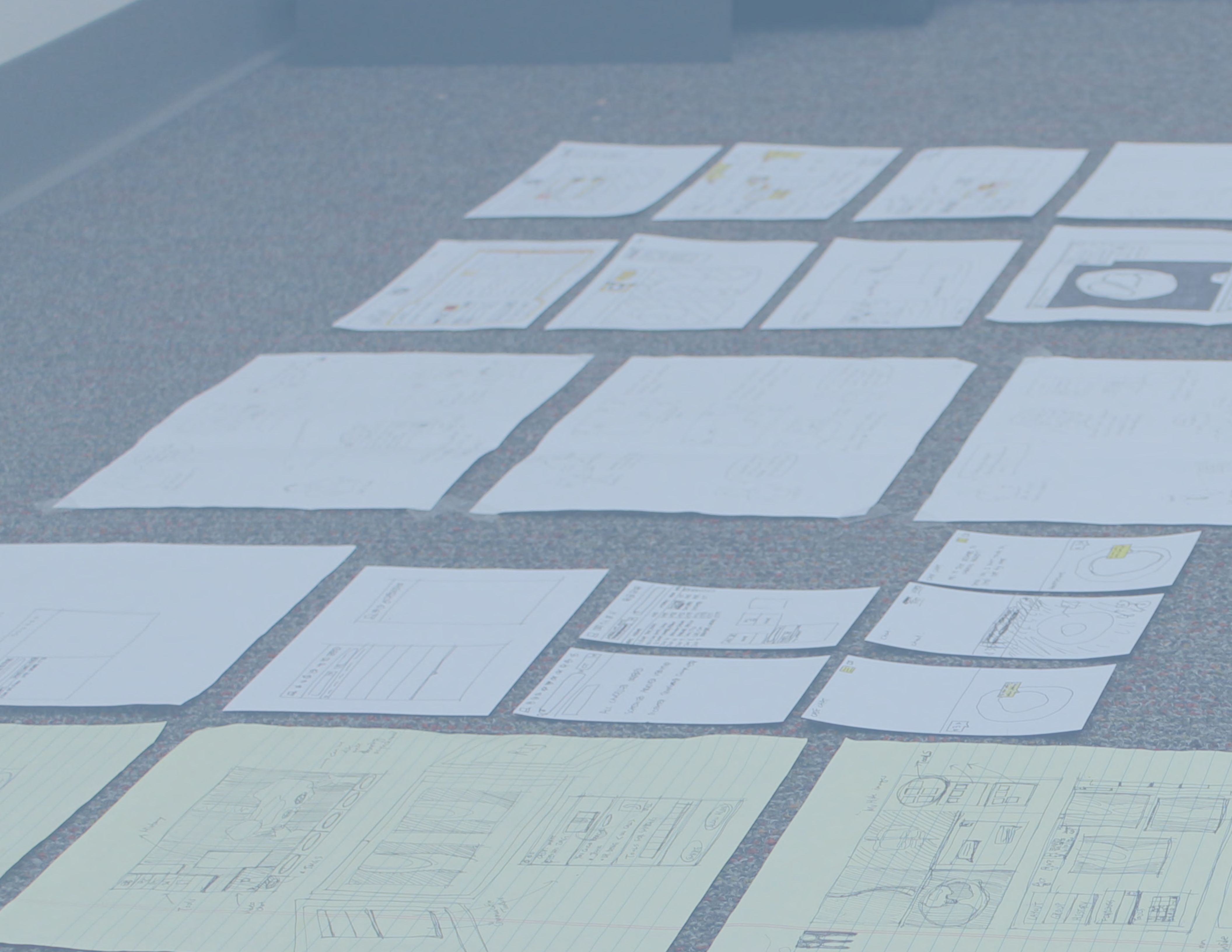
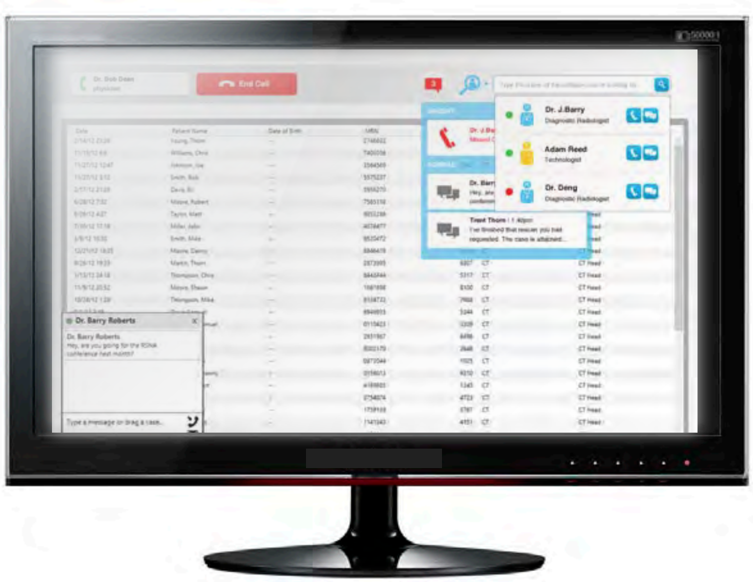


EXECUTIVE SUMMARY

We present our vision, Synaptic—a real-time collaboration and priority-based communication interface integrated into a unified RIS/PACS system. Our interface gives radiologists the control and flexibility they need to more efficiently connect with colleagues, conference around cases, and handle incoming requests.



Solution › See page 30

Over the past eight months, Team Shoal has worked with GE Healthcare to prototype a usable, desirable, and cohesive solution for radiologists' current communication and collaboration needs. Radiologists can now communicate and collaborate seamlessly within RIS/PACS, maintaining or breaking focus at their informed discretion. Furthermore, our interface is backed by comprehensive user-centered research, concept validation, and six rounds of iterative prototyping and testing. As a result, radiologists described our final prototype as fast, efficient, timesaving, convenient, and easy to use.

Research › See page 10

In the spring, we researched the problem space and its users, focusing on the ways radiologists communicate, with whom, and how these fit into their workflow. We performed a competitive analysis and literature review to gain perspective. Then, we conducted field research at five hospitals with 27 participants in seven different roles, organizing the data we gathered into four categories of key findings: **Teamwork, Mobility and Presence, Prioritization, and Reliability**. Overall, we found that while GE's current platform enables radiologists to read images and distribute work by providing a strong connection between the reading room and imaging equipment, radiologists frequently experience collaboration and communication breakdowns that the platform leaves partially or fully unaddressed.

Design › See page 60

In the summer, we designed, usability-tested, and developed our proof-of-concept prototype to help GE capitalize on our findings. Our prototype demonstrates a vision for an integrated communication and collaboration interface. Its combination of synchronous and asynchronous communication tools supports radiologists' current communication needs while alleviating many of the workflow disruptions they currently experience. Every step of the way, we improved our designs with generous feedback from our GE mentors, faculty, peers, radiologists and their colleagues. This report documents our solution, the iterative design process behind it and future considerations.

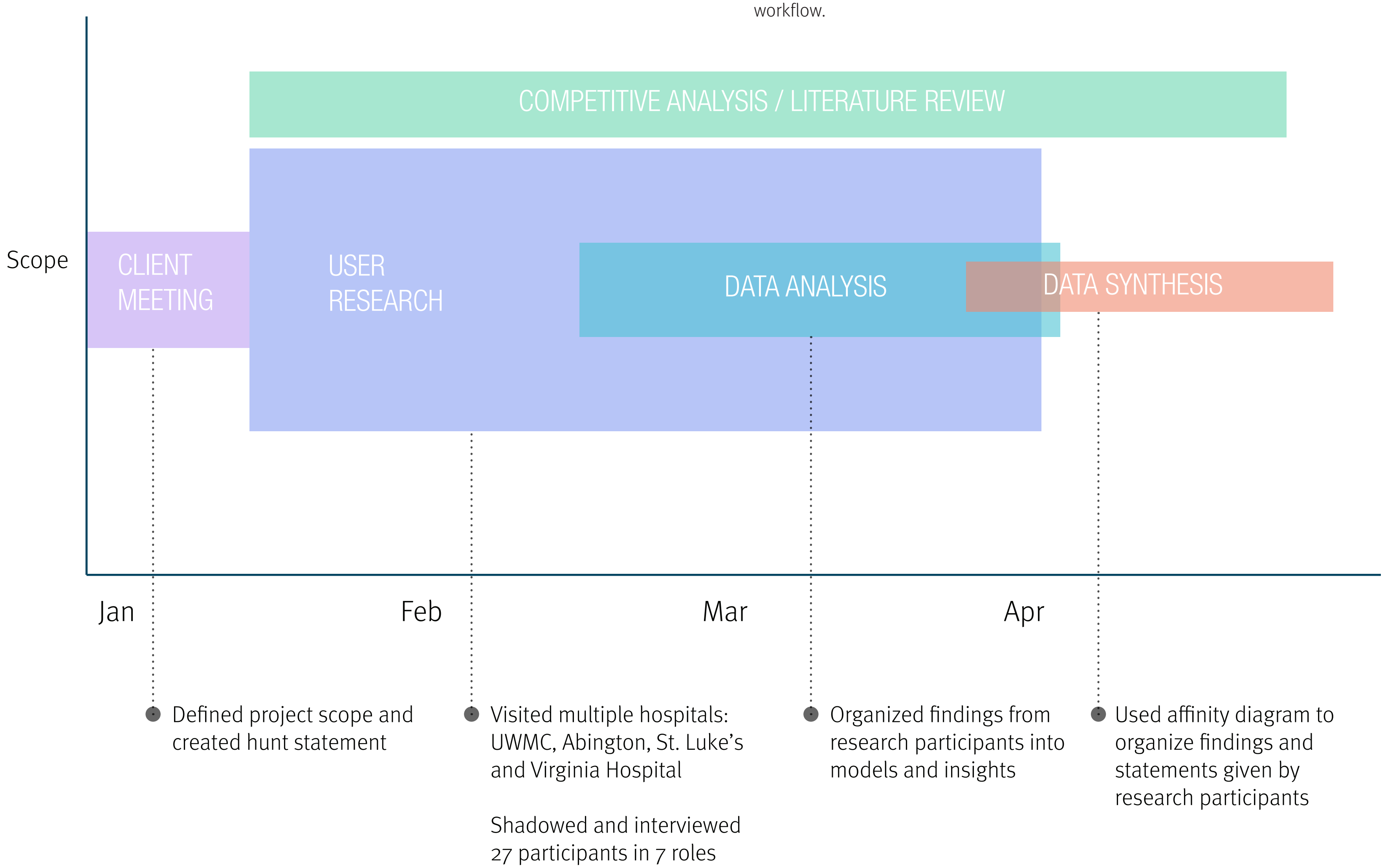
PROJECT OBJECTIVE

Understand communication-management techniques in radiological settings in order to design an integrated, collaborative interface that streamlines workflow and increases productivity among stakeholders.

PROJECT TIMELINE

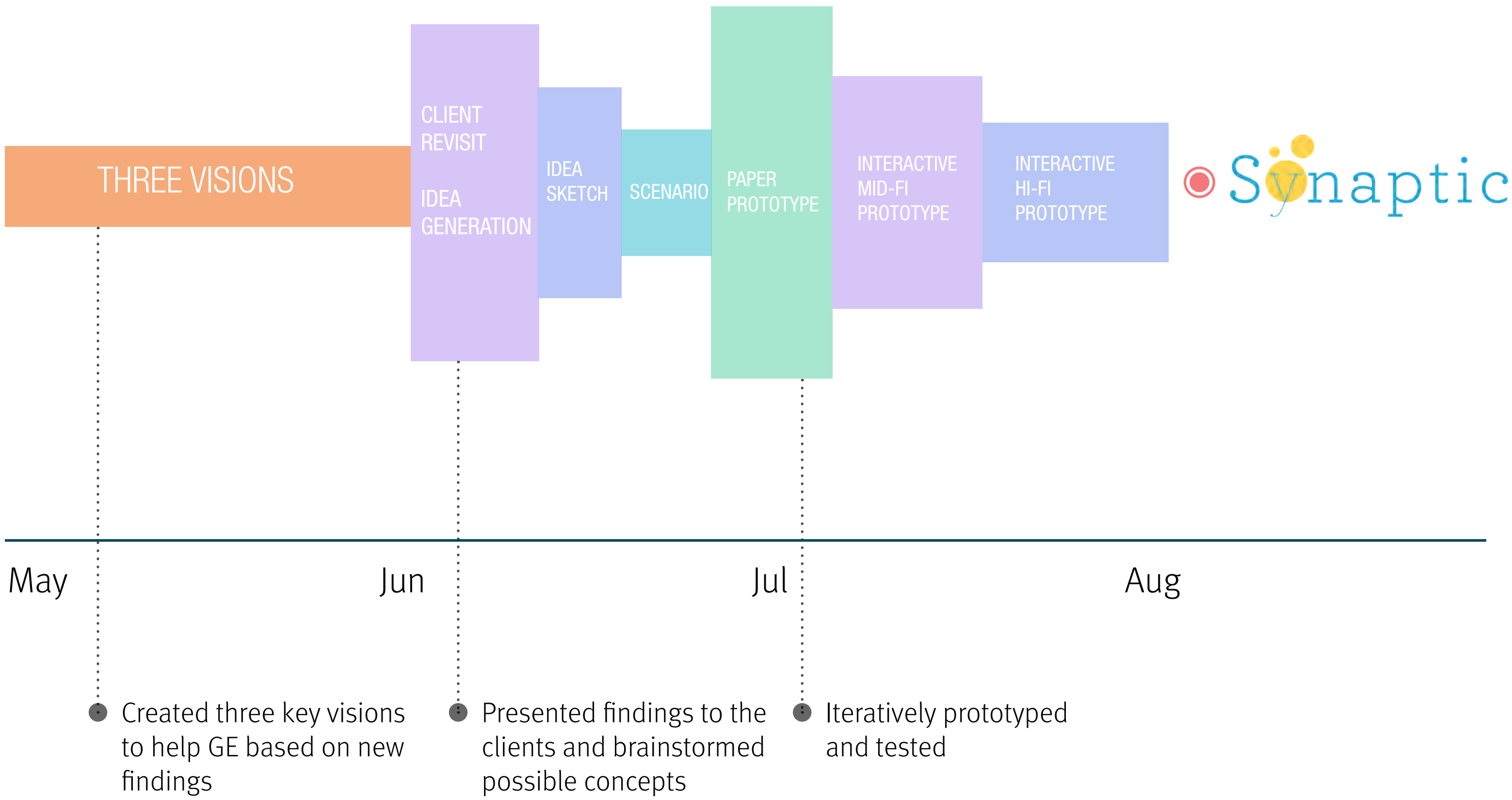
Spring

In the spring, we researched the problem space, focusing on the ways radiologists communicate, with whom, and how these fit into their workflow.



Summer

In the summer, we built on our findings to iteratively design, usability-test, and develop our proof-of-concept prototype for GE. Our process involved multiple phases of narrowing and broadening of our focus as we reframed our solution based on feedback from radiologists.



RESEARCH

Research Process

In the spring, we researched the problem space and its users, focusing on the ways radiologists communicate, with whom, and how these fit into their workflow. We performed a competitive analysis and a literature review to gain perspective. Thus prepared, we engaged radiologists in contextual interviews and quietly shadowed them while they worked.

Returning from the field, we organized our data into four categories of key findings: **Teamwork, Mobility and Presence, Prioritization, and Reliability**. We also created a consolidated workflow model to reveal common types of interruptions and vulnerable periods within the radiologist's workflow where interruptions have a larger impact.

In the summer, we revisited our data to create a communication model (see page 24) to highlight areas of incoming and outgoing communication we could improve with our forthcoming design.

OVERVIEW

Background Knowledge

We started our research phase by conducting a literature review and a competitive analysis. We surveyed 20 peer-reviewed articles and eight analogous products. Our studies provided valuable insights into the nature of computer-supported collaborative work and showed us how a solution for radiologists would fit into this broad domain.

Client Kickoff

When our project began, our clients joined us in Pittsburgh to discuss their goals and the overall problem space. We took this opportunity to absorb our clients' domain knowledge and expertise in healthcare solutions, as well as to learn about known breakdowns in radiology workflow. We left this session with a stronger understanding of GE's priorities and of our project's scope.

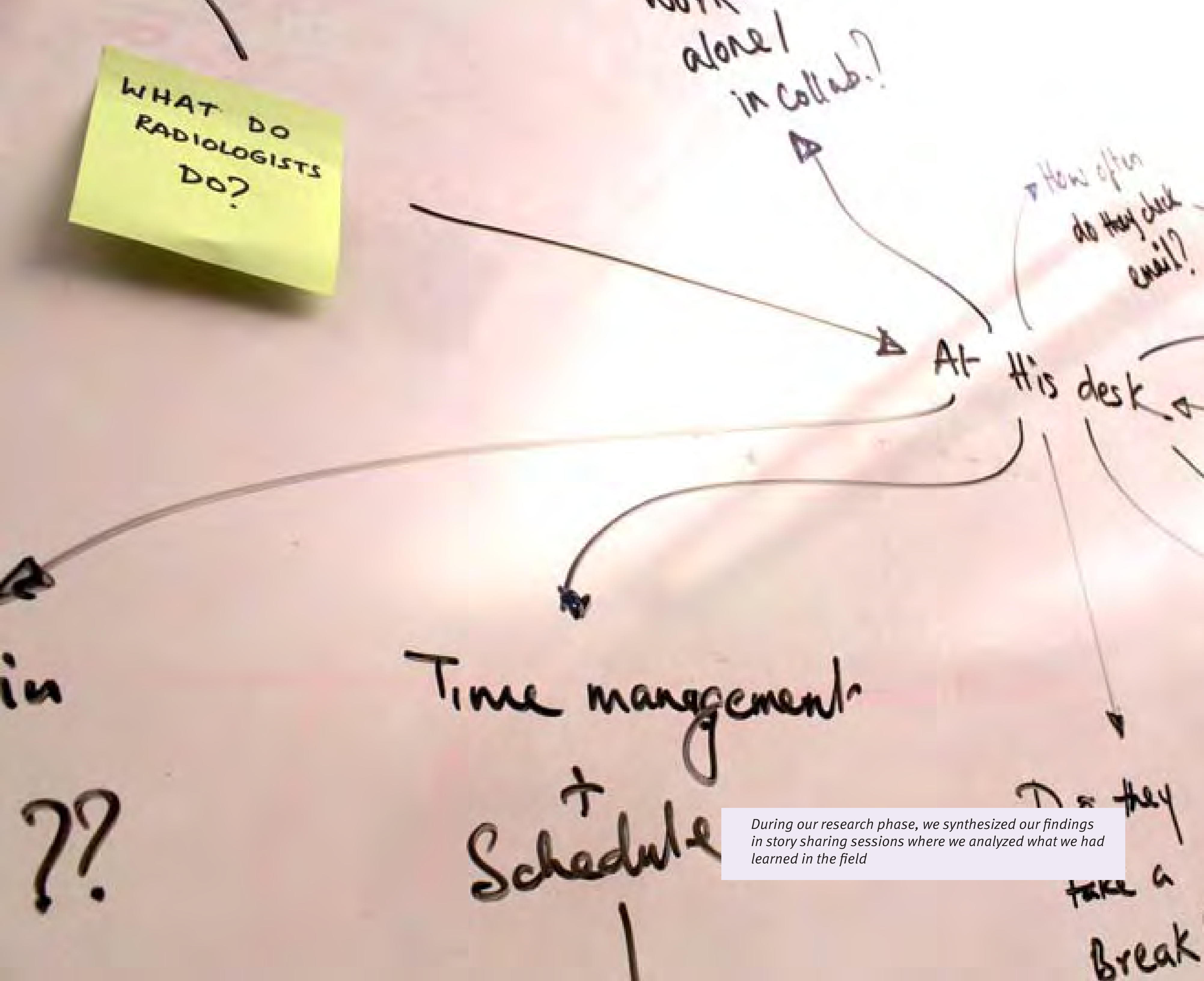
Ethnographic research

We spent a large part of our research phase conducting ethnographic field research. We interviewed and shadowed 27 participants in seven different roles within their normal work contexts at five hospitals. Among the diverse roles we studied were general diagnostic radiologists, those specializing in specific areas, and interventional radiologists. Even within these groups, we spoke with attendings, residents, and fellows. We also met technologists with different levels of expertise, referring physicians, specialists, one I.T. representative, and two Physician Support Services employees responsible for coordinating radiologists' communications on-location.

Documenting our findings

We tailored our research methods to work around our participants' busy schedules, shadowing during high-volume periods and saving clarifying questions for free moments. We followed up with semi-structured interviews to further discuss issues we observed. However, HIPAA requirements prevented us from recording audio or video of our sessions. We were also restricted to two-person research teams to avoid overwhelming participants or crowding small reading rooms.

To make sure that we captured as much data as possible, we shared our handwritten notes, sketches, and stories with teammates immediately following field visits. We also made intermediate affinity diagrams and contextual models to visualize the communication flows, cultural atmospheres, physical settings, and artifacts that we encountered.



During our research phase, we synthesized our findings in story sharing sessions where we analyzed what we had learned in the field

KEY FINDINGS

“If you get the best equipment but can’t communicate, you will fail.”

– Janis, Coordinating Technologist

At the end of spring, we synthesized all of our insights to reveal four key findings. Please see our Spring Research Report in the attached Appendix CD for details on our Research Findings and Process.

1. Teamwork is undervalued
2. Systems fail to account for presence and mobility
3. Interruptions create desire for prioritization
4. Low system reliability wastes time and causes frustration

1. Teamwork is undervalued

We found strong relationships between radiologists and other radiologists, technologists and referring physicians. We saw that these were central to good patient care and valued by radiologists. However, they were ill-supported by current software tools.

Radiologists thrive on quick, focused conferences

"Scheduled conferences are extremely effective. You can discuss interpretations with other radiologists."

–Dr. Bob, Attending Radiologist

We saw radiologists improve diagnosis quality by collaborating with and educating other radiologists and referring physicians. Systems should be designed to allow for quick scheduled meetings resulting in better diagnosis and training.

Technologists benefit from collaboration with Radiologists

"We have a great relationship with techs. I encourage them to come whenever they have a question. It's like every fifteen to twenty minutes, someone needs an opinion or answer for something."

–Dr. Adama, Radiologist

Technologists often collaborated with radiologists about cases and protocols in person, by phone or by pager. Systems should allow technologists to request timely feedback on protocols without multiple communication tools, minimizing patient wait time.

Technologists and radiologists may collaborate in the control room to establish research protocols

We saw technologists and radiologists collaborating closely at teaching hospitals. Systems should be flexible enough to support heavy interaction between technologist and radiologists for complicated or untested protocols.

Radiologists at some research facilities remotely control scanning equipment

Because we saw the use of these tools, we recommended considering integrating live scanning feeds and approval mechanisms into PACS for teaching hospitals and other research institutions.

Collaboration solves unexpected problems

We often watched radiologists ask for second opinions on challenging images and unprecedented situations. Systems should be designed to help radiologists get and give peer advice.

2. Systems fail to account for mobility and presence

We saw radiologists commonly working different shifts on different days, sometimes at different hospital sites or in different reading rooms. Many of them did not have assigned offices or desks and switched workstations during shifts. We also found that referring physicians are often not at their desks and can be hard to get hold of.

Current systems lose track of mobile physicians

> *"The radiologists are very busy. It's hard for them. The worklist is so long, and they keep getting called away to meetings, clinicians, conferences, all over."*
>
> – Laura, Physician Support Service Staff

We saw radiologists use different workarounds to make sure that they were reachable when collaborators needed to get hold of them. Systems should be designed so that radiologists can receive urgent messages conveniently even when mobile.

Patients are affected by communication breakdowns between radiologists and collaborators

Several radiologists asserted that communication between the radiologist and referring physician is key to good patient diagnosis. Lack of timely communication between technologists and radiologists can result in serious breakdowns in patient care. Systems should be designed to ensure patient requirements be satisfied by or before scheduled appointments.

Calling referring physicians is a game of phone tag

> *"Push a button in PACS and it calls the referring physician, that would be useful. I want to be able to do everything in real time. Later, I tend to forget cases and there is no good way to queue cases. When are you going to catch up anyway? You need to do it all on the fly?"*
>
> – Dr Bob, Attending Radiologist

Radiologists often struggled to alert physicians to discoveries of critical results–potentially life-threatening abnormalities observed in patient images. Because of the time wasted in getting hold of the referring physician and the overhead in keeping track of findings that need to be communicated, systems should be designed to more conveniently connect and facilitate communication between the radiologist and referring physician.

3. Interruptions create desire for prioritization

Participants at every provider we visited stressed the importance of prioritizing radiologists' communication to prevent it from overwhelming them. Radiologists saw these interruptions as valuable to their work, but wanted to be able to handle them at their convenience.

Some interruptions are essential

"I need to get hold of a radiologist immediately and cannot wait for phones to ring. I need direct access."

– Dr. Ronson, Referring Physician

Certain communications, like those from the emergency department or the referring physician, are more urgent than others and require more timely responses, but there is currently no way to quickly filter communications by urgency. Systems should enable radiologists to prioritize urgent cases.

Lack of coordination breeds poor communication

"Referring physicians get no notification when the radiologist is done reviewing a study and reporting his findings."

– Dr. Tsai, Radiologist

We saw poor communication cause a lot of overhead. Collaborators were unaware of what had or had not been communicated already, so they interrupted each other for redundant reasons. Asynchronous communication would enable collaborators to reduce redundant communications and share information with all relevant stakeholders.

Disputed protocols cause delays and increase urgency

"The patient has to wait on the table. Techs and patients start to freak out."

– Earl, Technologist

Technologists rely on protocols for instructions on scanning patients. This is particularly important where contrast dosage is involved. When specified protocols need correction or clarification, the resulting delays cause anxiety among technologists and, most importantly, patients. Systems should encourage radiologists to prioritize communications that directly affect patient care.

Radiologists strongly desire asynchronous communication when mobile

"I wish there was more instant messaging for radiology. All information notification phone calls could sgo through a notification system instead."

– Dr. Sun, Radiologist

Unprompted, several radiologists expressed a desire for asynchronous communication tools like instant messaging. Systems could integrate mobile and remote technology capable of transmitting supplementary images and information.

4. Low system reliability wastes time and causes frustration

Unreliable systems affect radiologists' productivity and quality of care. Every radiologist we studied highlighted opportunities to improve PACS.

Radiologists lack quick access to recent cases

"Why can't I just get the last ten studies that I've accessed in a separate menu or something for easy access?"

– Dr. Deng, Radiologist

Enable radiologists to easily access recent PACS cases.

Lack of grammar correction leads to slower dictation

"We're doctors for doctors. For the most part, I'm only as good as the information I provide. That is how I judge myself."

– Dr. Cranston, Radiologist

Integrate grammar and syntax correction with dictation software, and provide upgrades for existing software.

Redundant PACS features slow things down

"I waste over 40 minutes of my day doing exactly this: selecting each and every image with my mouse while trying to cross-reference them."

– Dr. Tsai, Radiologist

Thoroughly review the sequence of PACS functions to eliminate redundancy and provide shortcuts for frequently used functions.

Worklists are not prioritized and must be constantly monitored

A lot of scheduling happens on the fly."

– Holly, Technologist

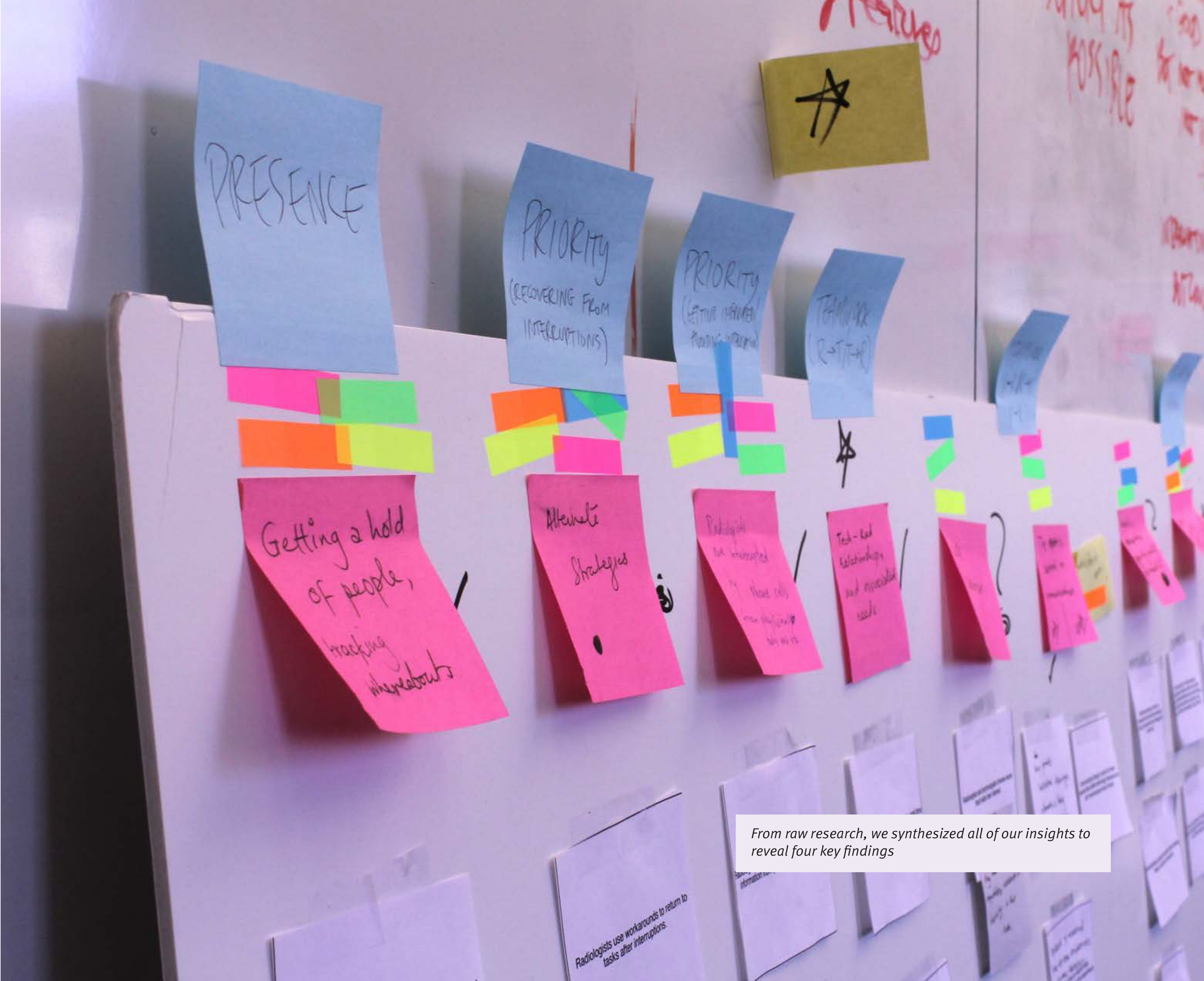
All radiologists said that they constantly monitor the RIS for new cases. Systems should enable radiologists and technologists to prioritize and customize worklists without abandoning less appealing cases.

Disconnected patient data and inaccurate patient history cause interruptions

"Labs are not available. There is no data integration. There is clinical integration, but that is useless for radiologists."

– Dr. Alberts, Interventional Radiologist

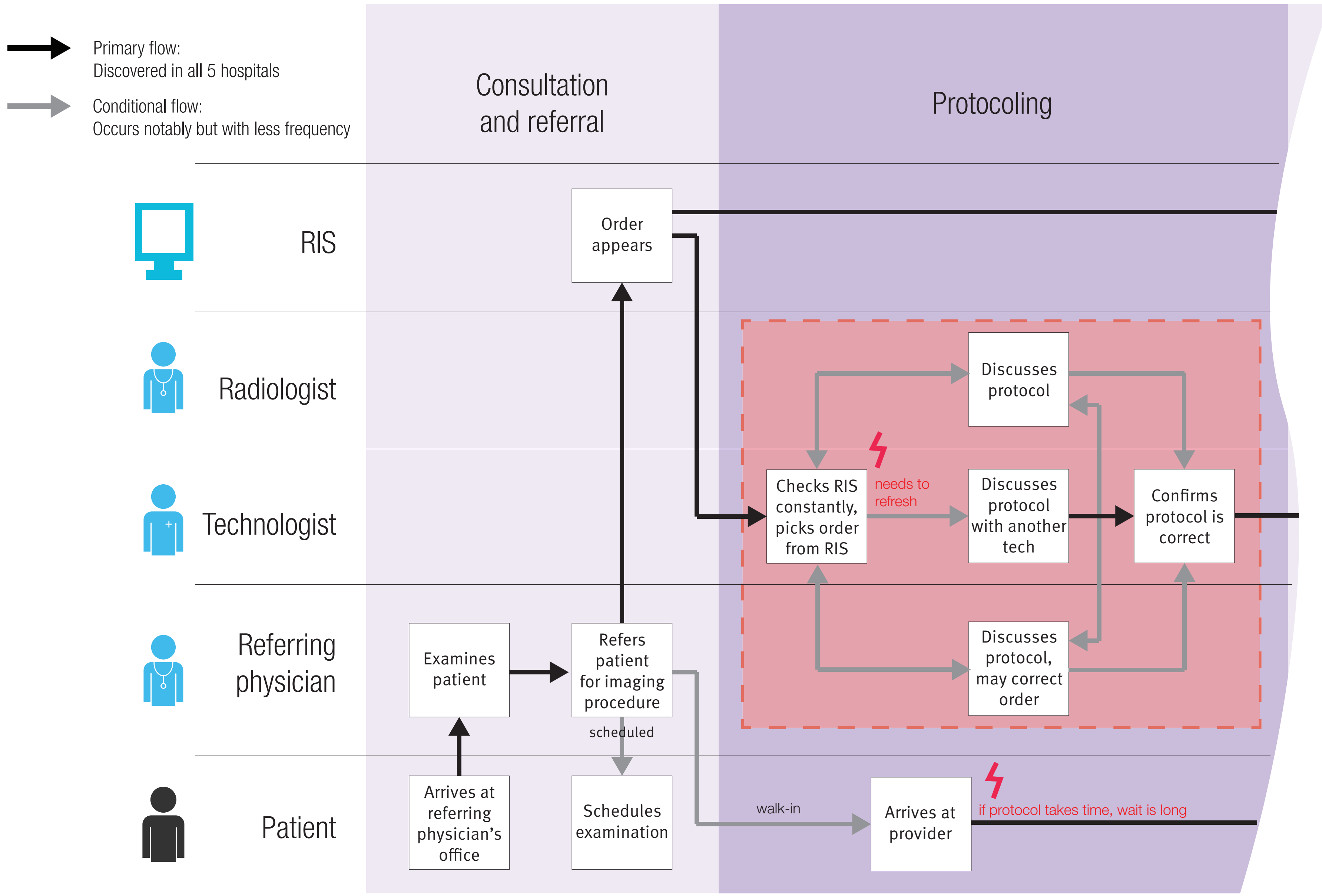
Although RIS systems enable access to clinical data, we saw that pathology results were sometimes not integrated into PACS or RIS systems. Radiologists had to dig through multiple systems to locate clinical information for each case, resultng in significant overhead. Sometimes, the patient data was incorrect. As a result, radiologists were concerned about the potential for serious consequences. Improve integration of EMR with the RIS and PACS, and consider providing radiologists with the ability to add findings directly to the EMR.



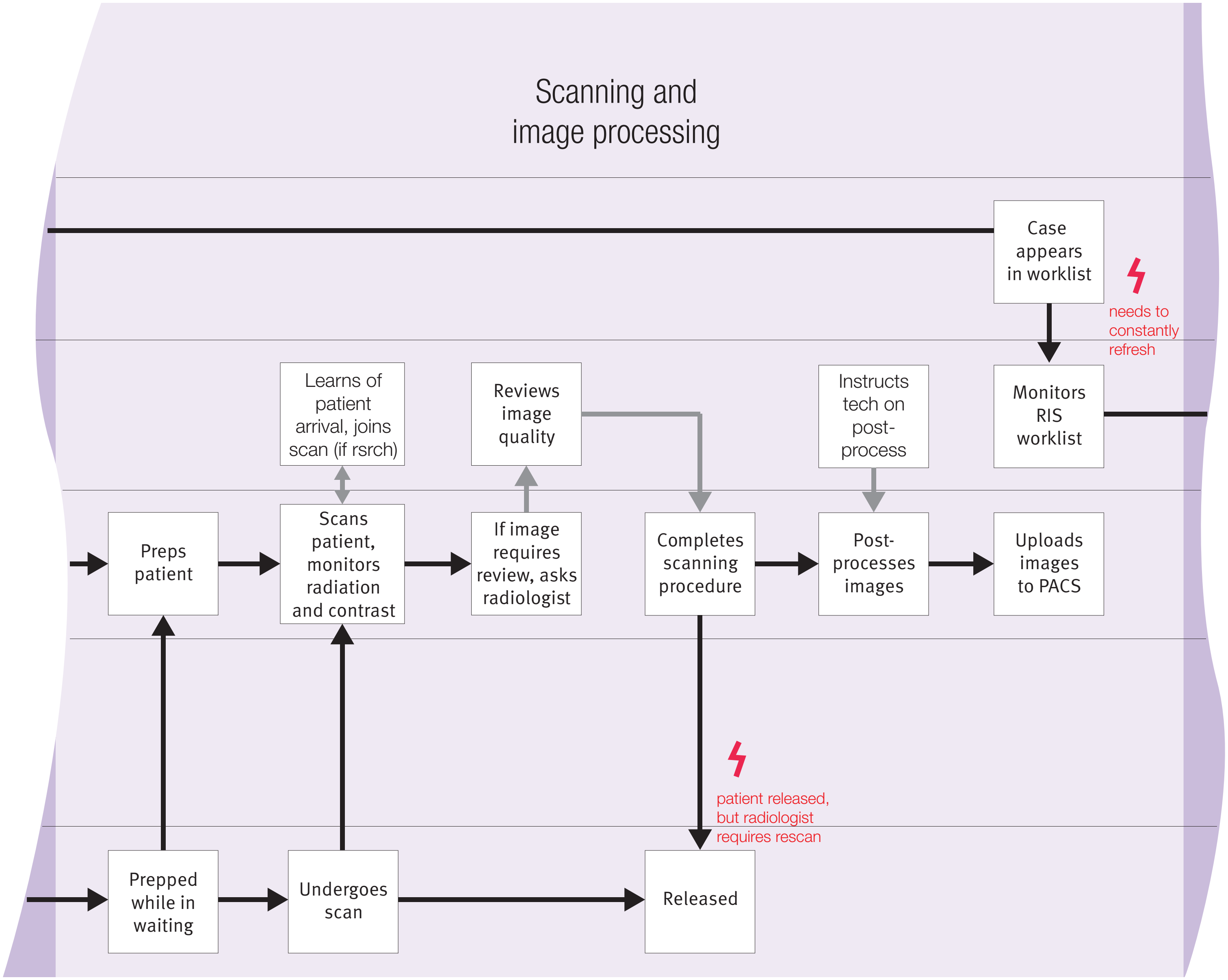
From raw research, we synthesized all of our insights to reveal four key findings

WORKFLOW MODEL

We consolidated our research findings into a workflow model. This model shows the entire case workflow from referral through report signoff and the involvement of all relevant collaborators: radiologists, physicians and technologists. Breakdowns are marked in red. More details about this workflow model can be found in our Spring Research Report in the Appendix CD.


Primary flow:
Discovered in all 5 hospitals
Conditional flow:
Occurs notably but with less frequency
Consultation and referral
Protocoling
RIS
Radiologist
Technologist
Referring physician
Patient
Order appears
Discusses protocol
Checks RIS constantly, picks order from RIS
needs to refresh
Discusses protocol with another tech
Confirms protocol is correct
Examines patient
Refers patient for imaging procedure
Discusses protocol, may correct order
scheduled
Arrives at referring physician's office
Schedules examination
walk-in
Arrives at provider
if protocol takes time, wait is long

WORKFLOW MODEL



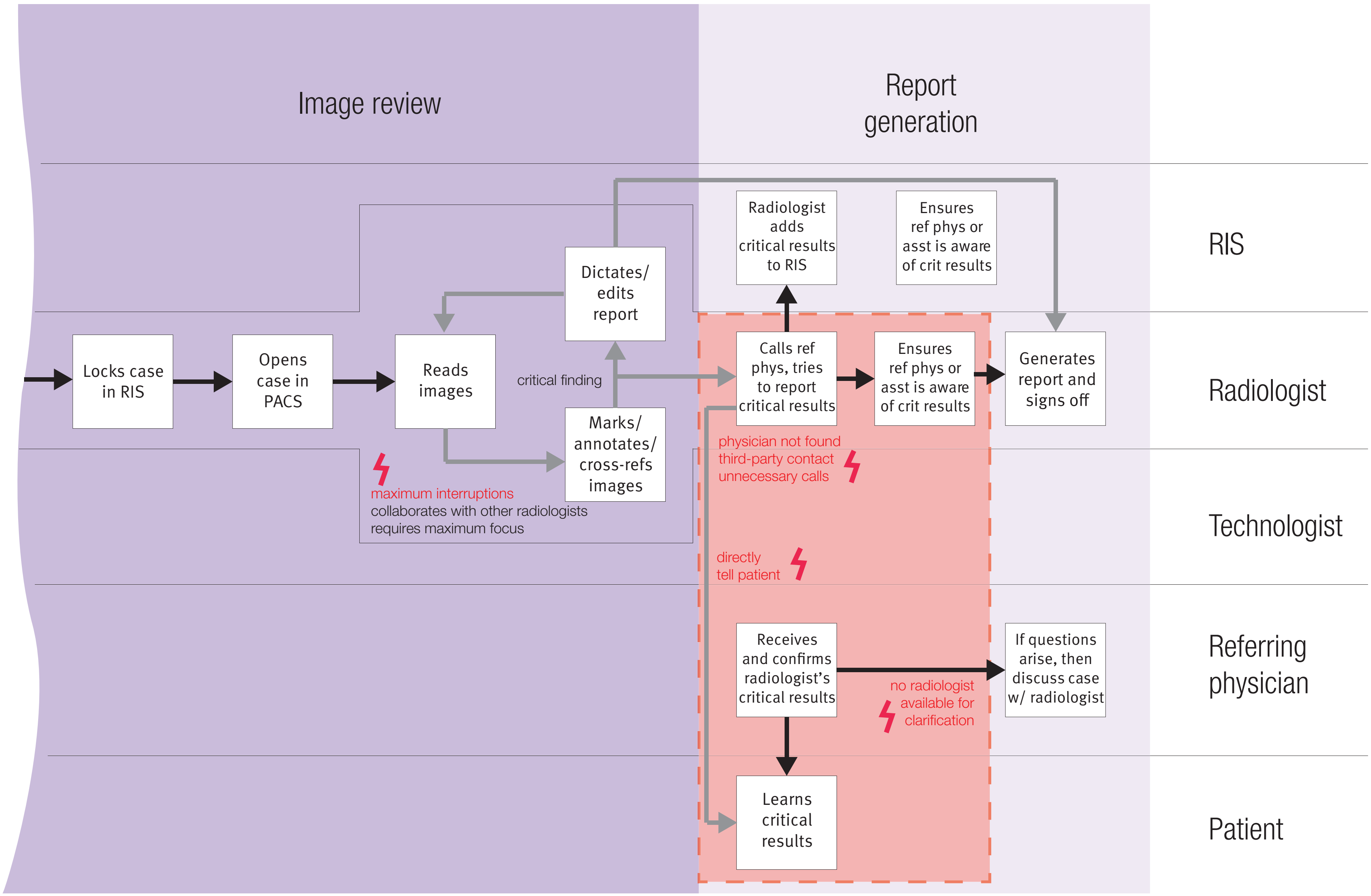


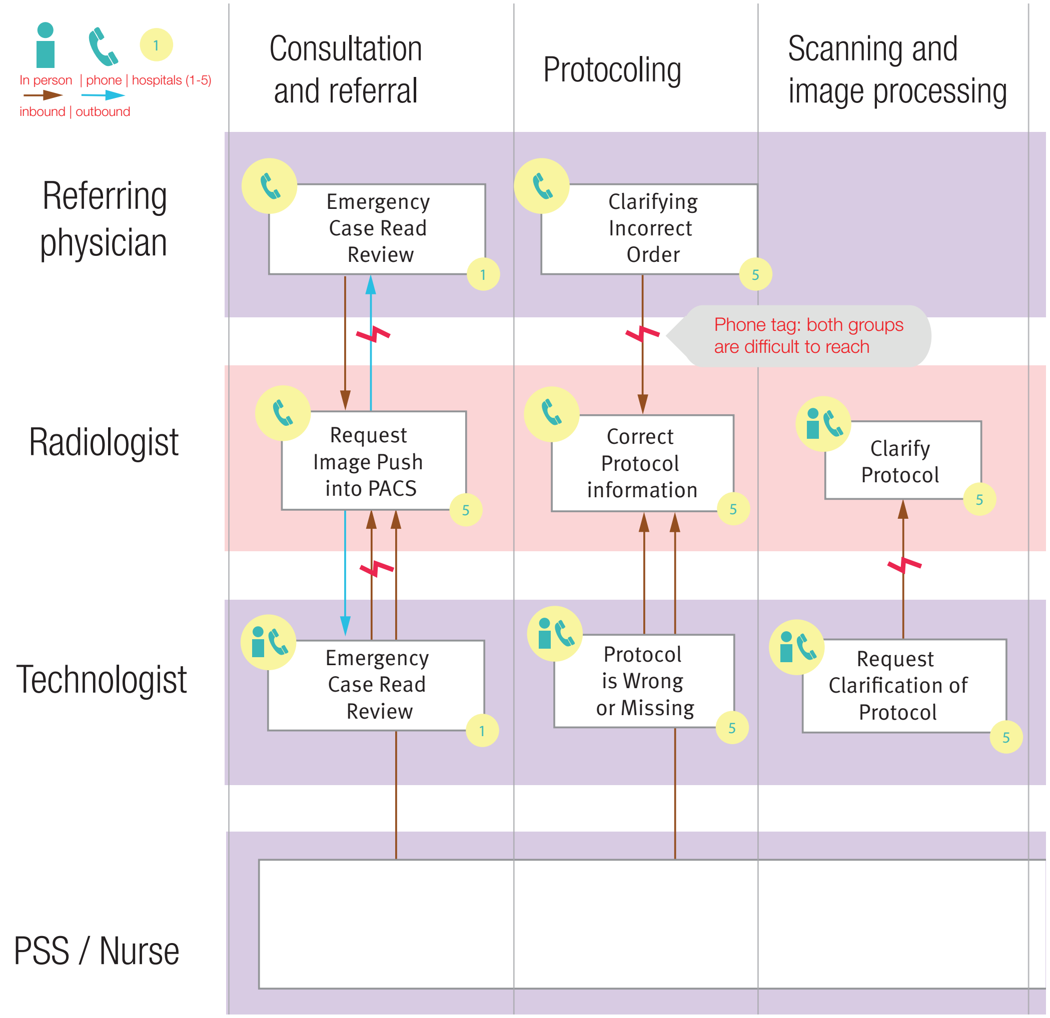
Image review
Report generation
RIS
Radiologist
Technologist
Referring physician
Patient
Locks case in RIS
Opens case in PACS
Reads images
Dictates/ edits report
critical finding
Marks/ annotates/ cross-refs images
maximum interruptions
collaborates with other radiologists
requires maximum focus
Radiologist adds critical results to RIS
Ensures ref phys or asst is aware of crit results
Calls ref phys, tries to report critical results
Ensures ref phys or asst is aware of crit results
Generates report and signs off
physician not found
third-party contact
unnecessary calls
directly tell patient
Receives and confirms radiologist's critical results
no radiologist available for clarification
If questions arise, then discuss case w/ radiologist
Learns critical results

COMMUNICATION MODEL

Inbound/Outbound Communication Flow

In addition to the findings and the workflow model, we synthesized data from our research to develop an inbound-outbound communication visualization during the summer semester. From our research findings, we found the need for asynchronous communication tools, e.g., messaging. We developed this visualization to identify the specific interactions for which these tools need to be used, ensuring that we would support those tasks.

The visualization is from the perspective of the radiologist—incoming communications are those received by the radiologist, and outgoing communications are those that the radiologist initiates. Each box represents a communication. The top left of each box indicates the tools that were used for the communication: phone or in-person. Frequency of this communication is indicated by the number in the bottom right of each box. Breakdowns are marked by the red lightning symbol.



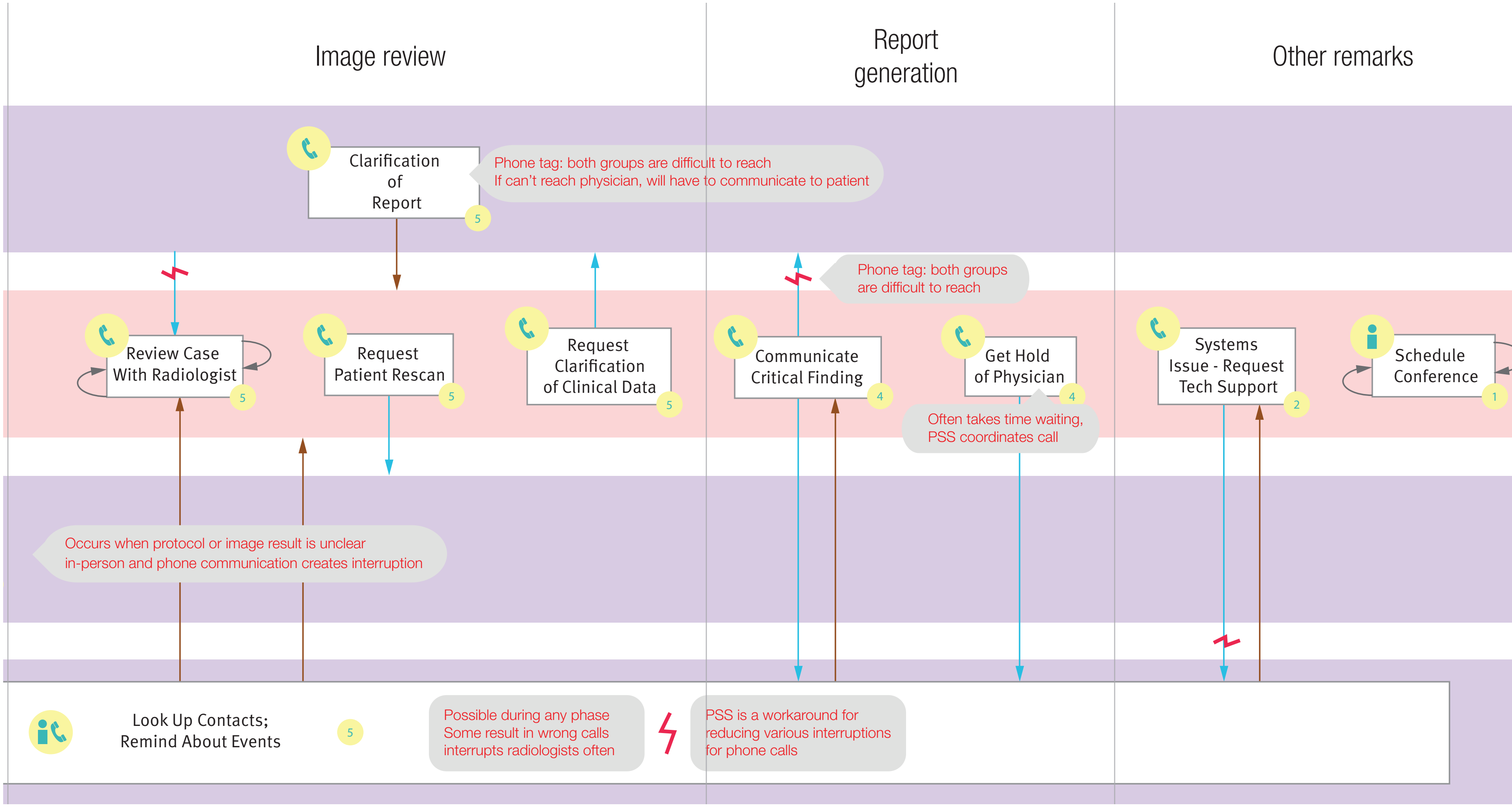


Image review
Report generation
Other remarks
Clarification of Report
5
Phone tag: both groups are difficult to reach
If can't reach physician, will have to communicate to patient
Phone tag: both groups are difficult to reach
Review Case With Radiologist
5
Request Patient Rescan
5
Request Clarification of Clinical Data
5
Communicate Critical Finding
4
Get Hold of Physician
4
Often takes time waiting, PSS coordinates call
Systems Issue - Request Tech Support
2
Schedule Conference
1
Occurs when protocol or image result is unclear
in-person and phone communication creates interruption
Look Up Contacts; Remind About Events
5
Possible during any phase
Some result in wrong calls
interrupts radiologists often
PSS is a workaround for
reducing various interruptions
for phone calls

PERSONAS

We consolidated our research findings into representative personas for radiologists, technologists, and referring physicians. Although we met a variety of people within these roles, we used these personas to highlight similarities. Details about how these personas were developed can be found in our Spring Research Report Appendix CD.

RADIOLOGIST

"Things are constantly grabbing your attention."

Age: 40 years old
Context: Moves daily between reading room workstations
Alternate contexts: Operating room, imaging suite

Goals:

- Be as efficient as possible
- Provide good patient care
- Engage in timely communications
- Complete cases—with help, when necessary
- Stay current on technology and procedures
- Earn the respect of other radiologists and stakeholders

Frustrations:

- Bureaucracy
- Inability to locate needed stakeholders
- Redundancies and task loops (e.g., finding new cases or playing phone tag)
- Interruptions by mundane tasks
- Lack of sufficient insight into patient condition and history
- Lack of integration between systems and services

The radiologist protocols and reads patient examinations, sometimes requesting second opinions from other radiologists. He then dictates his findings in reports, attempts to inform referring physicians of any critical findings, and signs off on the reports. He communicates with other radiology stakeholders mostly in person and by phone. Occasionally, he teaches residents, helps them to read their own patient examinations, and signs off on their reports. If an interventional radiologist, he also performs interventional procedures approximately 30% of the time.

Radiologists are early adopters of new technology. We observed radiologists using and storing case data on personal devices such as smartphones, feature phones, tablets such as the iPad, and USB flash drives. These were in addition to their work devices such as pagers, laptops, and cordless companion phones.

PERSONAS

TECHNOLOGIST

"Not putting patients in danger is the most important thing."

Age: 27 years old
Context: Imaging suite, alternately chaotic and empty
Reports to lead technologist

Goals:

- Keep patients safe and provide quality care
- Develop specialization and perform interesting work

Frustrations:

- Lack of integration between systems, e.g. HIS, RIS, Excel
- Late or missing protocols

The technologist validates patient paperwork and prepares patients for imaging. She operates patient-scanning equipment based on protocols that sometimes require careful interpretation or double-checking with the radiologist. During scanning, she manages administration of radiation and contrast. She post-processes images per the radiologist's instructions. She also helps and covers for other technologists as needed.

REFERRING PHYSICIAN

“I don’t care about interrupting anyone. People’s lives are at stake.”

Age: 45 years old
Context: In hospital or private practice, usually mobile

Goals

- Provide best quality of care without regard for interrupting other stakeholders

Frustrations:

- Inability to locate radiologists
- Anxiety waiting for critical results, e.g., looking back at RIS

The referring physician determines the need for patient scans and orders these from the radiology department. After patient scans, the referring physician reviews the radiologist’s reports and informs patients of critical results. He diagnoses patients and creates treatment plans based on his observations and the radiologist’s reports. He may also collaborate with radiologists to improve patient care on a case-by-case basis.

SOLUTION

PRESENTING SYNAPTIC

Synaptic is a real-time collaboration and priority-based communication interface integrated into a unified RIS/PACS system.

Our interface gives radiologists the control and flexibility they need to efficiently connect with colleagues, conference around cases, and handle incoming requests. Radiologists can now communicate and collaborate seamlessly within RIS/PACS, maintaining or breaking focus at their informed discretion. Our interface is backed by comprehensive user-centered research, concept validation, and six rounds of iterative prototyping and testing. As a result, radiologists described our final prototype as fast, efficient, convenient, timesaving, and easy to use.

This section starts with a detailed look at Synaptic's features, continues with scenarios of use within our primary users' workflow, and concludes with the design rationale behind the features.

The presented screenshots are of the application as it might appear in a unified RIS/PACS. We simplified aspects of the depicted RIS/PACS interface to highlight our proposed features and, while we explored concepts for a unified RIS/PACS, we ultimately left those design decisions to a future design team. The main purpose of our design is to demonstrate our solution and how it can be integrated into a unified RIS/PACS.

PRESENTING SYNAPTIC

Synaptic consists of four primary features:

Prioritized Notification Inbox

Radiologists are constantly interrupted without prioritization. The Notification Inbox allows incoming messages, calls and conference requests to be prioritized based on urgency and stored in an easy-to-access, non-intrusive, and intuitive format. The Notification Inbox allows radiologists to access incoming messages at their convenience, improving focus and productivity.

Integrated People Search

Finding contact information for someone in a hospital can be a time-consuming and frustrating experience. People Search addresses this problem through a single, simple, and elegant interface integrated with the RIS/PACS. It provides radiologists with a single point of contact with their colleagues.

Integrated Messaging & Audio

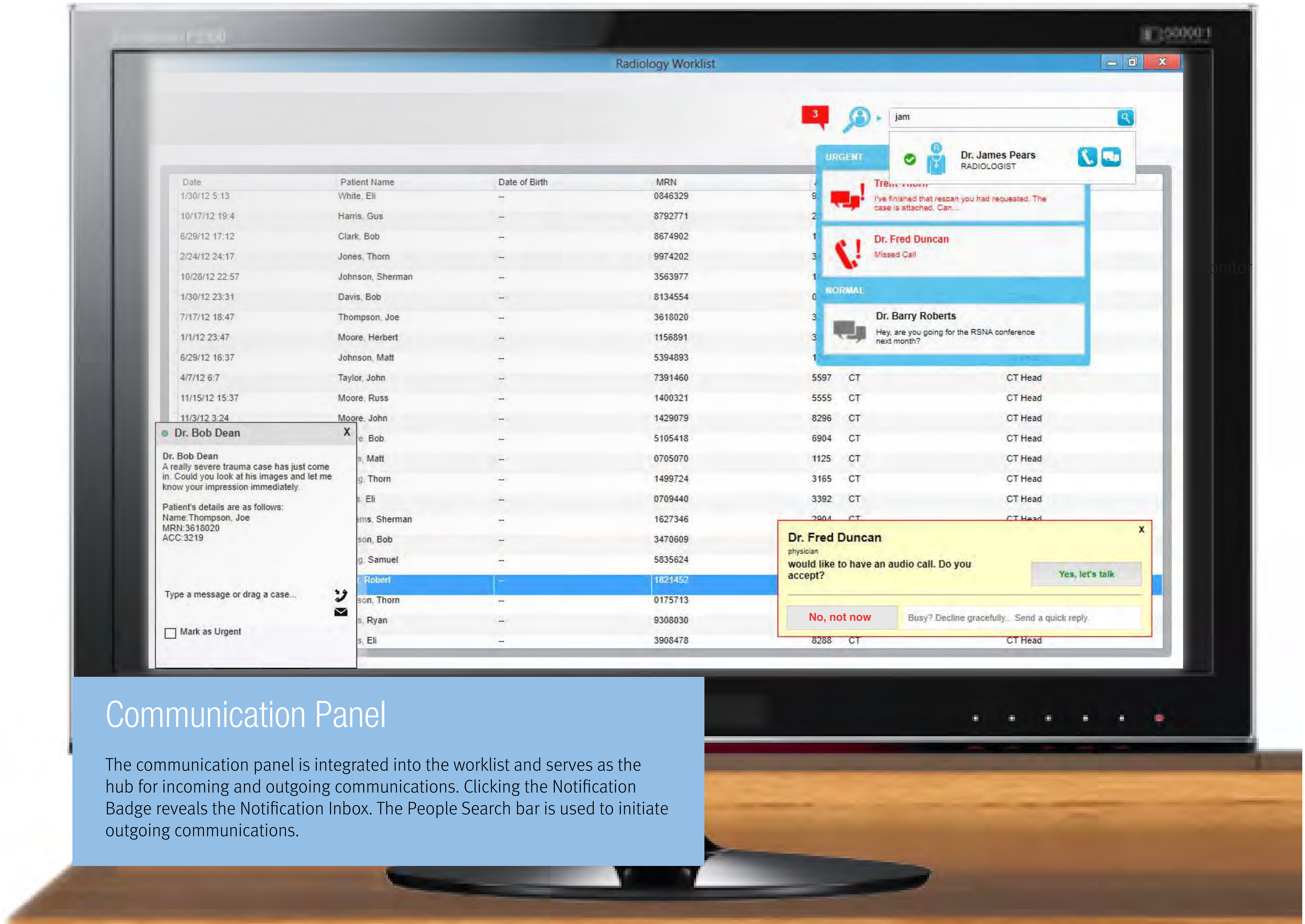
Today's radiologist receives too many unnecessary phone calls. Synaptic's text and audio messaging feature allows radiologists to communicate at their convenience in a non-intrusive manner. Moreover, they can share cases and their components by dragging and dropping them into messages as attachments.

+ Contact a Colleague

Image Centered Conferencing

Radiologists reported needing a second opinion for more accurate diagnosis on 5-25% of cases. Synaptic makes it easy to review cases with peers through real-time image sharing, audio conferencing and shared cursors. It's like sitting face-to-face around a common PACS viewer.

Synaptic



Communication Panel

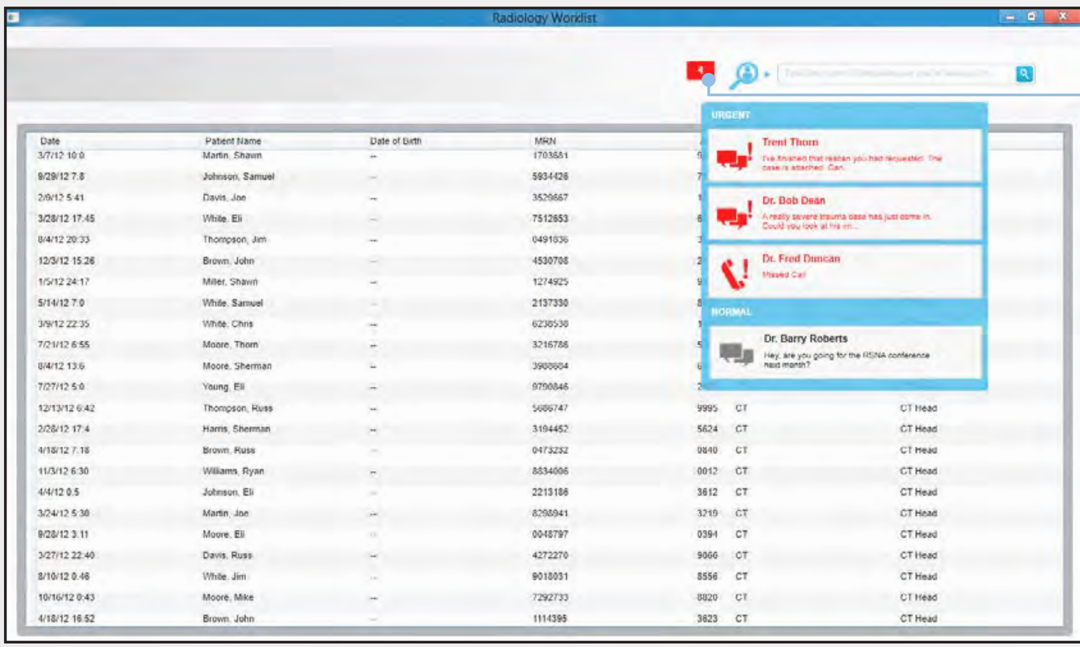
The communication panel is integrated into the worklist and serves as the hub for incoming and outgoing communications. Clicking the Notification Badge reveals the Notification Inbox. The People Search bar is used to initiate outgoing communications.

PACS Conference

Integrated, fullscreen PACS conferencing allows radiologists to share screens and cursors, monitor who is on the call, and invite multiple colleagues. Radiologists can draw highlights and scroll between images to quickly get on the same page.

Prioritized Notification Inbox

Incoming communications are prioritized so radiologists are no longer disrupted unnecessarily while reading a case. The Notification Inbox organizes incoming communications into two priority levels: urgent and non-urgent. Communications enter the Notification Inbox if they are either non-urgent or urgent but unaddressed. They may then be addressed at the user's convenience.



How the Notification Badge works

The Notification Badge reveals the Notification Inbox. A red badge color indicates queued messages, while a gray color indicates no messages. The number of queued incoming messages is displayed on the badge. Users can preview queued messages by clicking the badge.

No messages in inbox

Unanswered message in inbox

Icons and prioritization

A red message icon with an exclamation point indicates an urgent communication, while a gray color indicates a non-urgent communication. The addition of the exclamation point is important for proper interpretation by colorblind users.

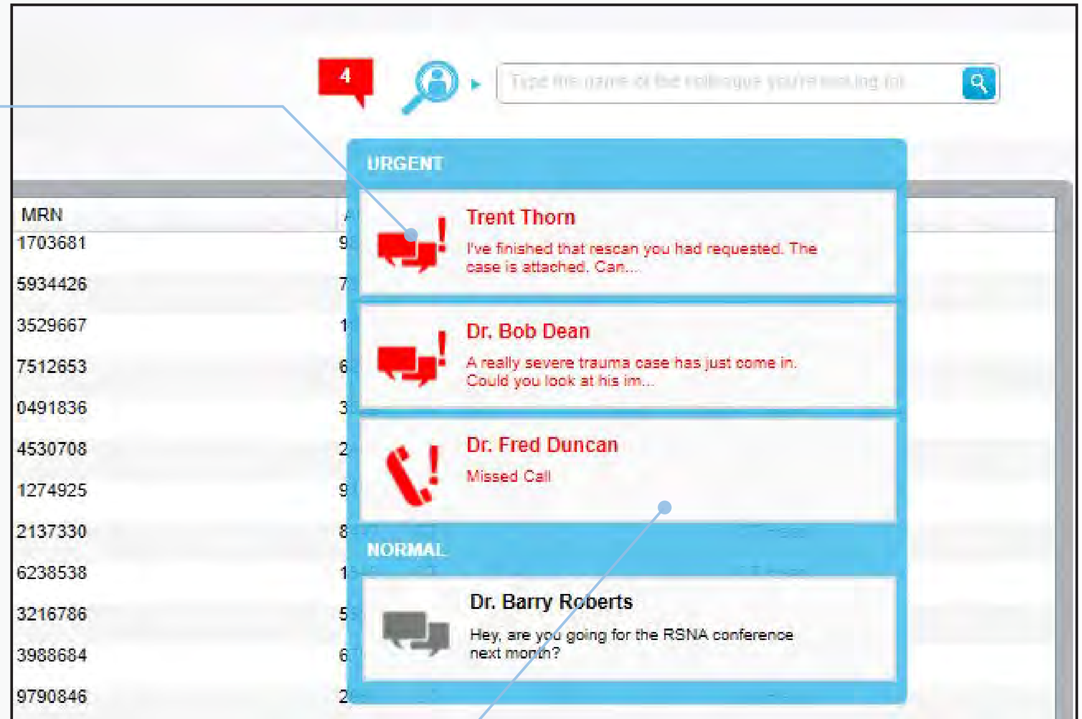
Incoming Messages

Conference Requests

Phone Call Requests

Clicking on a Notification

Clicking on a notification opens a messaging window at the bottom of the worklist where the conversation can be continued.



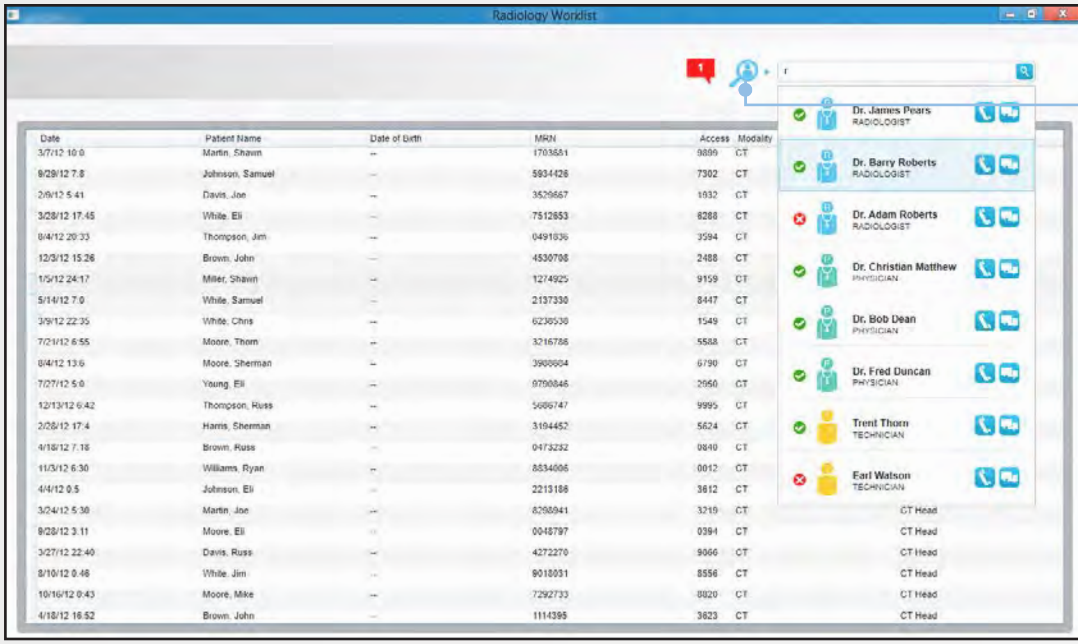
Addressing the need for prioritization

"In radiology, there are lots of distractions and interruptions. You need complete focus for every study you read. Ideally, that's what radiology is: being in a darkroom by yourself and not have any distractions. It's impossible to achieve, but that's the ideal. So, if you can minimize or multitask away distractions and interruptions, that's optimal."

—Dr. Heet, Radiologist

Integrated People Search

Tracking down colleagues as they change shifts, workstations and sites can be time-consuming for radiologists. With the People Search tool, everyone can now get in touch with each other by simply searching in RIS/PACS. Integrated People Search serves as a single point of contact for all users, including emergency physicians and technologists. Availability indicators show whether a contact is currently preoccupied or free to talk.



How the Search Panel works

Clicking on the Search icon reveals the search bar. Users can search for others in the system by name, role, and location. The matching results show availability status as well as role information. Users can choose to communicate with a contact by text message or audio call.

Icons and Contacts

Availability indicators show whether a contact is currently preoccupied or free to talk.

User is logged in but unavailable

User is logged in and available

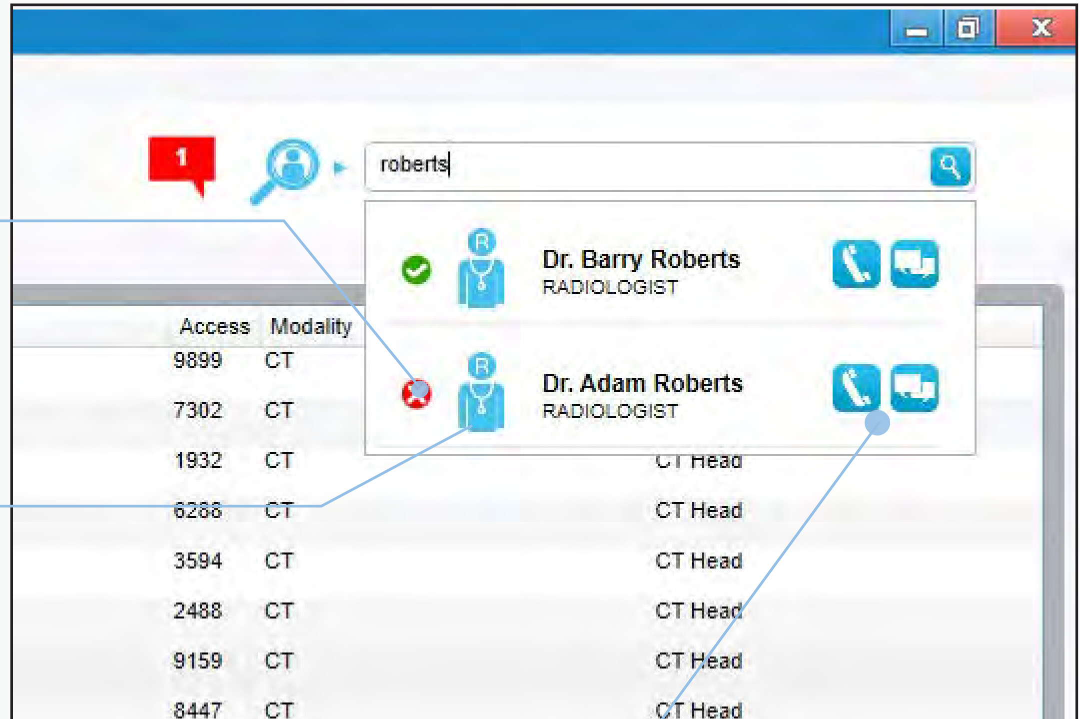
Contact roles can be determined through icons and text descriptions in search results.

Radiologist Physician Technologist

Users can choose to communicate with a contact by text message or audio call.

Send a text message

Place an audio call



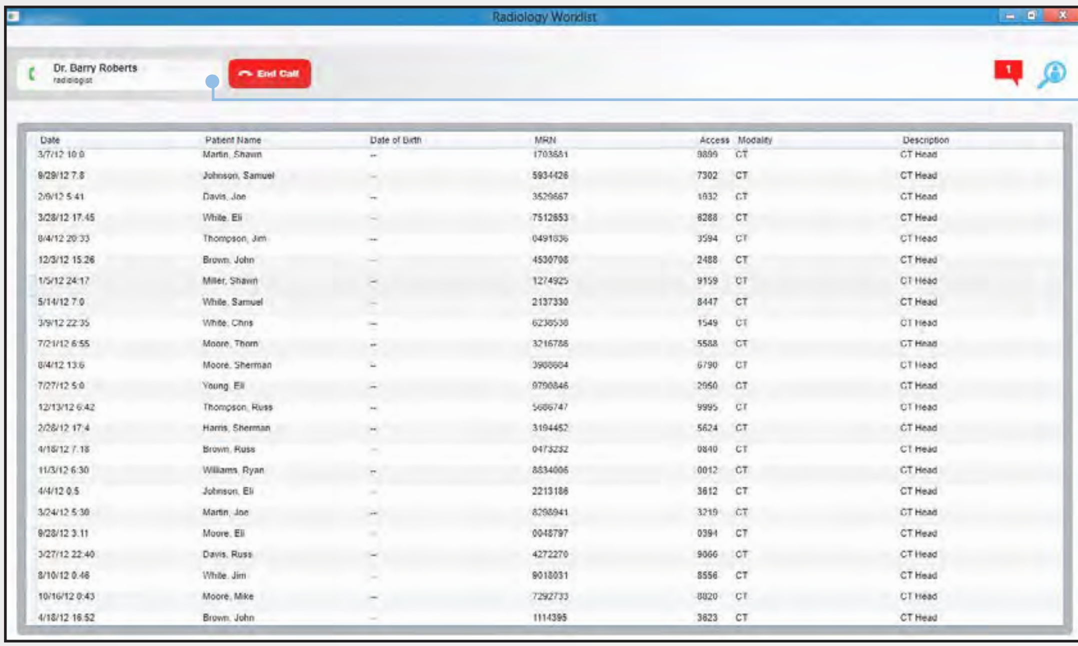
Considering presence and mobility

"I think it would save me time. The way we work is we're at our computers at multiple hospitals, multiple sites. If I want to get hold of somebody, I have to ask Mike or Lynn, 'Hey, can you get hold of Dr. Schultz? I think he's at Quakertown, I don't know.' Then, if I don't know where he is, they have to look at their list, get a phone number and call him. So if I had this, it would save that extra step."

—Dr. Ford, Attending Radiologist

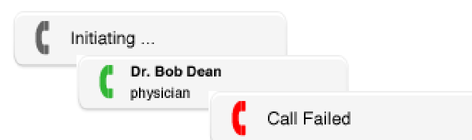
Integrated Audio

Users can now place and receive audio calls directly within RIS/PACS and no longer need to be tracked down if they log in at different workstations. Calls routed through RIS/PACS can be prioritized, queued, and handled at users' convenience. As a result, users don't waste time transferring calls from colleagues who were actually looking for someone else. When unable to take calls, recipients can ignore them or choose decline gracefully by sending the caller a text response. Later, recipients can respond to the call by checking the Notification Inbox.



Having an audio call

An audio call can be initiated from People Search results by clicking on the phone icon next to a contact. An ongoing text conversation can be escalated to a phone call by clicking on the phone icon in the message window. Information about the current phone call appears on the left side of the communication panel.

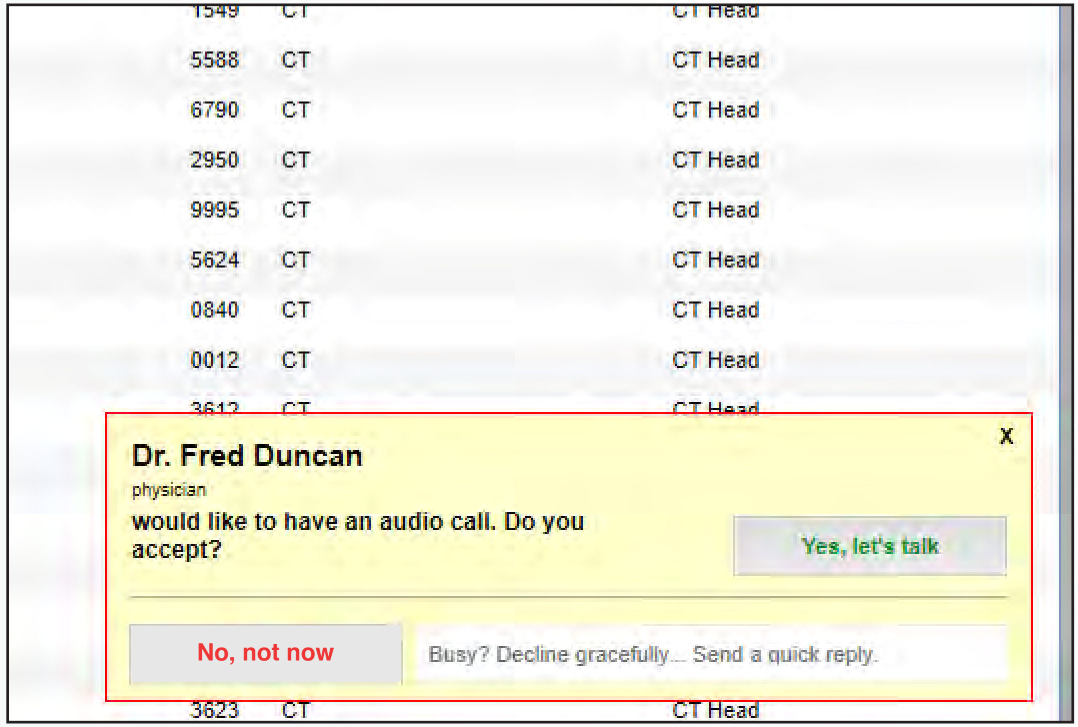


Declining gracefully

When receiving an audio call request, the receiver can choose to take the call, to ignore it until it is missed, or to decline gracefully by leaving a text message for the caller. The receiver can return the call later from the Notification Inbox.

Ending a call

Clicking the red End Call button on the left side of the communication panel ends the call.



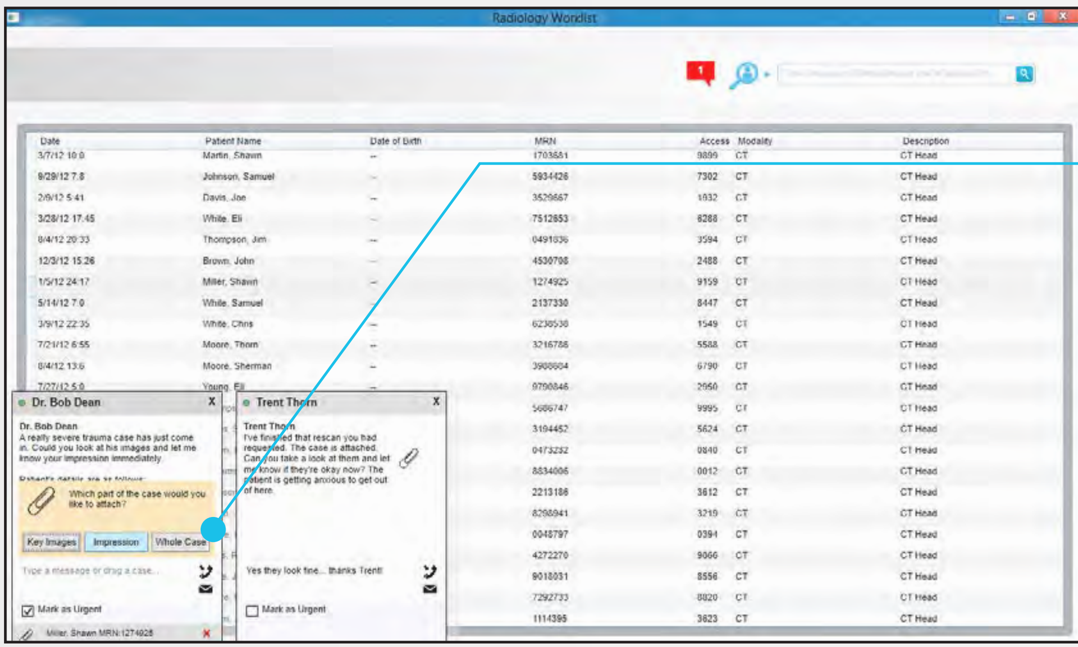
Considering presence and mobility

"What you guys have done is neat because you're integrating communication with PACS, which is awesome."

—Derek, Director of Imaging I.T.

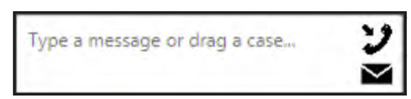
Integrated Text Messaging

Not all communications need responses in real-time. Integrated messaging lets users multitask conversations and also allows them to respond to requests at their convenience. Non-urgent notifications are no longer routed through phone calls. Instead, messages can be received in a non-intrusive way and feedback about receipt of the message can be provided. Additionally, integrating messaging into RIS/PACS allows users to seamlessly attach case information like key images, impressions and links to whole cases. This supports case-centered conversations.



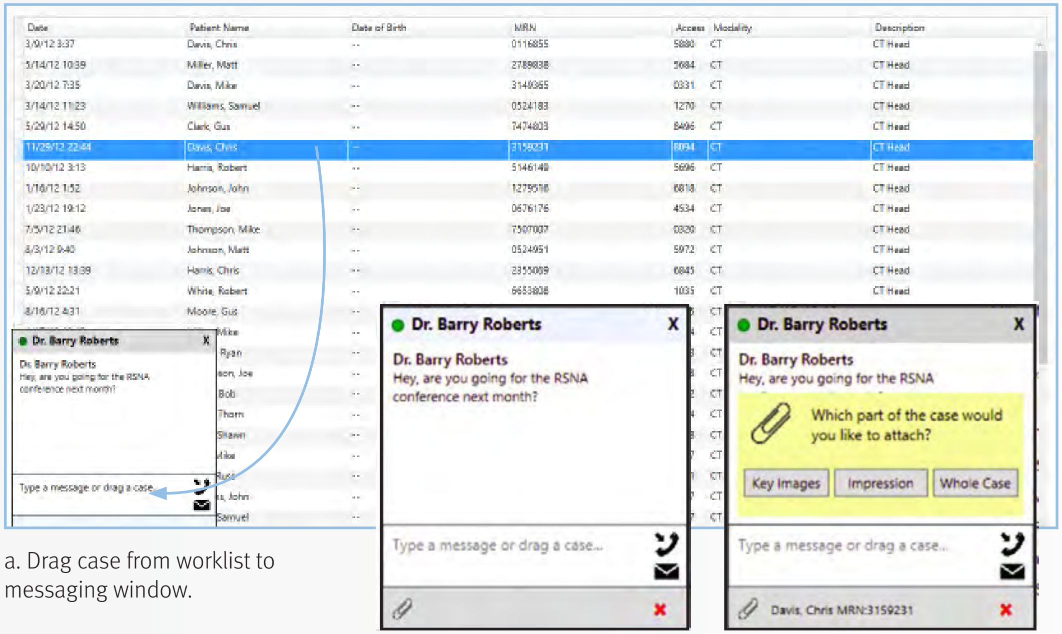
Sending a text message

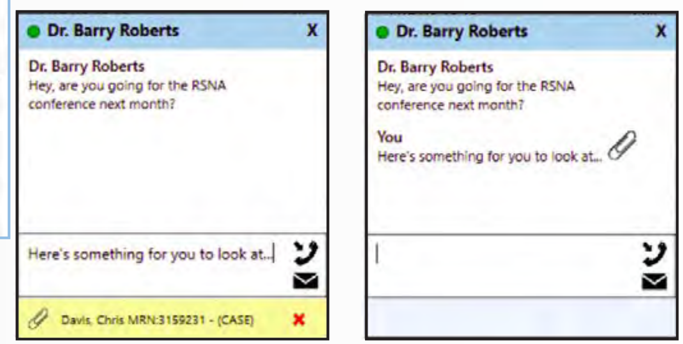
Text messages can be initiated by clicking on a notification in the Notification Inbox or the message button next to a contact in the People Search results. A chat window opens in the bottom right corner of the RIS screen with any previous message history. A text communication can be escalated to a phone call by clicking the phone button in the chat window.



Drag and Drop a Case

Conversations are between people and can optionally revolve around cases. When appropriate, cases, key images or impressions can be attached by dragging and dropping the case into the messaging window.





a. Drag case from worklist to messaging window.

b. Feedback communicates affordance for dropping case.

c. Window requests information about part of case to attach: key images, impression and the whole case.

d. Dropping case shows attachment information at bottom of panel.

e. Attachment icon appears at end of message.

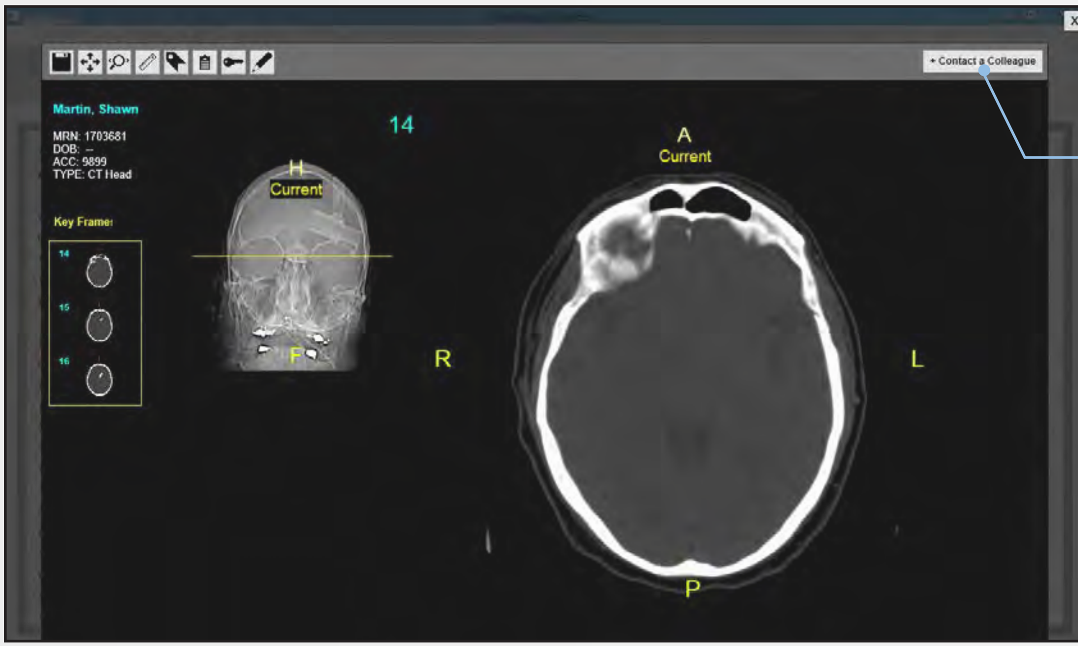
Considering presence and mobility

"It's right there in front of them. They're used to computer usage. They can continue doing what they're doing, looking at the patients, whatever, and still see their message up on the screen at the same time."

—Janis, Technologist

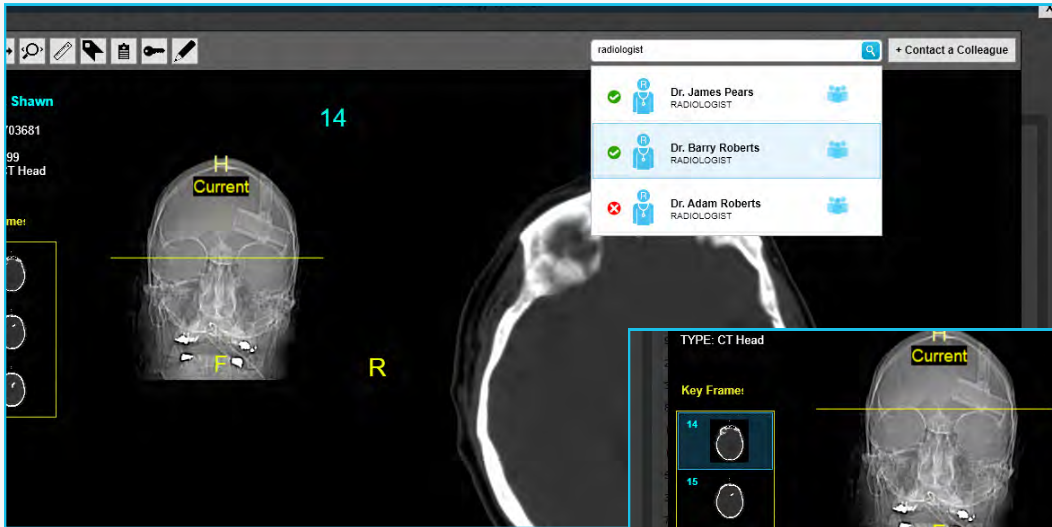
Image-centered Conferencing

Radiologists told us that 5-25% of their cases need second opinions. Currently, radiologists need to coordinate these discussions around their busy schedules. With integrated image-centered conferencing, radiologists can now reach out to their colleagues for second opinions on cases without interrupting their workflow. An integrated solution results in quick, efficient meetings. PACS images can be shared in real time while reading a case, keeping integrated audio conversation focused on interpreting images, not finding them.



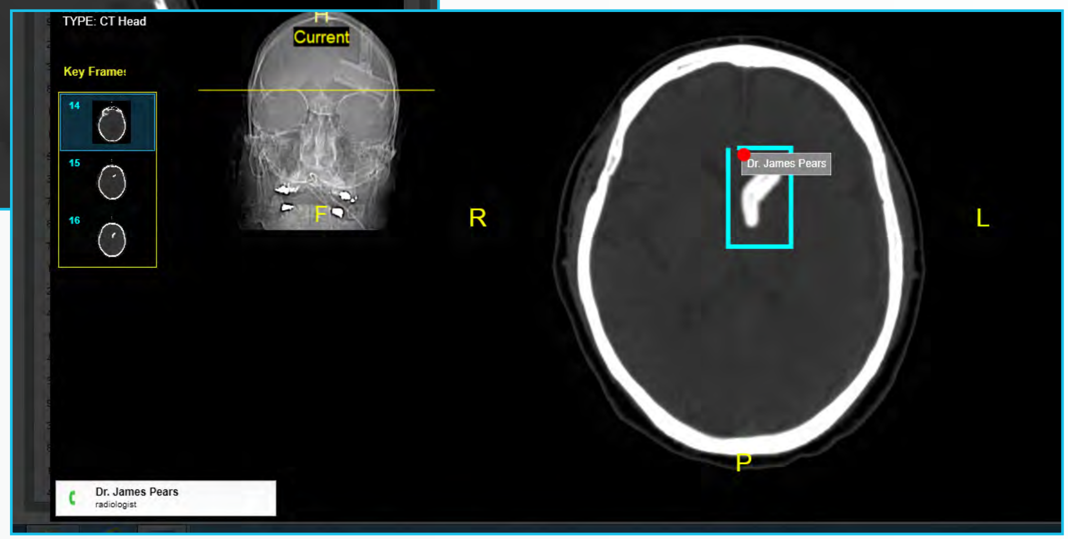
Starting a conference

Click on Contact a Colleague.



Inviting collaborators

Click People Search to find radiologists to collaborate with. The bottom left corner shows colleagues currently in the conference.



During a conference

Real-time cursor information, temporary image highlight, and synchronized slice scrolling ensure that everyone is part of the discussion.

Supporting teamwork

"The PACS collaboration component is absolutely outstanding. Not only for radiologists, but for clinicians in the ED and elsewhere."

—Dr. London, Attending Radiologist

DESIGN RATIONALE

While our research revealed a strongly felt need for better tools to facilitate radiologists' relationships with referring physicians, we found competitors currently offering closed-loop notification systems to address this problem. We felt we would have a larger impact by focusing on streamlining communications between other groups.

Guided throughout our work by the User-Centered Design process, we have aimed to design for our users' needs. We used our research findings as core design values to ensure that our solution would address specific needs we saw in the field.

During our research phase, we watched radiologists maintain different types of relationships with other radiologists, technologists, and referring physicians based on unique sets of tasks and communications. We discovered that teamwork was undervalued and unsupported by the tools that radiologists use, causing overhead and ineffective communication.

Working with GE, we focused our design efforts to address radiologists' relationships with other radiologists and technologists. However, our solution might also be used to address radiologists' other relationships—for example, one radiologist discussed how she would use our conferencing tool to discuss exams with in-house surgeons.

We also found that the RIS/PACS was the best place to integrate these solutions. Radiologists frequently move between different hospital sites and shifts, logging into multiple workstations every week or even every day. Establishing RIS/PACS as the radiologist's point of contact ensures he is reachable wherever he logs in. In fact, we believe that a mobile RIS/PACS solution will play a strong role in radiologists' future workflow, and therefore that an integrated communication interface would take advantage of that solution.

We used our research findings as core design values to ensure that our solution would address specific needs we saw in the field.

Our Design Goals:

1. Teamwork
2. Mobility and Presence
3. Prioritization
4. Reliability
5. Integration
6. Efficiency
7. Simplicity

1. Teamwork: Design tools for quick and efficient collaboration and communication around tasks within the radiologist's workflow. We allowed radiologists to collaborate during image consultation by providing real-time image conferencing and integrated audio directly within PACS. Text messaging with support for case-information attachment enables radiologists to leave notifications and reminders as well as to have asynchronous conversations in between cases.

2. Mobility and Presence: Provide feedback on colleagues' availability and allow messaging and notifications to check this. Text messaging enables users to leave messages for colleagues with confidence that these will be easy to find when colleagues are next available. Because RIS/PACS serves as a point of contact for users, notifications routed to colleagues' accounts become available wherever they are logged in.

3. Prioritization: Incoming communications are organized into two levels of priority so that radiologists can detect urgent communications even when focused on a case, while they can wait until convenient moments to read non-urgent notifications.

4. Reliability: Radiologists should be able to trust the system. There should be feedback about the status of communication—for example, missed call, in conference, audio call, and so forth. Using notifications and messaging supports reliability. Users know their communications have been sent and trust that their colleagues will receive them.

Based on the personas we developed for our users and our discussions with GE, we decided to support the following additional design goals:

5. Integration: Features should be seamlessly integrated into RIS/PACS, allowing users to collaborate with colleagues at the click of a button.

6. Efficiency: Systems should allow users to efficiently access the most applicable tools in the context of their workflow. Features like videoconferencing should not be employed as defaults because they unnecessarily increase rapport while decreasing efficiency.

7. Simplicity: Avoid error and redundancy by omitting irrelevant features and providing quick, simple ways to find, share, and communicate task-related information. Integrate People Search and case attachment while removing features that complicate the system, like Case Chat.

Radiologist to Radiologist communication

One radiologist spent over a minute describing how he usually initiates a case discussion: He searches for his colleague’s phone number, calls him, asks him to open a case with a particular MRN in one of several worklist tabs, marks each key image with an arrow annotation and asks him to close and reopen the case so the annotation will load into view, and directs him to a specified image number [1].

We found a **complete lack of support for collaborative image-review**. At the same time, we saw the importance that radiologists place on conferences around PACS. Currently, when radiologists request peer advice, they must devise workarounds to navigate one another to the images and areas of interest.

Our conferencing tool allows radiologists to bypass lengthy workarounds by handling all case-conferencing directly within PACS. Radiologists reported that 5-25% of cases require a second opinion.

[1] Image scanners like those used by radiologists are capable of scanning a patient one cross-section at a time. Because of this, a single exam often consists of hundreds of images that can be scrolled through.

Radiologist to Technologist communication

While our drag-and-drop attachment interaction is not part of the current RIS/PACS, many of our test participants described it as familiar and intuitive. One even insisted that his current system already provided this ability! We checked, and it did not.

When we asked Dr. Mazda whether he found these interruptions to be disruptive, he affirmed, “It is, but it’s part of the job. If I have a question, I’ll call them, too. But if you’re looking at 317 images and suddenly have to switch to protocol [an unrelated case], then yes, it is disruptive.”

We watched radiologists experience **constant interruptions from technologists while reading cases**. However, radiologists saw these interruptions as important and tried to maintain a good relationship with technologists, encouraging them to ask questions. From this, we saw a need for a communication tool that would allow radiologists to keep these channels of communication open without forcing them to respond at inconvenient moments.

We initially tried to impose structured, task-specific ways of notifying radiologists. However, we found too many differences in communication styles and preferences, so we changed course toward more familiar, less task-specific interaction metaphors.

During our research, several radiologists asked for “instant messaging for radiology.” Since most discussions revolved around cases, we created a worklist-centered communication system that allows users to easily discuss and attach cases and the components unanimously requested by our later test participants: key images and the report impression.

Radiologists were anxious to incorporate the asynchronous aspects of our interface into their current systems. Routing communications through our messaging system would enable radiologists to reduce synchronous overhead by eliminating the need for many types of phone call—radiologists could review asynchronous notifications at their convenience in between cases, which usually demand maximum focus.

In the spring, radiologists had complained that incoming communications were not prioritized based on importance and urgency. Through trial and error, we found that two priority levels—urgent and non-urgent—were enough to satisfy most radiologists’ needs.

Meet Dr. Harrison, Diagnostic Radiologist

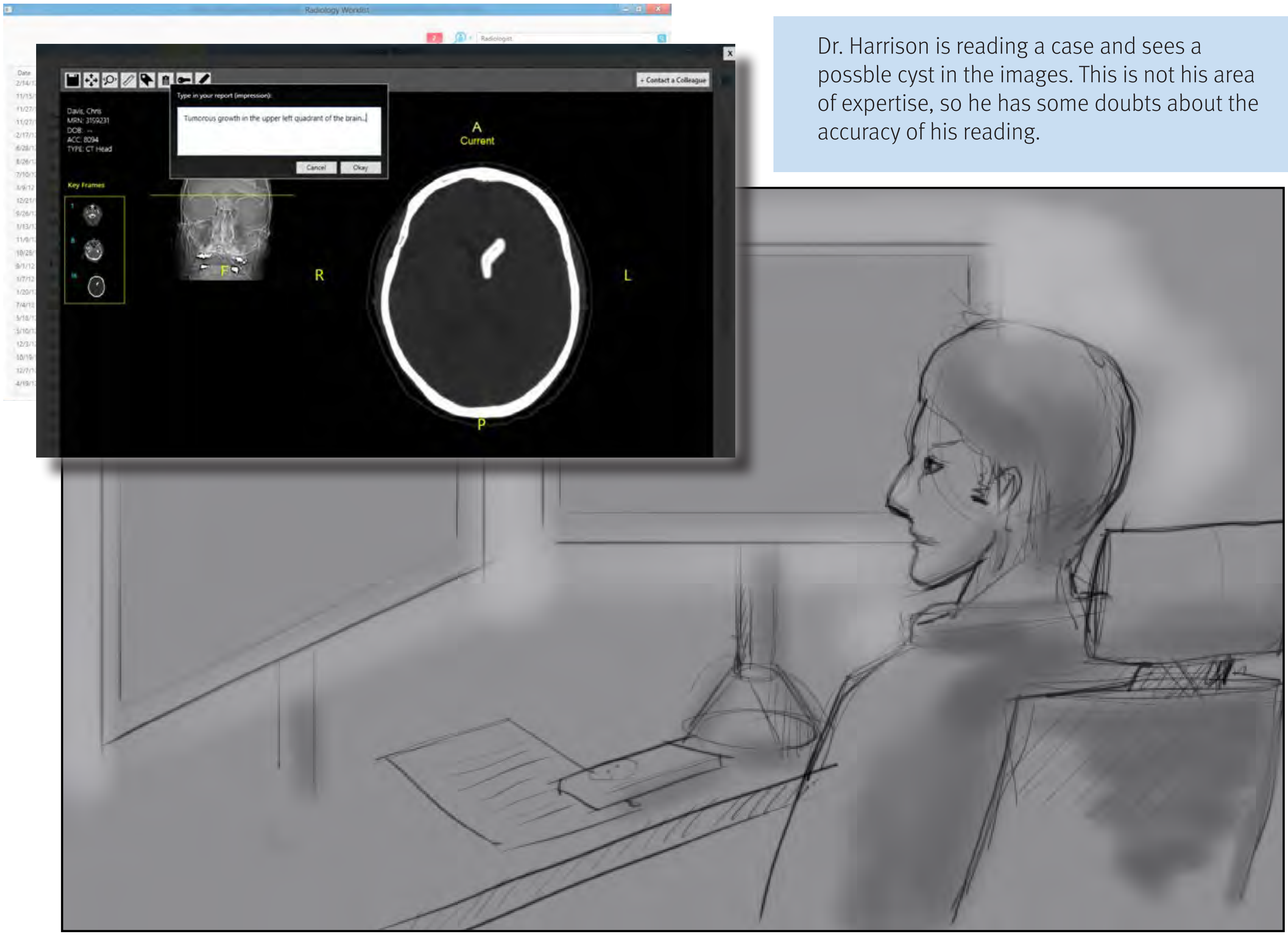
Dr. Harrison is 40 years old and has been working at St. Martha's University Health Network for the past five years as a diagnostic radiologist. The hospital has four locations in the area, and he moves between them during the week.

Unlike radiologists in a private practice, Dr. Harrison receives most of his cases from referring physicians within the hospital system. He spends most of each day reading examinations, going through around 100 on average. On lighter days, he reads cases from the other hospital locations. Although Dr. Harrison is an experienced radiologist, he sometimes comes across rare cases that he needs a second opinion on. He often consults Dr. Barry Roberts. Dr. Roberts has been practicing for 10 years and works in the same hospital system. Dr. Harrison and Dr. Roberts often have lunch together.

Dr. Harrison saves rare cases to his hard drive to discuss them with his colleagues at regular journal meetings. Because Dr. Harrison works at a university hospital, he tries to publish some of these cases at conferences. Dr. Harrison also attends a regularly scheduled tumor board. Although funding for tumor boards is scarce, he finds them informative and useful for getting better patient insights.

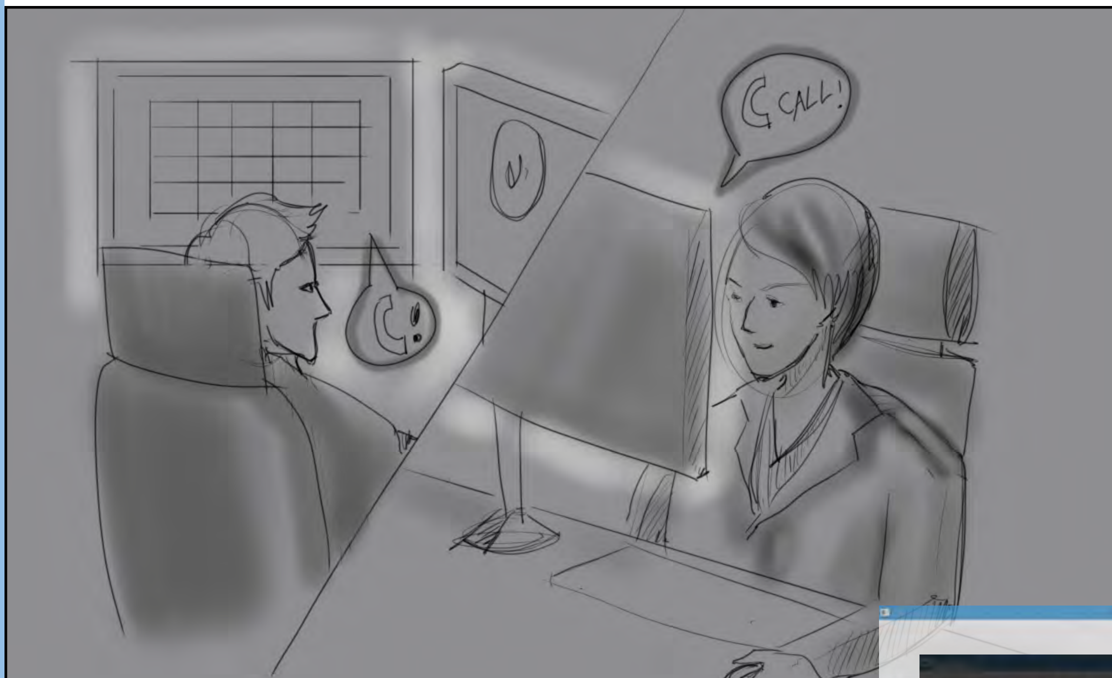
Sometimes, while reading an exam, Dr. Harrison fields urgent requests to read emergency cases demanding immediate attention for patients in poor condition. Although Dr. Harrison sometimes feels that the emergency physician orders too many unnecessary exams, he makes sure to read emergency cases as soon as they come in.

1. Collaboration with Other Radiologist



Dr. Harrison is reading a case and sees a possble cyst in the images. This is not his area of expertise, so he has some doubts about the accuracy of his reading.

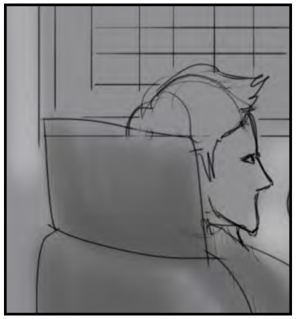
SCENARIO WALKTHROUGH

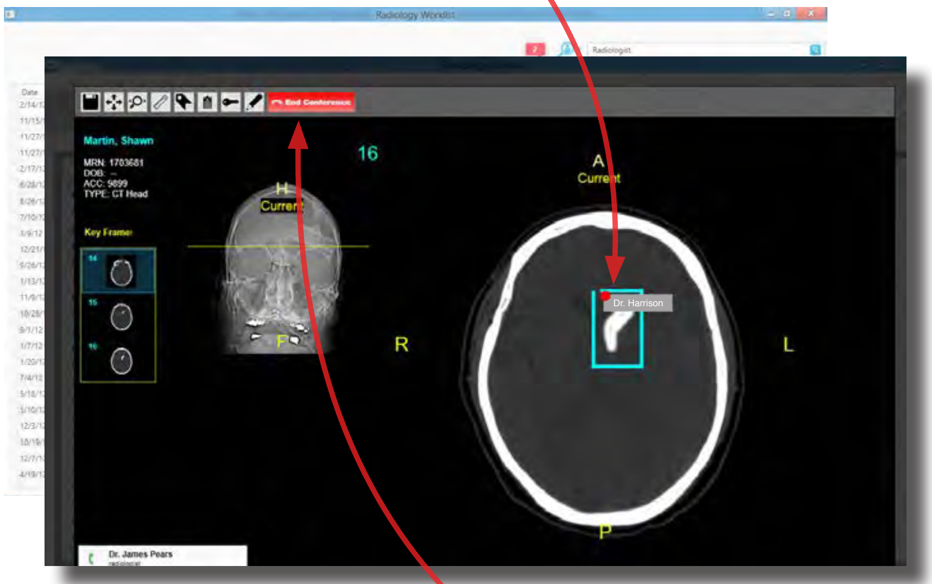


He decides to get a second opinion from a colleague of his, Dr. Barry Roberts. He types in “radiologist” into his People Search and sees Dr. Roberts’ name pop up.

Dr. Harrison clicks the People Search bar and invites Dr. Roberts to a conference.

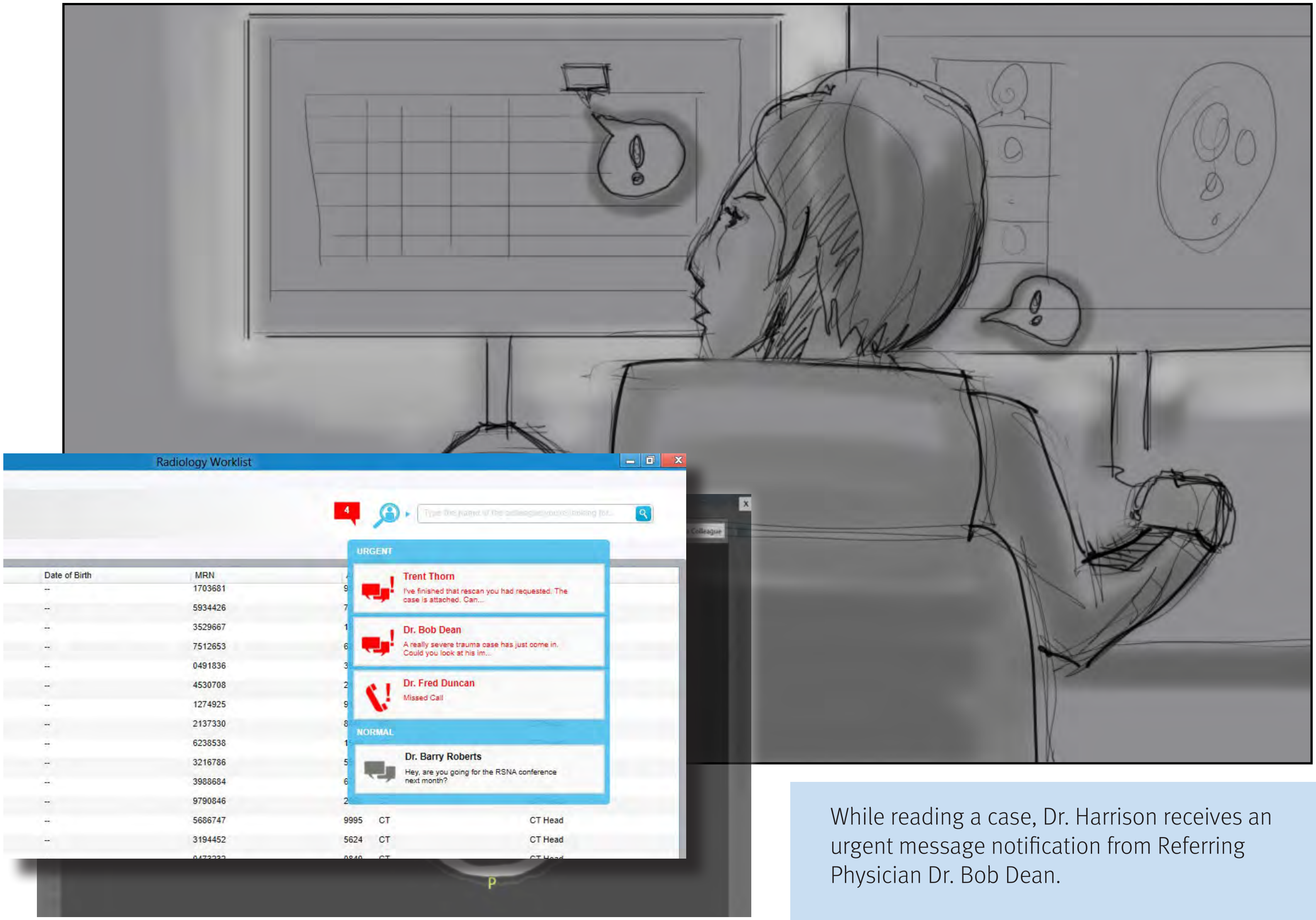
Dr. Roberts uses his guest cursor to point at the cyst and tells Dr. Harrison that it is indeed a critical finding.



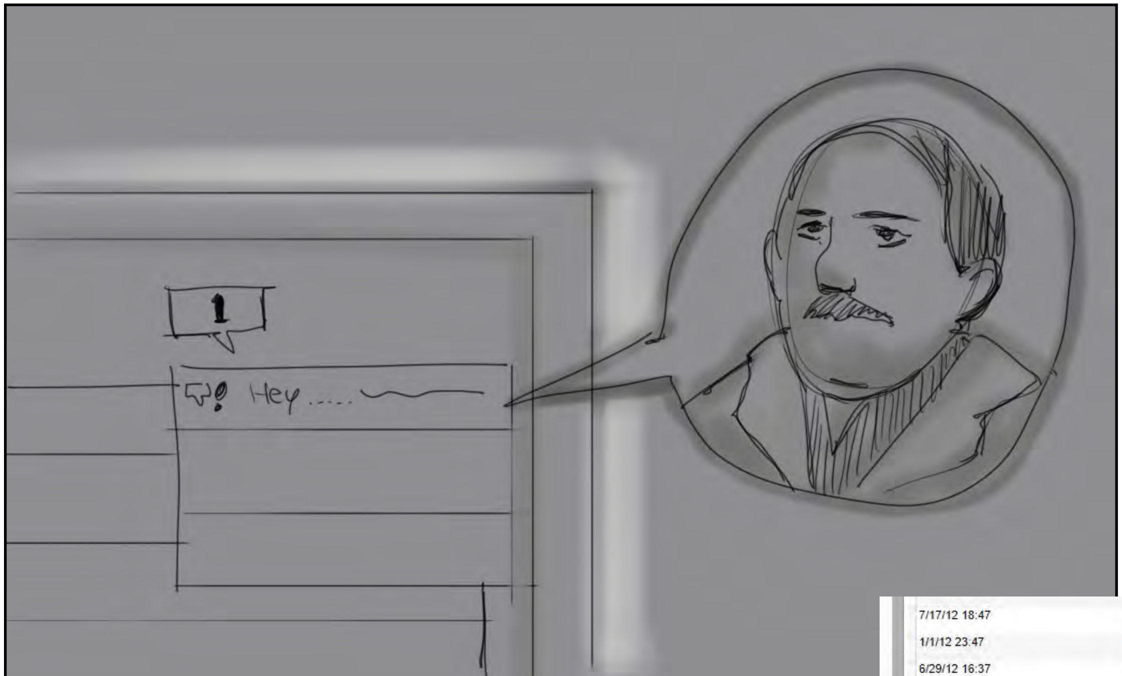


When they are done, Dr. Harrison ends the conference.

2. Receiving Urgent Communication

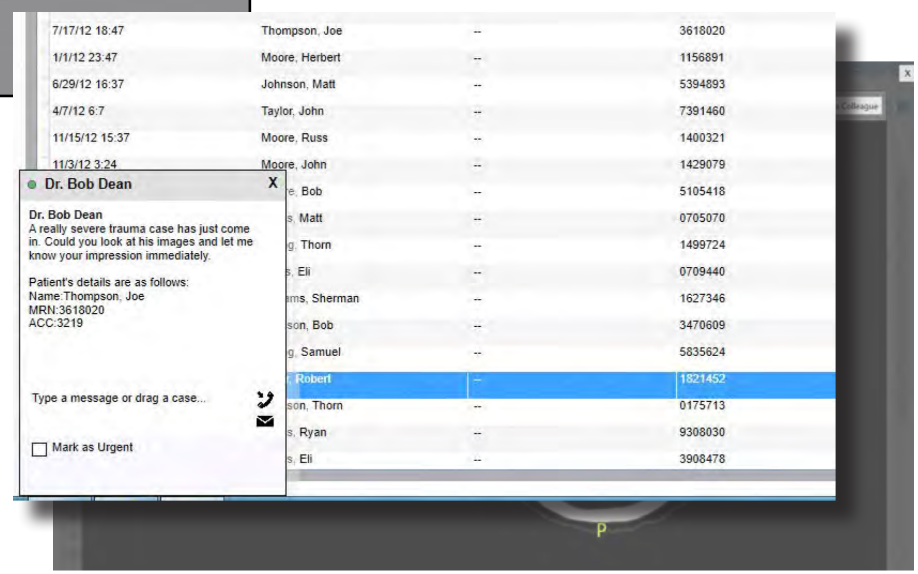


While reading a case, Dr. Harrison receives an urgent message notification from Referring Physician Dr. Bob Dean.



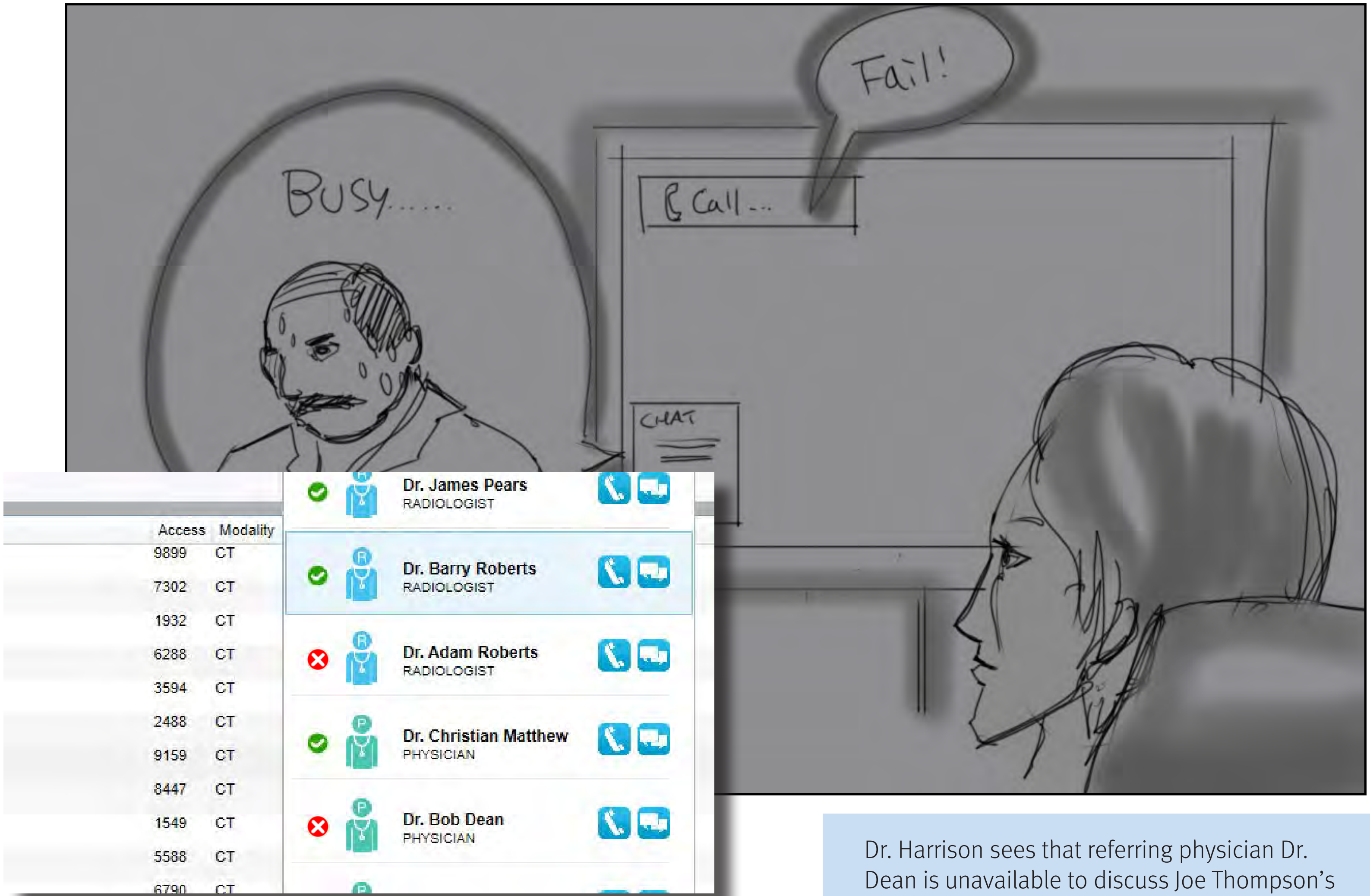
Referring physician Dr. Bob Dean has asked Dr. Harrison to review an emergency case for patient Joe Thompson.

Dr. Harrison clicks the attachment to open Joe Thompson's case.

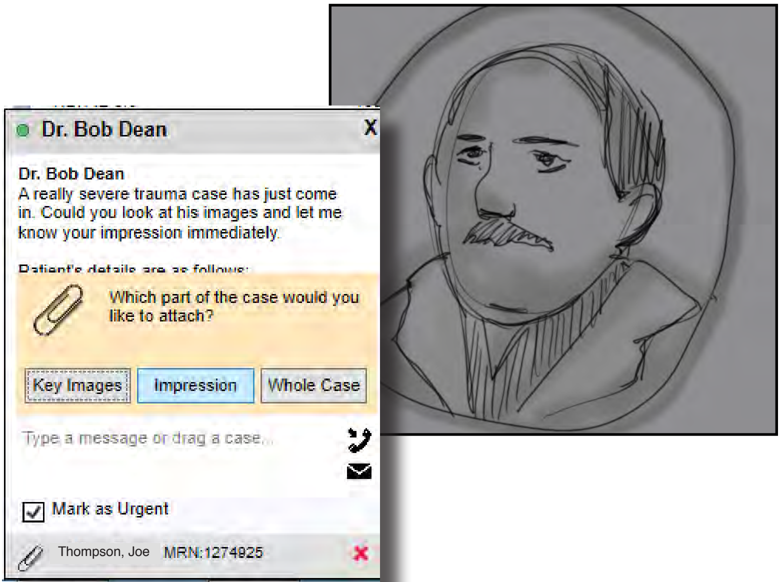


SCENARIO WALKTHROUGH

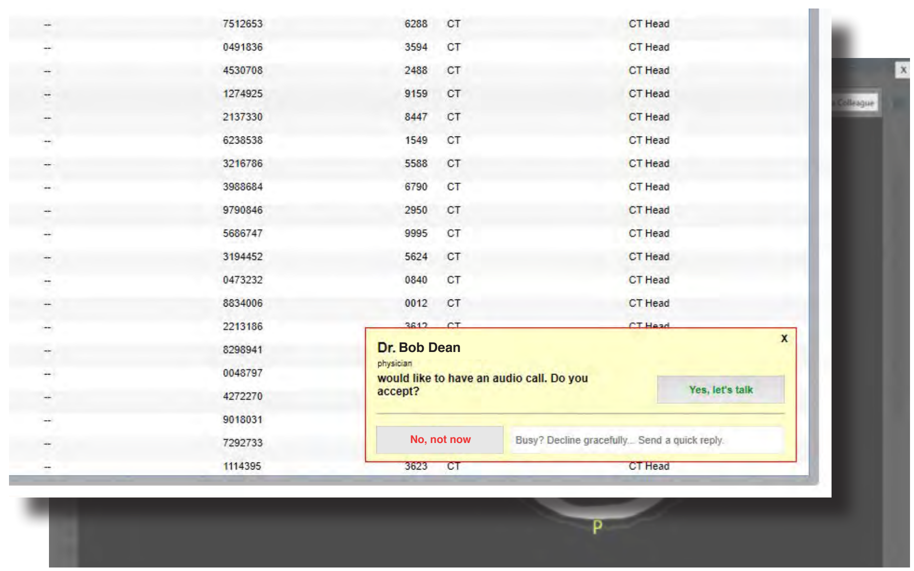
3. Case Attachment



Dr. Harrison sees that referring physician Dr. Dean is unavailable to discuss Joe Thompson's critical finding. Dr. Harrison tries to call Dr. Dean anyway but is unsuccessful.



Dr. Harrison attaches his report's impression to the message.

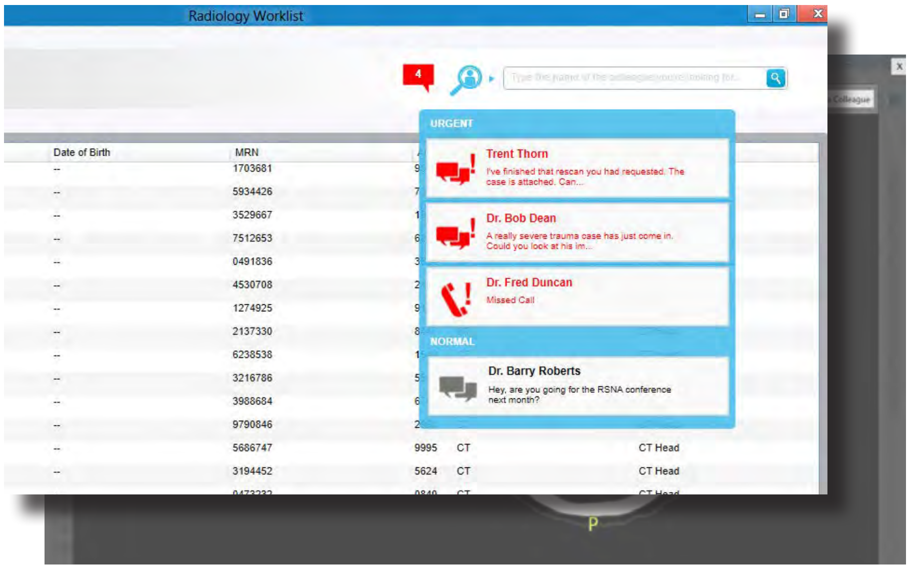


After a few minutes, Dr. Dean calls Dr. Harrison to confirm receipt of the critical finding.

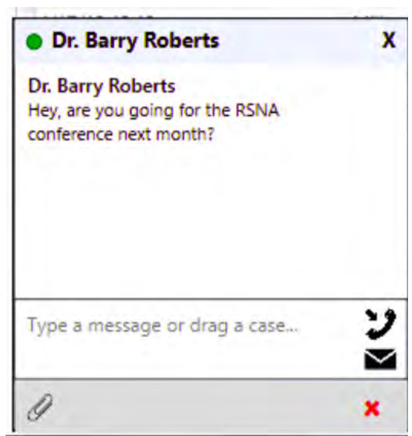
SCENARIO WALKTHROUGH

4. Non-Urgent Communication

Dr. Harrison finishes reviewing his last open case and closes it.
Noticing his Notification Badge is red, Dr. Harrison opens his Notification Inbox and sees the non-urgent message he ignored earlier alongside two other messages, one of which is an urgent missed-call from a referring physician.



After returning the referring physician's call, Dr. Harrison opens his non-urgent message from Dr. Roberts.



Dr. Harrison replies to Dr. Roberts that he plans to attend next month's RSNA conference.

DESIGN

DESIGN PROCESS OVERVIEW

Our design process consisted of two main phases. In our Exploration phase, we conducted visioning, ideation, and concept exploration. In our Iterative Design phase, we conducted iterative prototype design, development, and evaluation.

Exploration

We spent the Exploration phase brainstorming design ideas and converging toward a single final concept. However, we had begun brainstorming before summer even began. In the spring semester, we kicked off our ideation process by brainstorming 78 design opportunities[1] sparked by our field research. We organized these opportunities into 16 themes and presented the three most exciting ones to GE as icebreakers for a workshop in which they helped us take our ideas even further.

At summer's outset, we had generated 135 ideas[1] through our previous brainstorming activities. We sketched, discussed, clustered, and validated our ideas, filtering and shaping them into six visions. When we attempted to validate our visions with radiologists and our clients using a method called Speed Dating[2], two scenarios received the most favorable reactions: one around real-time collaboration tools and the other focusing on EMR integration with data visualization.

After sketching wireframes, building an interactive paper prototype, and comparing both concepts in light of our research findings, we chose to pursue our vision for real-time collaboration tools.

Iterative design

We adhered to user-centered design principles in our Iterative Design phase. Our testing participants showered us with feedback that guided our prototypes through six "waved" iterations from low to high fidelity.

We first tested the waters with interactive paper prototypes designed around core features. Based on participants' feedback, each feature was discarded, redesigned, or integrated into the next prototype. We then introduced new features to the next prototype which each underwent a similar trial. At higher fidelities, we created wireframes of new features in a prototyping tool called Axure and overlaid printed copies directly on top of our prototypes, eliciting gut reactions and exposing usability issues.

By relying on usability tests to advance our designs, we made constant progress toward an effective, usable, and desirable final prototype.

[1] Our ideas and sketches can be found in Appendix B.

[2] Speed Dating is a design method we employed to gain rapid validation of concepts by radiologists without requiring any technology implementation. We presented storyboarded scenarios of high-level concepts, interactions, and contextual dimensions and analyzed radiologists' physical and verbal reactions. [3].

DESIGN PROCESS OVERVIEW

	Exploration	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 05
Participants					Liason	I.T.
Hospital	UPMC Foundation	UPMC Foundation Allegheny	St. Luke's	Wellspan	St. Luke's	UWMC
Methods	Speed Dating "I wish, I like"	Think Aloud	Think Aloud	Think Aloud Feature Cards	Think Aloud Feature Cards Survey	Think Aloud Feature Cards Questionnaires
Takeaways	Narrowed to two final concepts	Real-time collaboration gained additional credibility	Omnipresent but subtle communication panel desired	Concept succeeded at higher fidelity but required several tweaks	Different roles desired customizable versions of the solution	Solution described as efficient and time-saving

By relying on usability tests to advance our designs, we made constant progress toward an effective, usable, and desirable final prototype

Exploration

Findings and activities shaped our visions

We spent the early part of our Summer Semester brainstorming design ideas and converging toward a single final concept. In fact, our thinking caps were on before summer even began. In the spring, we kicked off our ideation process by brainstorming a diverse range of design opportunities sparked by our field research. We organized these opportunities into themes using affinity diagrams and presented the three most exciting ones to GE as icebreakers for a workshop in which they helped us take our ideas even further.

At summer's outset, we filtered a smaller set of key concepts from our 135 ideas. We then explored these concepts further—as seen in Appendix B—as we sketched, discussed, clustered, and validated them. Finally, we filtered and shaped these concepts into six visions. When we conveyed our visions to radiologists and our clients as storyboarded scenarios using a method called Speed Dating, two received the most favorable reactions: one around real-time collaboration tools and the other focusing on EMR integration with data visualization. After sketching wireframes, building an interactive paper prototype, and comparing both concepts in light of our research findings, we chose to pursue our vision for real-time collaboration tools.

We asked our clients what excited them

When summer began, we visited GE at their Barrington, IL offices to present our spring research findings. At the end of our presentation, we shared our three most exciting design opportunities with GE as icebreakers for a workshop in which they helped us take our ideas even further. During our workshop with GE, we collaborated to brainstorm solutions to problem statements derived from our research findings. We asked four questions:

1. How can we design systems that support and encourage teamwork at collaborators' mutual convenience?

2. How can we create solutions that facilitate effective communication in consideration of mobility?

3. How can we provide mechanisms to help radiologists rank incoming communications or prioritize personal workflow?

4. How can we improve access to case and patient data either on or off RIS/PACS workstations?

Then, we plotted as many ideas as time allowed on a 2x2 impact vs. achievability grid. The larger purpose of plotting ideas on the grid was not to find the best ideas, but to see which ones our clients thought should belong together, and which clusters they found most interesting. We concluded by surveying the entire grid and asking GE to respond to its contents: "What do you see that excites you?"

Team Shoal and GE Healthcare discuss visions after meeting and sharing presentations

EXPLORATION

Findings and activities shaped our visions

We returned from our workshop with a better sense of GE's priorities and 27 new ideas (see Appendix B). It was time to begin filtering all our ideas into a scoped vision that would address our research findings.

We carefully distinguished two groups of ideas—complete systems and standalone features that could be integrated into any system—and began to explore how they might materialize.

Sketching as a brainstorming tool

Sketching scenarios of use for our key concepts allowed us to explore them in the context of our research findings—who would actually use them, where, and how. The practice of sketching enabled team members to communicate each idea quickly and effectively while facilitating better-directed team discussion.

> *"Sketching in the broad sense, as an activity, is not just a byproduct of design. It is central to design thinking and learning. Sketches are a byproduct of sketching. They are part of what both enables and results from the sketching process. But there is much more to the activity of sketching than making sketches."*
>
> \- Bill Buxton [1]

Team members drew sketching inspiration from various sources: analogous systems, academic articles, and even opposing concepts. We balanced our depictions of ideas by basing some on our research findings while sketching others as experimental variations.

We brainstormed and sketched concepts, such as richer report generation with embedded metadata. We then validated these internally and with radiologists. See Appendix B for the complete set with comments

Validation through clustering idea sketches and evaluating positive and negative remarks

"I Wish, I Like" kept us focused

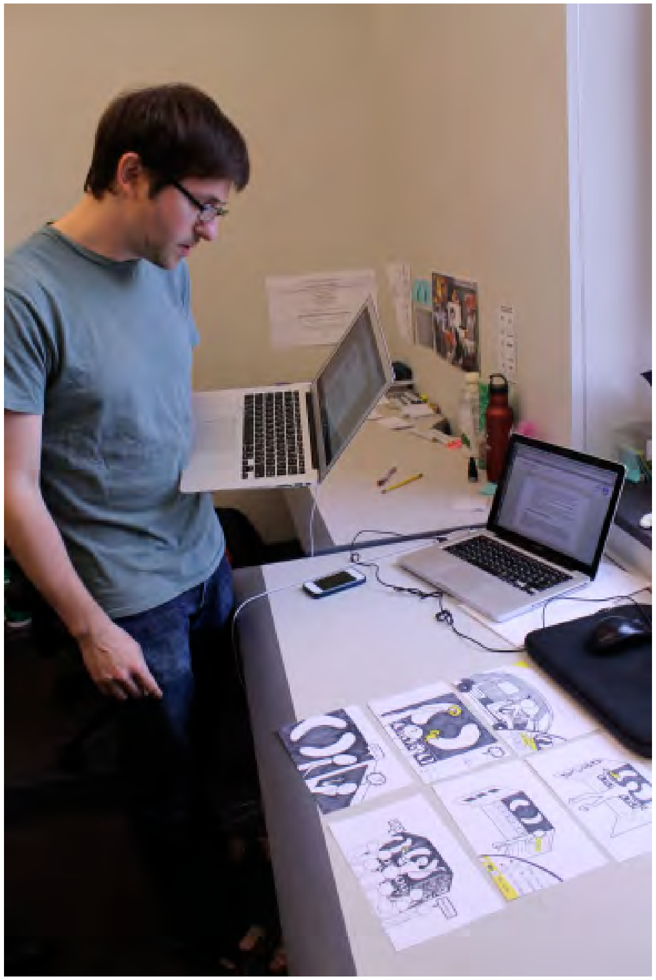
With 30 sketches to consider, we facilitated an internal critique session using a method called "I Wish, I Like, What If." [12]. Team members took turns presenting their sketches for one minute apiece. Then, the other team members spent thirty seconds writing positive observations on green Post-its and missed opportunities on pink ones. Both categories contained "What If" design ideas. We then spent 90 seconds discussing our notes as a group.

Timing the activity enabled us to consider, compare, and synthesize all our ideas as a group in a single session without drifting off-track.

We clustered sketches into concepts

We clustered thematically related sketches into ten visions, which we ranked based on impact. From these, we chose the top six to present to radiologists and GE for feedback. In preparation, we scripted and sketched six storyboards, described over the several pages, one for each of our unified visions. Each storyboard considered the different people involved, scenarios of use, hardware and software setups, and important interface aspects.

To assess how radiologists felt about our ideas, we showed them our storyboards and elicited reactions using a method called Speed Dating.



Creating storyboards for each possible scenario

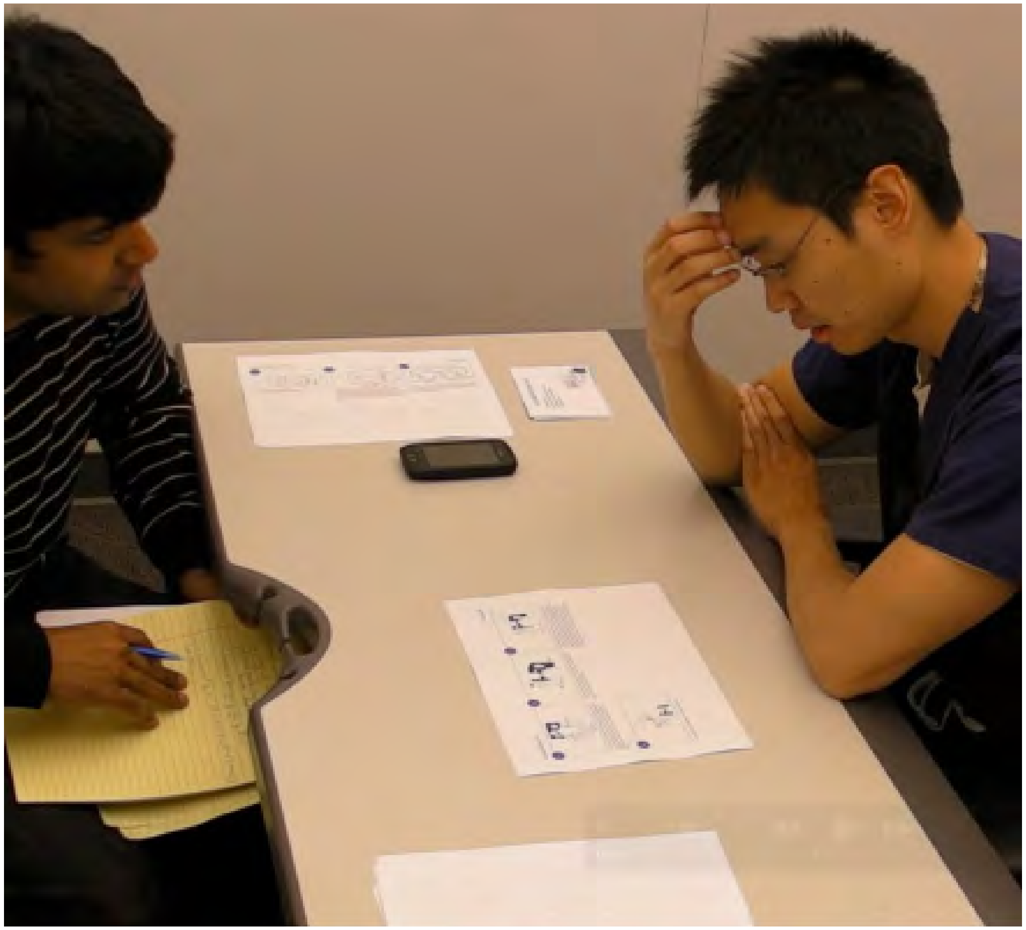
Speed dating our visions

Meet the Participants

Dr. Stevenson is a resident radiologist at UPMC. He has spearheaded previous projects to make his hospital's technology more usable, and was one of our subject matter experts during this project's spring research phase. He is in his late twenties.

Dr. Gupta is an attending radiologist at UPMC. He studied at UWMC and reminisced about his days as a resident there. He is in his mid thirties.

Dr. Osfelt is a diagnostic radiologist. She performs ultrasounds in a small, tight-knit office with her three technologists generally within speaking distance. Throughout her day, she occasionally communicates with others in her hospital system using Spark, a non-integrated, enterprise-level instant messenger. She is in her early thirties.



A participant evaluating one of our visions

1. Real-Time Collaboration

Response

Participants were thrilled by real-time collaboration, ranking it as their favorite vision

"This sort of interface would improve my entire workflow."

–Dr. Stevenson

We proposed real-time conferencing around images

We proposed the ability to share and discuss patient examinations by video conferencing around images. We also suggested discussion logs.

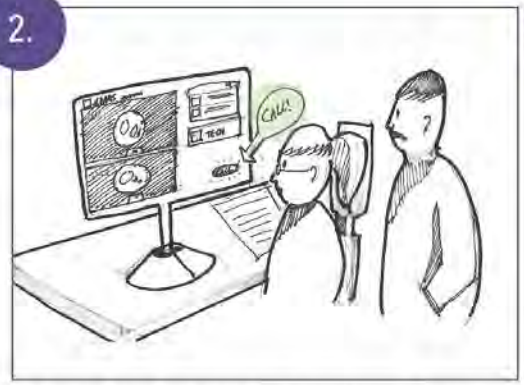
Radiologists were floored by this vision

All three participants ranked this as their top vision, but thought the radiologist-technologist angle was not exemplary of the vision's ideal use. They instead recommended we tailor this vision to radiologist-radiologist and radiologist-specialist communications. Dr. Gupta estimated that one in four cases requires a second opinion. This vision also received positive reactions to assessing availability through chat and real-time, shared annotation.

1.

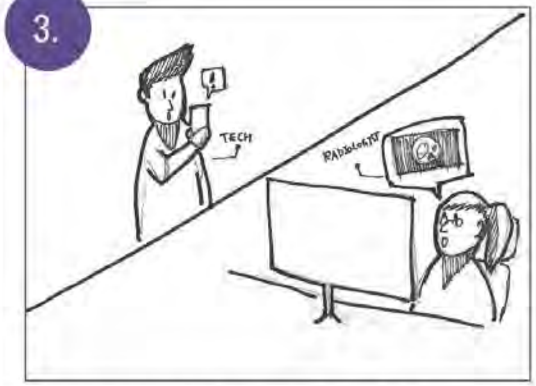
Dr. Deng, the attending radiologist finds something to demand this x-ray be taken again. He tells the resident, Dr.Boyce to find a particular technologist to discuss with.

2.



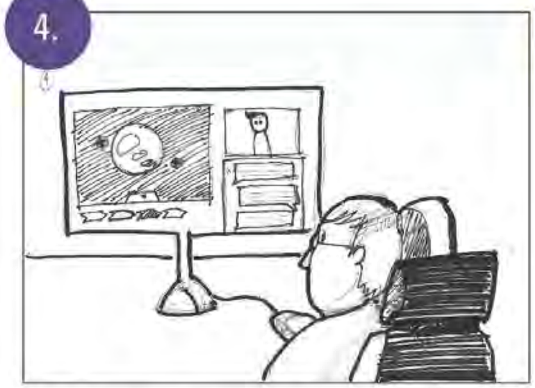
Dr.Boyce finds the technologist responsible for the image in the system and asks for video call.

3.



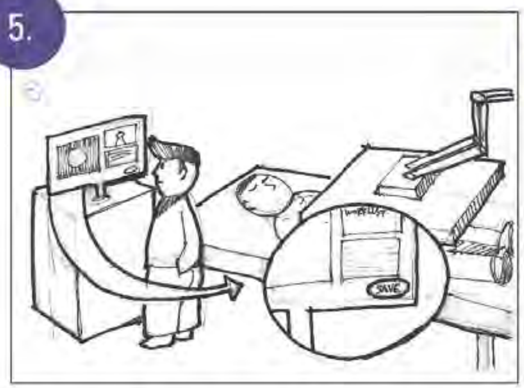
The radiologists brief technologist on the situation and asks for more post-processing. Technologist (working on off-site location) is surprised but asks exactly what to look for this time.

4.



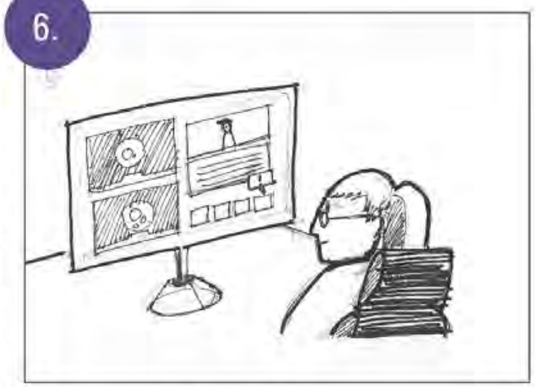
Dr.Boyce shares the images and highlights a particular area, explains what needs to be done there.

5.



Technologist still has patient at off-site location and is able to keep her there long enough to get the second scan. The video chat event and its contents are added to a case history.

6.



The resident tells the tech to let him know when scans are added. Then, a reminder is added to alert the resident when new scans are added.

EXPLORATION

2. Patient Timeline

Response

The timeline visualization was easy to understand, would save time and substantially improve patient care

"I don't understand why we don't have this already. If you make this, my life will be much simpler. Currently, I have to log into five separate systems 10-15 times a day to look up patient information for each case."

–Dr. Gupta

We proposed a patient dashboard

We envisioned a single sign-on Patient Timeline with integrated EMR, affording a single view of a patient's entire clinical and examination history with preview images and contact information for all involved parties. The Patient Timeline would not only provide quick access to all patient information but also notify the user of urgent patient-related tasks.

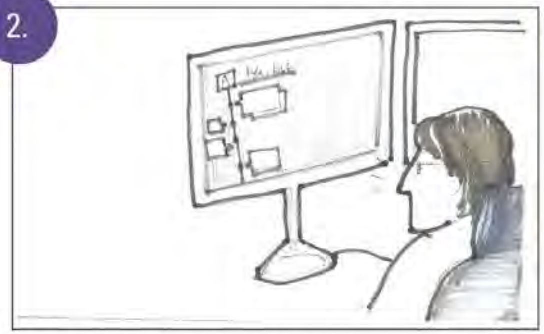
Radiologists wished this already existed

All three participants responded favorably to this vision, asserting that the timeline visualization was easy to understand and commenting that EMR integration would save a lot of time searching through different systems. Dr. Gupta added that he would like to be able to customize his view of timeline information and events based on his specialization.

1.

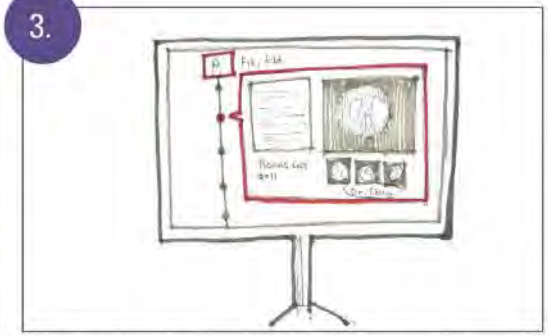
Dr. Smith, a resident receives an emergency case in midst of working on other tasks. The smart communication queue indicates the case needs immediate attention, so he opens the patient timeline to look at the case.

2.



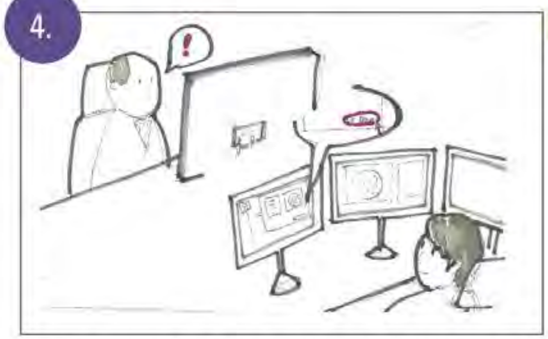
Luckily, the visualized patient timeline indicated that this patient has been treated once in the same hospital due to a disease that shows similar symptoms.

3.



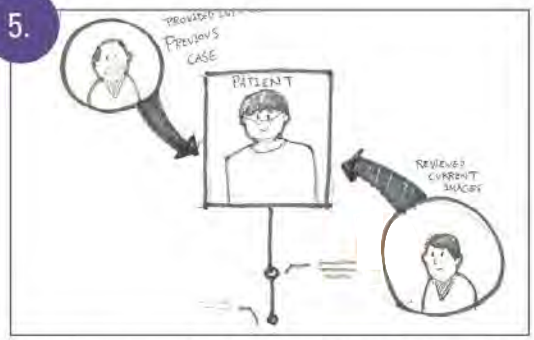
Dr. Smith checks the integrated patient EMR data and looks for details on how the patient has been treated. He goes through previous PACS images as well as relevant conversation history on discussing the symptom.

4.



Dr. Smith contacts Dr. Deng, who previously took care of the same patient, in order to discuss specifics about previous patient case.

5.



The emergency case has been treated appropriately and the necessary steps were never omitted since visualization helped the whole process to be much faster.

3. Smart Walls

Response

Smart Walls showed potential for tumor boards or mobile use, but too futuristic

“I appreciate how my PACS administrators make sure that my interface stays the same between upgrades.”

–Dr. Gupta

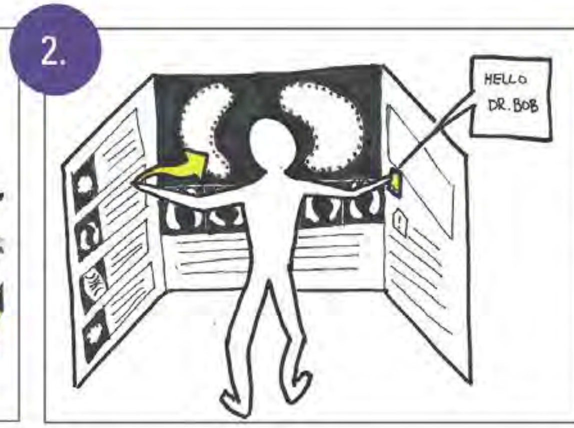
We proposed giant multi-touch screens

We proposed Smart Walls: floor-to-ceiling, gesture-enabled, multi-touch screens with one entire screen dedicated to communication—both asynchronous and real-time. We presented these screens in the context of everyday use and tumor boards. We also suggested a mobile version of these screens for use on the go.

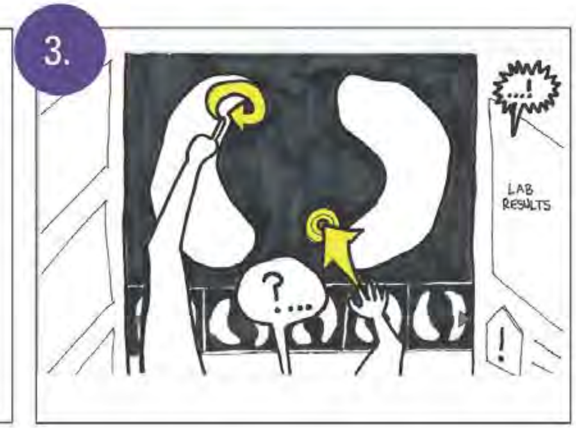
Radiologists’ response was mixed

While intrigued, all three participants had difficulty relating to Smart Walls, preferring that upgrades not drastically change their interfaces and fearing that frequent arm movements would grow tiresome. However, two saw potential for the mobile version despite concerns about image quality, and Dr. Stevenson felt the full-scale version would be useful for tumor boards.

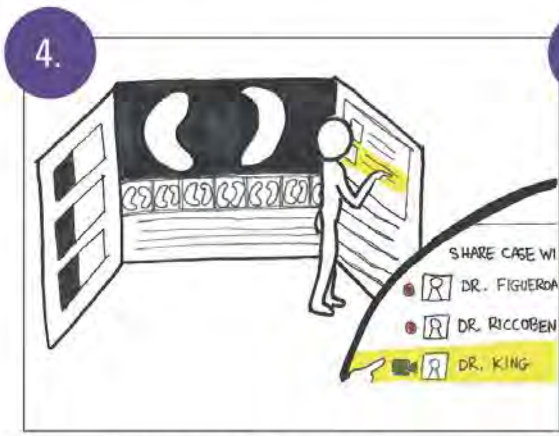
Dr. Bob is driving to work when Kim the Tech contacts him about a scan in progress.



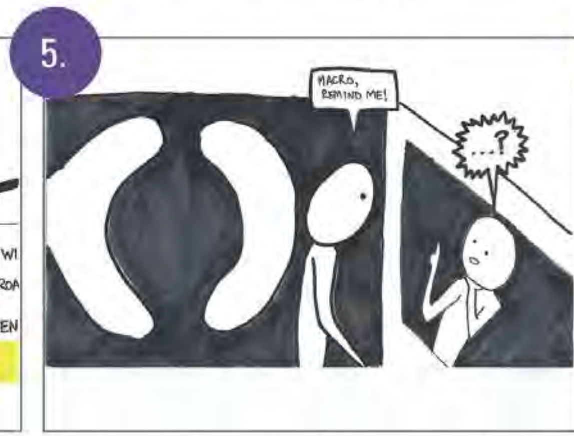
At work, Dr. Bob places his phone against a smart-wall workstation to log into his preferred setup. He finds the case Kim scanned earlier and drags it open.



Dr. Bob circles what might be a tumor and verbally requests lab results from the system. He drags in related images to cross-reference.



For a second opinion, Dr. Bob sends the case to a radiologist the system says is available, Dr. King.



Via video chat, Dr. King says his interpretation is murky. Dr. Bob speaks a macro, adding a reminder to discuss this in today's tumor review board.

For the tumor review board, Dr. Bob expands the images to fill his smart walls. As other physicians shed light on the case, Dr. Bob taps the wall to capture their comments.

4. Smart Agent

Response

Geolocation raised hackles, but integrated communication and People Search shone through

"I like being able to get hold of someone, but when I go to the café, I want my downtime. Let me have my five minutes of peace!"

–Dr. Osfelt

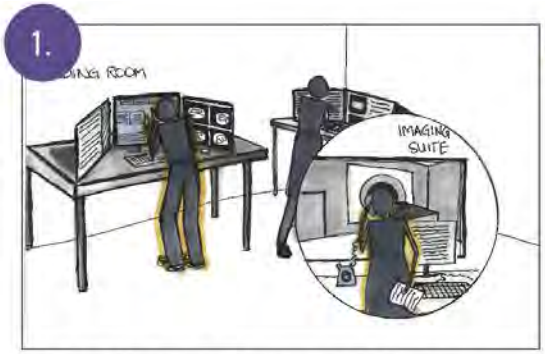
We proposed a new way to make contact

Through the RIS, users could request to speak with hospital personnel, and a Smart Agent would connect them via audio calls whenever they both become available, or alert them whenever they were in physical proximity on premises. The system would also provide ER alerts and instantly lock cases. Users could contact personnel involved in a case from within the case itself, or leave them messages there. Case updates, automatic communication logging, and an automatically prioritized worklist rounded out this vision.

Radiologists did not welcome geolocation

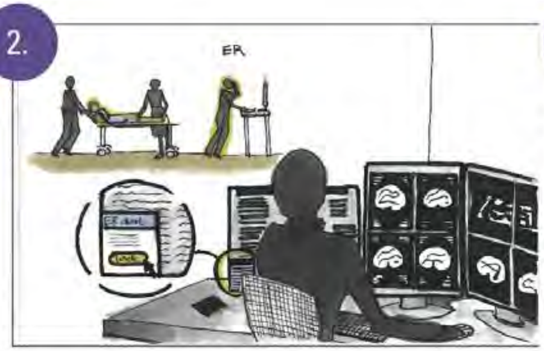
All three participants disliked geolocation, particularly Dr. Osfelt. One participant also wondered how a Smart Agent would be able to keep up with schedule changes. At the same time, integrated asynchronous messaging and People Search won some fans.

1.



Dr Bob is at his desk dictating a report while looking through the images. Meanwhile, in the Emergency Room, a tech submits a request to verify a protocol. Because the patient isn't scheduled to arrive until later this afternoon, he indicates the urgency accordingly and sets a deadline for the protocol to be verified.

2.



At same time, a patient arrives at the ER and needs to be rushed to be scanned. The ER doc submits an alarm to the system which alerts the reading room. Dr Bob locks the case so that he will be notified when the images come in. He goes back to the case he was working on.

3.

Dr Bob sees a potentially lethal tumor in the images he's looking at. He adds the critical finding to the report and requests an urgent meeting with the referring physician. The system will alert him when there is an available match when both of them can talk.

4.

The system notifies Dr Bob that the ER images are in. Dr Bob switches to that case. He leaves a quick voice message for the referring physician after skimming through the images and then goes on to finish dictating and signing the report.

5.

Dr Bob checks his communication queue that has been sorted by priority and urgency. He sees a protocol that needs verification next on his list. He selects the protocol case next.

6.

Dr Bob decides to take a break and walks to the hospital cafe. While he is walking, he gets a notification from the system on his phone: one of the physicians he wanted to get in touch with, Dr Nick, is nearby and free to talk. He walks over and they have a quick chat about a case.

5. Shared Worklist

Response

Shared Worklists received a lackluster response

"Shared worklists? We already have them."

–Dr. Gupta

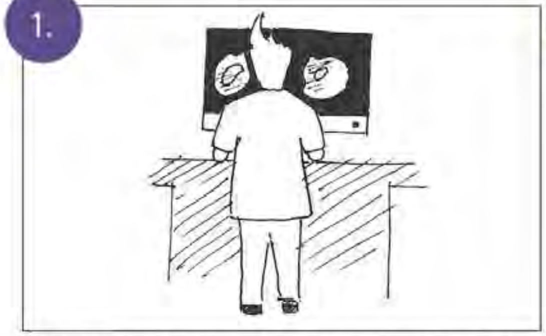
We proposed automatic case updates

Shared worklists could automatically update all stakeholders in a patient's examination whenever one of them contributes to a case.

Radiologists could care less

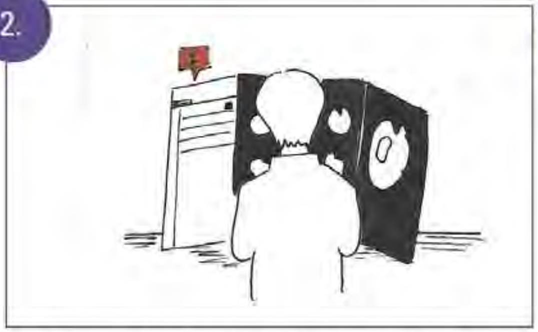
All three participants argued that their worklists are already shared, and that while shared updates are not afforded, they had little interest in receiving them.

1.



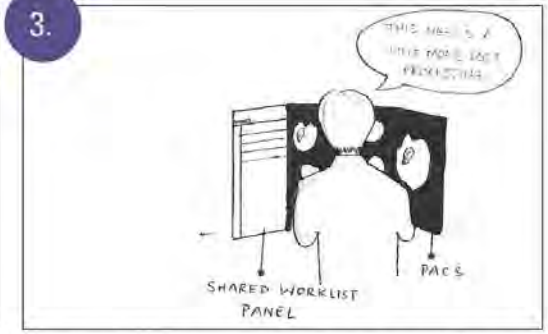
Dr. Bob contacts the tech, Adam, and informs him that the images need more work. He returns to reading other cases on his worklist. Adam finishes the appropriate post processing and pushes the new images into the PACS.

2.



Dr. Bob immediately receives a notification about this in his worklist. He finishes his current case and attends to the new images pushed by Adam.

3.



While reading the new images, Dr. Bob realizes that he needs to access the patient's lab results. He returns to his worklist and sees that the pathology department has attached lab results for this case. He picks the lab reports and loads them up in a separate pane on his PACS workstation. While completing the report, he realizes the images need a little more post-processing.

4.

Dr. Bob contacts Adam again for post-processing.

6. Unified Patient Interface

Response

The Unified Patient Interface did not much improve the way radiologists currently lay out patient data

"We already do this, but I like the dragging interaction."

–Dr. Stevenson

We proposed a single patient interface with draggable clinical data

A single, Unified Patient Interface would contain access to all clinical data, accessed using a patient's ID. Useful clinical data could be dragged into patient examinations.

Radiologists did not see advantages to our depiction of this vision

All three radiologists felt patient data's current availability was not much improved by this vision. One mentioned that radiologists manually lay out windows for each case on their systems.

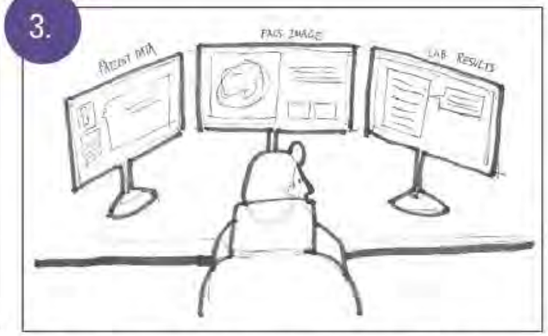
1.

Dr. Tom pulls a case from his worklist.

2.

Dr. Tom While reading the images, he realizes that he needs access to lab results for this patient. He then accesses his common patient interface, feeds in the ID for the patient, and has access to any documents across multiple depts for this patient. He finds out the document that he needs (lab results) and drags them over to his PACS.

3.



Dr. Tom has access to the patient's lab results and so, these render on his screen. He aligns them onto a different pane, allowing him to read the images and view the results simultaneously.

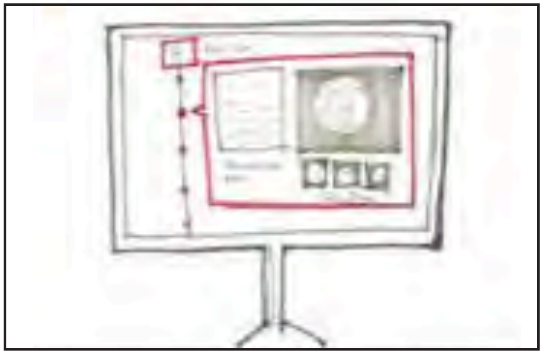
Two Final Concepts

Participating radiologists gave us a lot of qualitative information. Because their feedback to our fledgling concepts was consistent throughout, we were confident that we were headed in the right direction. Our radiologists' feedback pushed us toward two overarching concepts: a real-time collaborative interface and a systems-integrated patient timeline. We were now able to return to GE with the subset of visions we had sought after.

Based on our assessment of our participants' reactions to our two final concepts, we brainstormed possible features as well as pros and cons. We proceeded to sketch each concept in a detailed low-fidelity rendering. Then, we divided each concept's potential features into core features and optional add-ons and diagrammed these on Post-its. Some Post-its survived while others fell to the floor during an intense discussion session comparing participants' reactions with our spring research findings and gauging the technical feasibility of multiple versions of a possible final solution.

1. Real-Time Collaboration

2. Patient Timeline



EXPLORATION

Excitement about real-time communication and collaboration integration

In its recent “Roadmap for the Future,” GE Healthcare identified collaboration as its second-highest priority in developing forthcoming solutions. Our speed-dating participants seemed to agree.

One radiologist was especially excited about real time discussions around PACS images using separate cursors. Currently, most radiologists we studied collaborate by annotating an image, closing it, calling someone (e.g. another radiologist) they want to show it to and asking them to close and reopen it, and then describing each annotation. They sometimes repeat this process multiple times per call.

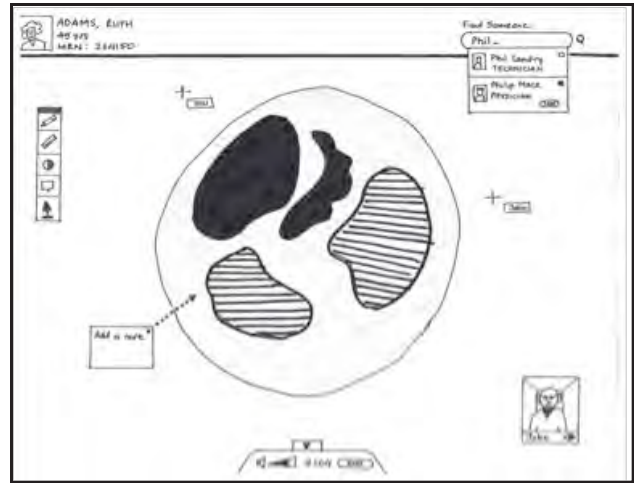
Our proposed concept would allow radiologists to quickly and effectively consult their peers on difficult cases while reducing the frequency of their incoming, non-urgent phone and in-person communications.

A clearer picture, faster, with patient timeline visualization

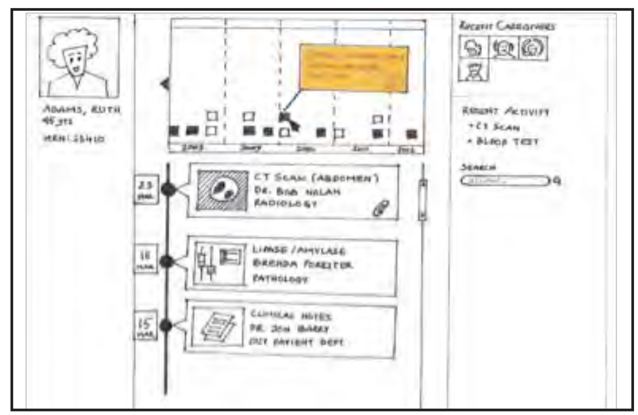
Radiologists liked our concept for patient timeline visualization with EMR integration, not only for getting an overall picture of a patient’s history, but also for accessing case-specific information. Such a system could help radiologists more quickly and confidently identify progress of symptoms and patient allergies. It could also help radiologists to clarify their questions about patient history with reliable sources.

One radiologist compared this to a similar in-house system for radiological images and said integrating EMR data would help him avoid logging into different systems 10-15 times a day for 10 minutes each time. Another radiologist saw potential for customizing data in the feed for different specialties.

Our proposed concept would support radiologists’ image-diagnosis process by providing correct and complete contextual clinical data including historical examination data, eliminating radiologists’ current need to gather this data on a case-by-case basis.



Our initial real-time image conferencing wireframe depicted cursor sharing, commenting on images, video conferencing, and an integrated People Search tool indicating collaborators’ availability



Wireframes for the integrated patient timeline depicted single login, one-click access to multiple systems, document previews using a timeline visualization, customizable views, and activity updates

Final Proposal

While the patient timeline visualization with EMR integration resonated loudly with radiologists and represented our most ambitious vision, many of its elements fell outside our project's scope or were not as closely tied to GE's business direction as were those represented by real-time communication and collaboration integration. Although we elected not to move forward with the concept, we strongly encouraged GE to conduct more focused research to explore radiologists' need and desire for it.

Based on our speed-dating participants' reactions, comparison with our spring research findings, the technical feasibility of our two competing proposals, and the strengths and weaknesses of each proposal's feature set, we recommended that GE pursue our real-time communication and collaboration integration concept.

All our speed-dating participants thought highly of our real-time collaboration story, and all three ranked it as their favorite.

Once our clients at GE Healthcare endorsed our proposal, we began to focus our efforts on the iterative design-build-test cycle through which our final prototype evolved.

ITERATIVE DESIGN

We took full advantage of user-centered design principles in our Iterative Design phase. Our testing participants showered us with feedback that guided our prototypes through six “waved” iterations from low to high fidelity.

We first tested the waters with interactive paper prototypes designed around core features. Based on participants’ feedback, each feature was discarded, redesigned, or integrated into the next prototype. We then introduced new features to the next prototype which each underwent a similar trial. At higher fidelities, we overlaid Axure sketches of new features directly on top of our prototypes, eliciting gut reactions and exposing usability issues.

By relying on usability tests to advance our designs, we made constant progress toward an effective, usable, and desirable final prototype.

Our first prototype

Low-fidelity paper prototype

We used a preliminary paper prototype to test a concept we felt would succeed—image centered conferencing.

In light of our early difficulties finding users, we wanted to make the most of our sessions. So, back when we were still crafting speed-dating stories, we decided to create a more detailed sketch of the central features of our concept for real-time collaboration and communication integration: sharable case sessions and cursors. Our goals were to evaluate the effectiveness of our proposed interaction and to get input about features that could enhance or support this concept's implementation.

Paper prototyping—faster and better

Quick and inexpensive, paper prototypes consist of screenshots or sketches of an interface. Combining paper prototypes with scenarios allowed us to dig deeper into our design ideas and to test each design's impact and usability for its target user group.

Significant research shows that low-fidelity paper prototypes are as effective in identifying usability issues as higher-fidelity prototypes [7].

"Paper prototyping is a variation of usability testing where representative users perform realistic tasks by interacting with a paper version of the interface that is manipulated by a person 'playing computer,' who doesn't explain how the interface is intended to work."

- C. Snyder, Paper Prototyping [6]

We made it interactive for a collaborative experience

We quickly realized that simple wireframe screenshots would not be enough to embody this concept's collaborative aspects. Cutting out widgets, modules, and cursors, we created an interactive paper prototype radiologists could role-play with in a Think Aloud scenario. This prototyping process was so effective in conveying our ideas to our Think Aloud participant that it became the hallmark of our subsequent paper prototypes.

Our paper prototype simulated several visions by allowing users to remotely discuss and annotate images, search for colleagues and gauge their availability, drag colleagues into a case, control colleagues' case-authorship access, and append data or metadata to a case.

Think Aloud evaluation revealed hidden expectations

We used the Think Aloud method during prototype tests to coax participants into explaining the immediate reasons behind their actions. Participants completed simulated tasks without our guidance while speaking to themselves about their experience: what was easy and what was frustrating. We followed Think Aloud testing with retrospective interviews, asking participants to reflect, discuss features, and provide additional feedback.

Participants' feedback helped us probe into specific decisions we had made, for example, whether communications should be logged. Our interactive paper prototypes' flexibility let us respond to unexpected participant actions with improvised alternate scenarios.

By Think Aloud testing, we discovered hidden expectations and reactions to design concepts while also testing usability.

First round with a particiant gave us a good grasp of the features radiologists want

ITERATIVE DESIGN | Evaluation

We tested the effectiveness of our proposed interactions for real-time collaboration and watched our sole participant excitedly breeze through them all.

We used:

Paper Prototype	Think Aloud Retrospective Interview	Story Sharing

Meet the Participant

Dr. Stevenson is a resident radiologist described in the previous Speed-dating section.

We saw opportunities to improve consultation

Dr. Stevenson easily completed the Think Aloud test without a single severe incident. Despite his initially lukewarm response to our speed-dating story about real-time collaboration integration, he grew ecstatic about the possibilities of using the prototyped real-time collaboration interface with other radiologists. Dr. Stevenson said, "When radiologists have questions about a case, this sort of collaboration would be helpful."

Mistakes were made—but not repeated

Dr. Stevenson responded halfheartedly to the face-to-face videoconferencing component of our prototype. When asked for elaboration, he merely said, "I guess video could be interesting—if I could move it out of the way." Dr. Stevenson also wanted access to a larger PACS toolkit, not just the three tools we presented. He felt it was cumbersome to pull open the "tool drawer" module to access the tools, as well as to drag comments to specific locations on the image rather than simply clicking a location and directly typing a comment.

We unwittingly referred to an image of the heart as "the brain." Dr. Stevenson kindly pointed out this rookie mistake, but we learned to be more cautious in future tests about the credibility of our images and other data.

What worked and what didn't?

Real-time image conferencing and cursor sharing
Our participant loved this capability and wished he had it already.

People search with availability indication
People search was easily navigated and praised for its simplicity and complete integration with the unified RIS/PACS.

Case-authorship control for case owners
Our participant felt case-authorship control would potentially be useful but nonetheless risky. Going forward, we chose to experiment with different levels of case-authorship control in sessions with varying degrees of privacy.

Appended case data and metadata
The ability to append data to a case was well received. However, our participant was unsure about the best way to do so. We let this feature pass through to the next round, reimagining it as an all-encompassing Patient Card.

PACS toolkit
There were not enough tools available to satisfy our participant, so we expanded the toolkit going forward.

Tool drawer module
Our participant considered the tool drawer module a cumbersome intermediary step, so we abandoned it in favor of the common toolbar.

Draggable comments on images
Our participant was also hindered by having to type comments into the tool drawer module and then drag them to the appropriate locations.

Face-to-face videoconferencing
Our participant was less interested in video and more excited about audio. However, because we felt video could establish needed rapport during consultations, we let this feature pass through to the next round for additional feedback.

ITERATION 1

Integrating with RIS/PACS Low-fidelity paper prototype

We validated our concepts with four unique sets of wireframes. The resulting paper prototype integrated conferencing into PACS and asynchronous messaging into the RIS.

After choosing to move forward with our vision for an integrated real-time collaboration and communication tool, we created a low-fidelity paper prototype based on feedback from our last round of testing. This time, we shifted focus from PACS to test a RIS-centered communication flow. Keeping our prototype at low fidelity allowed us to evaluate our design and fix its flaws without making the time-consuming mistake of developing a premature software solution.

We fleshed out our previous prototype

While speed dating revealed radiologists' desire for real-time collaboration and communication integration, we were still unsure of its full feature set and how to integrate it into a larger ecosystem of products. Additionally, GE now asked us to design for a future integrated RIS/PACS system.

We understood the importance of designing for the radiologist's entire workflow, particularly image review: a high-concentration, interruption-prone period when radiologists need to communicate quickly and efficiently with minimal context switching. Our communication visualization revealed that during image review, the majority of interruptions were either simple task reminders or non-urgent incoming notifications from technologists that could be handled asynchronously. As a result, we decided to continue supporting real-time collaboration around images in an integrated RIS/PACS as well as enabling coordination of tasks or cases using asynchronous communication methods.

Early iteration and activities led to internal validation

While recruiting users en route to testing our second prototype, we created several sets of internal wireframes. These wireframes were sketched individually to support user goals we had identified. Individual brainstorming has been shown to prevent group fixation on specific ideas [5], and we found that it allowed us to explore many different possibilities. By brainstorming at the wireframe level individually, each of us was able to work through concepts at a concrete level. Then, in internal critique sessions, we validated these wireframes using methods that helped us leverage data from our user research phase.

We tried to answer design questions using these methods as guides:

Persona validation
We routinely compared our designs' applications to the needs and goals of the personas we had identified in our field research.

Bodystorming
We acted out user roles in their imagined contexts to discover gaps in our proposed design solutions.

Design patterns
After considering common interactions with groupware and communications systems, we adopted some of the most universal patterns to make our designs more familiar.

Scenario analysis
We used our wireframes and the workflow models we created in spring to test the completeness of our designs by walking through validation scenarios.

Although these methods helped us leverage our user research to validate initial concepts, this strategy also resulted in significant time being spent doing group discussions. After our usability evaluation, we found that direct validation with users was much more effective in framing our problem space.

Evaluating opportunities for collaboration with sketches and paper prototypes

Certain variables framed our design decisions

After several sketches and four iterations of internal wireframes, we realized that our design depended on several variables. Every wireframe suggested different ways of using conferencing and asynchronous messaging tools to solve problems.

These following are areas and related questions we explored in designing our first iteration:

Communication tool consolidation or integration

Should communication tools be consolidated into a single panel in the RIS or PACS, or separately integrated into the existing RIS workflow? Should their space be dedicated or minimizable?

Communication tool options

Which communication tools would radiologists prefer: audio, video, chat, screen sharing, collaborative image and report editing, annotation, or commenting? We explored image and report commenting as ways for referring physicians and other radiologists to leave messages in cases, particularly for areas that need clarification. Could such asynchronous communications be helpful? Would synchronous annotations and comments made during real-time conference sessions persist after the session ends? For conferencing, we considered the ways radiologists could share information: through a separate panel where images could be dropped in, entire screen-sharing, or a combination of both.

Documentation of communications

From a persona perspective, which communications should be documented, and what are the legal issues associated with this documentation? Should the entire communication be documented, or merely that it occurred? We also discussed how important it was that these logs be accessible as opposed to just recorded.

RIS integration

We saw opportunities for personalized work lists and simpler work list information. We tried to reduce the large number of columns found in the current RIS work list, and discussed providing an overview of a patient's status and care team by adding a patient card to the integrated RIS/PACS.

Notifications

How should communication and notification features be integrated into the worklist? Should notifications go into the worklist and be tied to case conversations, or should all notifications route to one place? We looked at what these notifications should contain and what the notification interaction should be: app style, through pop ups, or a combination.

Finding people

We explored many ways to find people: for example, by documenting them in each case, or finding them through an integrated people search tool.

Messaging architecture

Should messages be left in cases for future visitors, directed to specific individuals, or both? Should messages directed to specific individuals be formatted or linked to images? We also explored the idea of case conversations and whether radiologists would prefer to discuss particular cases asynchronously, many times a day, with various individuals. What privacy concerns exist and would the added complexity be worth the difficulty?

Our wireframes helped us explore different variables while designing our solution. We created final side-by-side wireframes for the sender and receiver sides of communication to account for every possible interaction before creating our prototype. Then, we built our wireframes in Axure so they would be legible but still retain a sketchy look and feel.

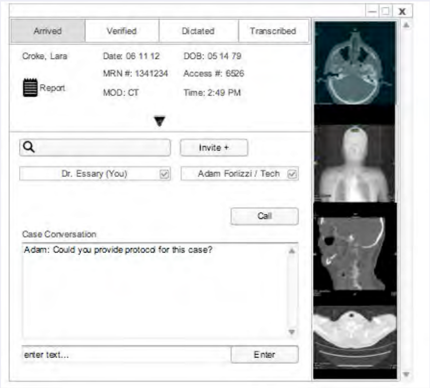
Our Prototype

PACS conferencing

In this prototype, we kept the conferencing tool integrated into PACS because radiologists were more likely to be reading a case when inviting others to a conference. The bottom toolbar was removed because of the negative feedback it received during the last round of evaluations. A case chat tool was added so collaborators could add text comments during a conference.

Patient Card

We integrated asynchronous messaging into the RIS workflow using an intermediate patient card that leveraged future RIS/PACS integration. The card provided a quick view of the patient's status and relevant caregiver contact information. Additionally, a caregiver could invite others to view and collaborate on a case.



A simpler worklist

We kept the worklist simple but added a notification badge to alert users to incoming and missed messages. Clicking the badge opened an inbox panel. Pop-ups alerted users to audio calls, video calls, and conference requests, all of which we considered urgent.

ITERATIVE DESIGN | Evaluation

We tested the feel and flow of communication and learned that one-on-one asynchronous messaging increased efficiency while our Patient Card impeded participants.

We used:

- Paper Prototype
- Think Aloud Retrospective Interview
- Story Sharing

Meet the Participants

Dr. Lopez is a resident radiologist in his first year at UPMC. He is frustrated with the telephone aspect and manual case-finding efforts required by the current collaboration process, and recently discovered that some of his callers randomly pick incorrect numbers such as social security from patient forms when asked for identifying case information. He is in his mid twenties.

Dr. Osfelt is a diagnostic radiologist described in the previous speed dating section.

Dr. Ginsburg is a diagnostic radiologist at Allegheny General Hospital.

Text is good, but let the user decide

Participants were often eager to communicate by textual chat rather than by phone. However, all participants associated chat more with individual communication recipients than with the case itself, preferring one-on-one discussion to group chat. Dr. Lopez said that for many topics, he would prefer the asynchronous nature of our chat feature to his current telephone conversations. Accordingly, participants appreciated the ability to personally decide which mechanism to use for a particular communication topic. This confirmed our hunch that thanks to the wide variety of communication preferences between providers, radiologists and their colleagues should be given the freedom to route types of messages through either synchronous or asynchronous channels at their own discretion.

The Patient Card upset a delicate balance

Participants felt hindered by the pop-up patient card, perceiving it as an unnecessary step between finding a case and viewing its images. The one exception was its “Case conversation” chat component: We realized we could reduce the patient card to an inline work-list preview while moving the chat to the PACS or RIS.

Participants demanded instant messaging for radiology

Participants echoed a sentiment often expressed during our research phase, directly requesting “Skype/AIM/Spark for radiology.” They responded well to a similar messaging metaphor, a Facebook-style message-waiting notification at the top of the work list. We began to see borrowing familiar interaction metaphors as an advantage over dreaming up more adventurous but unfamiliar ones.

We used retrospective interviews to solve burning questions raised in our marathon design discussions. Would participants use our system to supplement reports? Would they want customizable, personalized work lists? How did they currently protocol cases, and with what level of involvement from technologists and referring physicians?

What worked and what didn’t?

Case conversation
Participants reacted positively—but to one-on-one discussion possibilities, not group discussion as intended. Cases had shorter lifespans than we perceived. Case conversation was reimagined in various formats.

Message-waiting notification
Our notification badge was easy to spot and simple to learn. Still, its preview capabilities were somewhat limited, so we explored alternatives in the next round.

Patient card
The patient card was viewed as an unnecessary intermediate step. Still, we gave it another chance in the next round as an inline worklist case preview.

PACS chat window
Participants consistently mistook the PACS chat window for a one-on-one chat affordance. We reconsidered this feature going forward.

ITERATION 2

Exploring Alternate Designs

Parallel paper prototypes

We evaluated divergent concepts with three parallel prototypes, focusing mainly on interactions for asynchronous messaging.

While we received positive feedback about the conferencing feature during our previous set of Think Aloud tests, it became obvious that messaging and the patient card needed to be redesigned. In this iteration, we simultaneously developed three paper prototypes so that we could test several interactions at once and maximize the feedback we received from radiologists. The first two prototypes were based on feedback from our previous prototype; the third, however, was a new design.

Parallel prototypes—one with a twist—led to A/B/Z testing

We decided to create and test three prototypes, a method more effective in guiding design than working with a single one. Although time-consuming, testing all three prototypes allowed us to evaluate multiple interactions and flows at once.

> *"Once a design is prototyped and tested, it hardly ever gets rejected by the users. Rather, it typically leads to an iterative improvement of the same design, rather than a return to the drawing board (which might lead to an alternative right design)."*
>
> —Bill Buxton [8]

Developing three parallel prototypes resulted in spending less time validating our designs as a group. We were no longer forced to choose one concept and thus test a greater number of concepts with our end users. We gathered valuable feedback on multiple interactions and feature flows, but subsequently returned to testing only one prototype per round to reduce setup time.

Our Z prototype took risks within reason

While our A and B prototypes were incremental improvements based on feedback from previous tests, we used our Z prototype to free ourselves from our previous designs to find new solutions.

> *"Randomness is an essential element in any kind of creativity. The shuffling and recombination of genes, for example, is an essential element in the variation and selection that leads to the emergence of new life forms. The same principle works in the realms of thought and ideas."*
>
> –Gray et al [2]

Fail or succeed, the Z prototype was our ticket to fresh user reactions and new discussions. However, in the end, the Z prototype turned out less unusual than we had anticipated. Its components sparked discussions and helped us to better understand our users' mental models. Small elements of the Z prototype even made their way into our final solution.

We consciously avoided designing the entire unified RIS/PACS

Our focus had always been to design tools to support communication and collaboration for radiologists. However, after GE asked us to design our solution for the unified RIS/PACS of the future, boundaries between our solution and the nature of RIS/PACS blurred, and we constantly found compelling reasons to fully redesign the current RIS/PACS, for example, to simplify the data-intensive worklist.

In our last attempt to redesign major aspects of the current RIS/PACS, our Z prototype notably redefined the worklist in the form of a playlist, with the worklist moving to on-demand background status. The primary view was the current case, from which users could move back or forth using arrows reminiscent of rewind and fast-forward. Users could search for specific studies, when needed, using a search bar. Although feedback for the concept was promising, it was out of scope, so we did not pursue it further.

We hesitated to eliminate face-to-face videoconferencing

> *"I don't see the point of video. I want to get to the point and can't do that with referring physicians. Formalities are required—'Hey! How's it going?'—because I want them to feel good and send more customers my way. Audio and cursor sharing is enough. My goal is efficiency, not rapport."*
>
> —Dr. Osfelt

While radiologists in our previous round of evaluations were not interested in face-to-face videoconferencing, we retained this feature to compare results with our new prototypes.

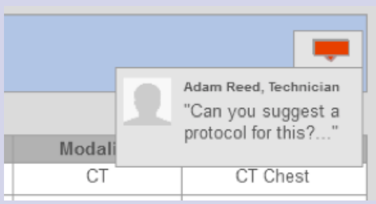
Creating three prototypes enabled us to compare asynchronous interactions

Some concepts, like image-centered conferencing, had been significantly successful in our previous iteration. We brought these features forward with few or no changes. Where our prototypes significantly differed was in the handling of asynchronous messaging. Also, our Z prototype allowed us to determine whether invitations were necessary for PACS conferences and how radiologists would react to a RIS redesign.

Similar features across prototypes

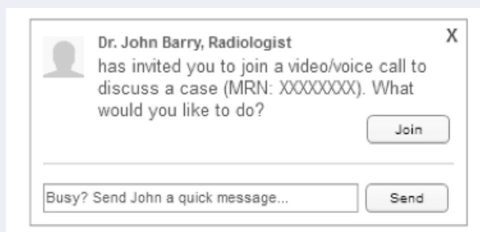
Notification

All of the prototypes used notification badges to alert users to incoming communications. Clicking on the badge revealed a panel containing notifications.



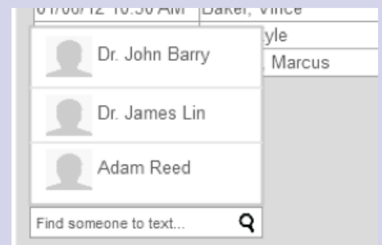
Pop-up alerts

Two of the three prototypes used pop-up alerts for conference requests.



People Search

All of the prototypes used People Search but differed in its placement. Prototype A placed it in both the RIS and PACS. Prototype B placed in the communication panel. Prototype Z hid it until the user initiated a new message or call.



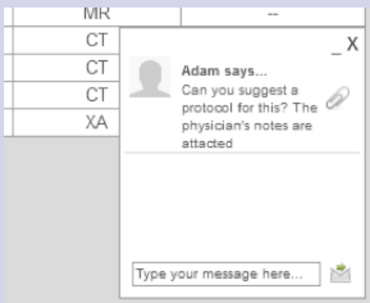
ITERATIVE DESIGN | Design

Different features across prototypes

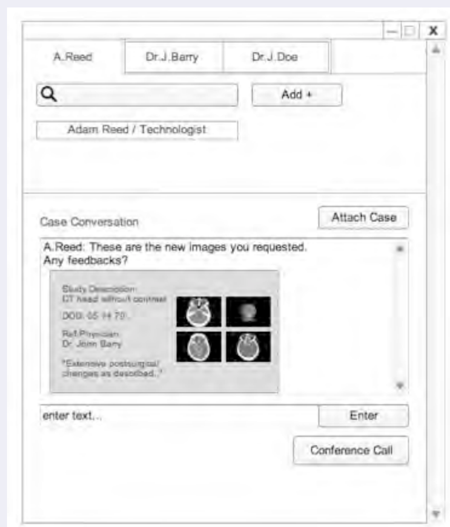
Asynchronous messaging

We explored three different ways of messaging. Prototype A used familiar instant-messaging metaphors. Prototype B used a dedicated communication panel with the option of attaching cases with previews and starting conferences from the panel. Prototype Z also used a dedicated communication panel but did not allow threaded messaging, while it did allow initiation of audio and video calls from within each message.

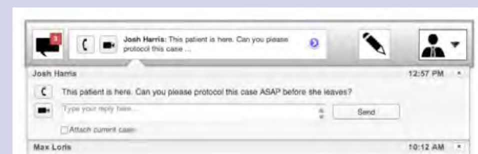
Prototype A



Prototype B



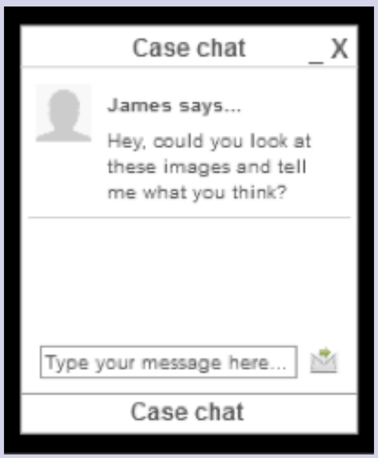
Prototype Z



Case-centered communication

Despite lackluster response, it was difficult for us to move away from messaging inside cases. All three prototypes continued to provide this capability. Prototypes A and B both used case chat inside PACS conferences, and prototype B also provided a redesigned Patient Card where users could see case updates. Prototype Z had a feature similar to case chat—from which audio and video calls could also be initiated—in the worklist rather than in PACS.

Prototype A



Prototype B

Prototype Z

ITERATIVE DESIGN | Design

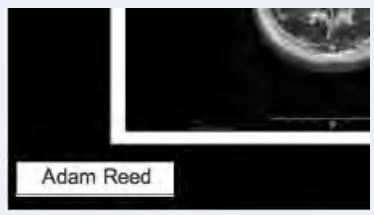
Unique features in Prototype Z

Worklist as playlist

In an attempt to better accommodate the ideal radiology workflow, Prototype Z redesigned the RIS worklist as a playlist. Cases were accessible by Back and Forward buttons, while the worklist remained accessible from an Adobe-style panel at the top. This redesign made increased of iconography compared to Prototypes A and B.

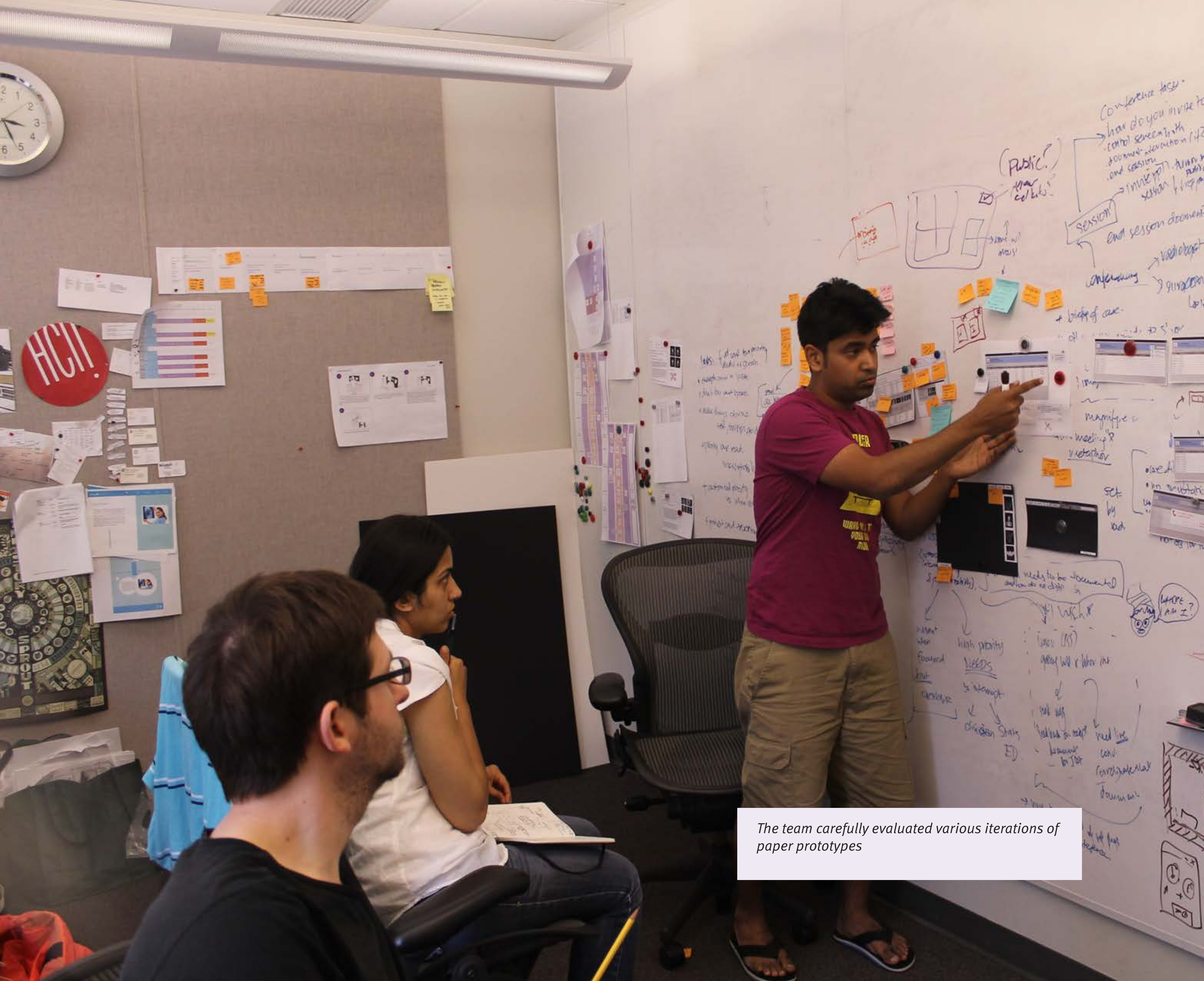
Open conferences

Prototype Z probed at case privacy concerns by testing radiologists' reactions to the ability to freely join open conferences without being invited.



Feed

We tested whether users would want to subscribe to feeds for case-update notifications.



The team carefully evaluated various iterations of paper prototypes

We cross-tested ways to integrate communication and found a winner—a panel based on familiar interaction metaphors.

We used:

- Paper Prototype
- A/B/Z Think Aloud Usability Aspect Reports
- Story Sharing Artifact Models

Meet the Participants

Dr. Stigler is a diagnostic radiologist at St. Luke's Allentown who has worked for several years with a faux-integrated RIS/PACS. He had not heard the term "RIS" before because his worklist was accessible from directly within PACS. He is in his early fifties.

Dr. Clark is also a diagnostic radiologist at St. Luke's Allentown. He firmly believes in proper procedure, observing that some of his peers settle for indirect reporting of critical findings to third parties who then pass the news along to referring physicians. He is in his early thirties.

Dr. O'Leary is a diagnostic radiologist and supervisor at St. Luke's Bethlehem. He claims a top-down view of radiology workflow in his department, stating that radiologists work faster when they can see a large number of cases sitting in their worklists. He is in his mid forties.

Design disputes were settled

Participants desired a communication panel or zone based on familiar interaction metaphors. Omnipresent but subtle and non-intrusive, the panel would afford initiation and response to most kinds of communication. At the same time, participants preferred to keep real-time case sharing in the PACS. Moreover, this test saved us from moving in unwarranted new directions, for example, removing the worklist from view in favor of a playlist-style case display, or aggressively placing a communication pane center-stage rather than at the periphery of workflow.

We hit some stumbling blocks

Dr. Stigler was shocked when told he might need to wait an entire minute for a colleague to answer his audio call. Handling availability quickly climbed our to-do list. Also, several participants pointed to the lack of patient history access somewhere in the system and lack of patient identification information in PACS as critical stumbling blocks in all three prototypes. Closing PACS also perplexed patients, as their usual affordance was not provided here. We remedied these inconsistencies going forward.

We learned lessons by trying out-of-the-box ideas

While the worklist-as-playlist visualization was not immediately obvious to radiologists, who are used to a RIS database case view, Dr. O'Leary later affirmed, "The playlist is probably the most efficient way to work, in an orderly fashion. If you could predetermine the filters prior to the start of the day, you could run down the list very simply." The collapsible, embedded patient card and the Adobe collapsible worklist panels and icons showed a similar learning curve. Finally, despite less interest in following case progress with an activity feed, participants felt compelled by the inline one-off messaging in our message notification ticker. In the end, however, we saw a stronger need for threaded conversation.

What worked and what didn't?

Instant messages with attachments
Participants reacted positively to both the one-on-one mechanism and the paper-clip attachment icon. Additionally, participants liked seeing case details in the attachment thumbnail.

Bright red notification badge
Every participant found it immediately. One exclaimed, "Ooh, what is that? I want to click it!"

Thumbnails of key images
Participants liked key-image thumbnails, but because we eliminated their home—the patient card—these thumbnails did not return until we later introduced the draggable attachment wizard.

Case chat
Once again, participants consistently mistook case chat for a form of one-on-one communication. This gave rise to a new team motto—"Kill Case Chat!"

Dispersed communication tools
When we strategically dispersed our communication tools, participants became confused about how to contact colleagues. We found it important to gather communication components into logical groupings.

Expandable patient card embedded in the worklist
The reaction to the embedded patient card was lukewarm. Participants noticed but did not use it and felt our case abstracts were wrong or skimpy.

Full-screen, center-stage communication panel
Participants reacted to a full-screen panel with persistent confusion, working upward despite an intended downward flow. They disliked halting proceedings to recall or manually search for patient identification.

Face-to-face videoconferencing
We finally laid face-to-face videoconferencing to rest after continued ambivalence from radiologists. They felt audio let them get straight to the point, while video forced them to make time-consuming small talk. At the same time, we noted that some radiologists felt the rapport-building effect of video was useful in communicating with referring physicians.

ITERATION 3

Moving to a truly interactive prototype
Medium-fidelity interactive prototype

We built our previous iteration's most familiar-feeling prototype—Prototype A—in C# and WPF, evaluating newer design concepts with feature cards.

Our previous round of evaluation provided the feedback we needed to choose impactful design elements for our solution. After our change-averse participants consistently described prototype A as more familiar than the others, we decided to recreate it in C# and WPF, incorporating various standout features from the other prototypes. Other minor additions included tooltips. We also explored visual look and feel for the high fidelity prototypes to come.

Change-aversion influenced our design

Some of our users were adventurous, but many were change-averse. While users got used to new interface elements even during the course of a single test session, they initially found them difficult to use, so we decided that perceived familiarity should be a factor in our remaining prototype designs.

"I appreciate how my PACS administrators make sure that my interface stays the same between upgrades. I wouldn't want a huge change every time a new feature is added."

—Dr. Gupta

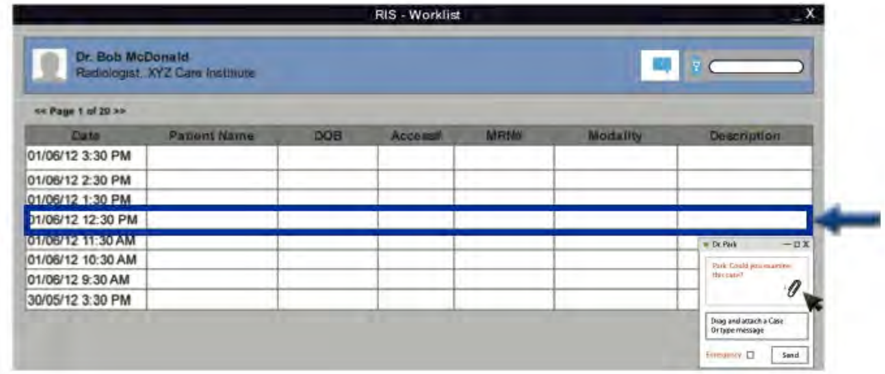
ITERATIVE DESIGN | Design

We evaluated newer concepts with feature cards

We also decided to evaluate other features that had been requested. For example, one participant had emphasized his desire to multitask away non-urgent communications while reviewing images. As one of our design goals was to provide notifications based on message priority, we tried to prioritize the traffic patterns and display of the notification inbox. We strove to design a priority system that was effective, easy for users to maintain, and accurate at requesting their urgent attention. This, along with other such designs, was validated using a combination of interviews and feature cards. Our feature cards consisted of wireframes of such features and we speed dated these cards with participants in retrospective interviews. From this brief activity, we learned which features participants might need and how they would use them.

We explored visual look and feel

At medium fidelity, we started exploring visual look and feel for the high fidelity prototypes to come. We collaged a mood board of visual elements in current, new, and future medical software, and this helped us to develop a new product that was visually appealing but still matched the current system's look and feel. It also helped us understand where our product would fit among existing offerings.

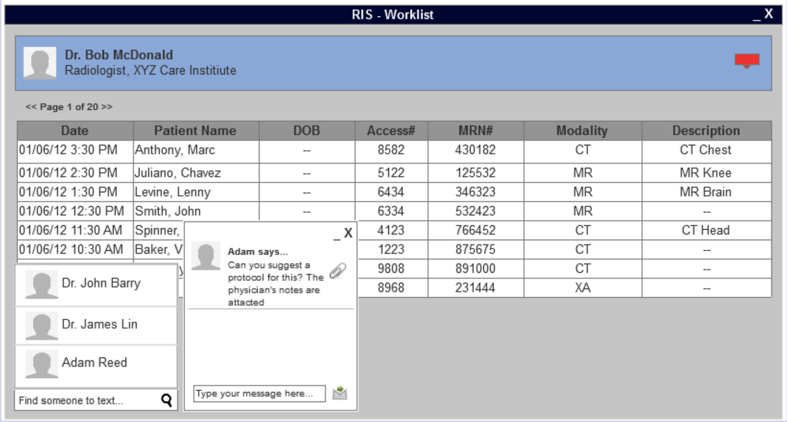


Feature card wireframes led to drag-and-drop attachment and revealed distaste for image sharing through the worklist

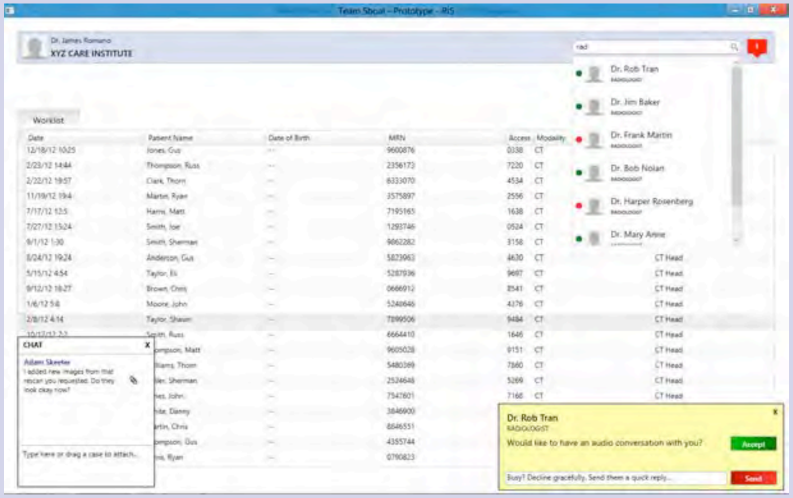
Our mood board explored look and feel

Our Interactive prototype

We built our next prototype based on design elements from Prototype A. However, we incorporated favorable concepts from other prototypes—for example, notification and People Search were consolidated into a single communication panel. On the PACS side, a blink notification feature was added to alert radiologists to worklist-side synchronous communication requests.



Prototype A



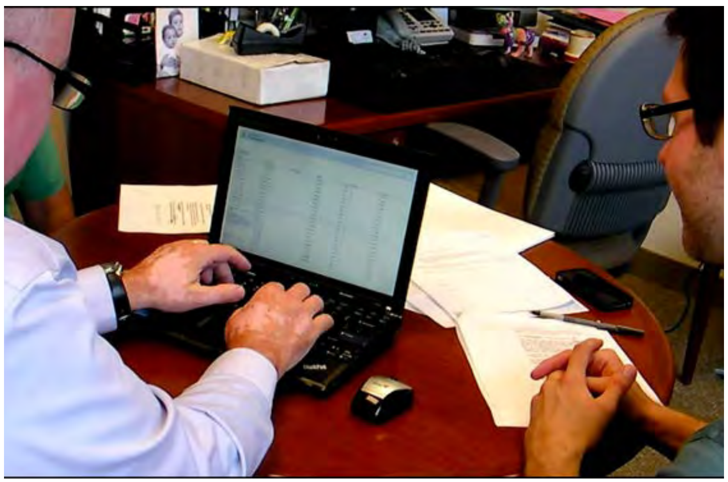
Interactive prototype

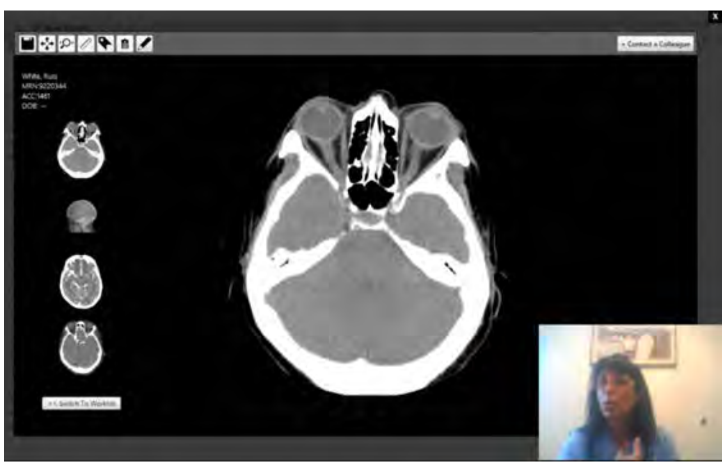
ITERATIVE DESIGN | Evaluation

We tested our first software prototype and saw great leaps of understanding with clear, actionable feedback suggesting small tweaks to a mostly successful solution.

We used:

- C#/WPF on Single Laptop
- Think Aloud Retrospective Interview
- Story Sharing Artifact Models





Meet the Participants

Dr. Rackow is a diagnostic radiologist and department head at Wellspan and the head of her department. She is frustrated by her radiologists' desire to cut corners, for example, by typing a period in a case description form field in order to avoid typing in general. She is in her mid forties.

Dr. Sharma is a diagnostic radiologist at Wellspan and has used five different RIS/PACS systems. He considers himself extremely tech-savvy. He punctuates completion of his Think Aloud tasks by exclaiming, "I bet nobody else got it right that fast!" He is in his early thirties.

Dr. Hudson is a diagnostic radiologist at Wellspan. He bears a quiet, unassuming demeanor and is in his late forties.

Dr. Murphy is a diagnostic radiologist at Wellspan and has very little prior RIS/PACS experience. Until recently, he hung x-rays in old-fashioned light boxes. He was anxious about testing with our prototype and was hesitant to try his hypotheses by clicking around. He is in his late fifties and highly change-averse.

Dr. Gardner is a diagnostic radiologist at Wellspan and was just coming onto the night shift when she tested with us. She is in her late thirties.

We narrowed scope with increased fidelity

After going wide in our previous iteration, we were now ready to focus our vision. We especially wanted feedback on the user experience of interacting with the system and on whether participants were able to detect the arrival of notifications without perceiving them as necessary interruptions. We also wanted to see if participants could distinguish between urgent and non-urgent communication attempts. Finally, we wanted to ascertain if participants could compare their experience of our prototype with analogous products.

The dawn of draggable case attachments

Every participant independently asked for the ability to attach more specific components of a case to an instant message, for example, key images. In our next set of retrospective interviews, we successfully tested a feature card depicting a drag-and-drop attachment wizard allowing attachment of specific components. This quickly became one of our most coveted features across participants.

By creating our task scenario in parallel with the final stages of C#/WPF prototyping, we were able to mold the prototype into the precise form it needed to take in order to support the specific tasks and interruptions we needed for testing purposes.

What worked and what didn't?

People search
Although People Search continued to receive a positive reaction, participants were unsure of what could and could not be typed. We considered redesigning People Search to show frequent contacts and depicted this possible addition in the next round as a feature card.

Message-waiting notification
Participants often failed to see new messages arrive. We considered fading in notification previews, especially for urgent notifications.

Hang up button in worklist
Participants were unable to find the hang up button in the worklist, and often left callers on the line. We considered unifying the look and feel of hang up buttons between the worklist and PACS.

Instant messages with attachment capabilities
Although soon to become a favorite feature with participants, instant messages with attachment capabilities started off shakily at this fidelity. Participants missed the paper clip icon altogether and had trouble attaching cases. We considered increasing the paper clip's size, showing identifying patient information as a tooltip, and implementing draggable cases in the worklist.

Single-screen system overlays
Participants found it difficult to switch between the worklist and PACS. This was not very similar to their everyday experience, resulting in frustration, for example, from closing cases simply to answer audio calls.

Flashing PACS backlight alerting user to urgent messages
Participants did not always see the flashing PACS backlight. We decided to increase its visibility.

Audio call ringtone
The ringtone received a negative reaction and was described as too abrasive. We searched for another, friendlier ringtone.

ITERATION 4

Refining our prototype

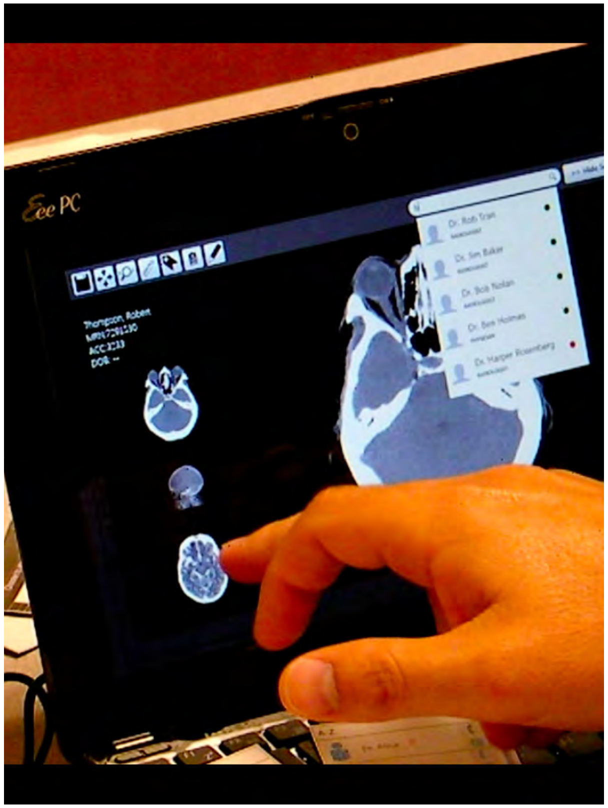
Medium-fidelity interactive prototype

As our final solution began to emerge, we added icons and other visual elements, locked down time-tested features, and evaluated newer ones by overlaying printed, interactive Axure wireframes.

In our fourth iteration, we aimed to lock down features so they could be safely implemented in high fidelity. Features such as conferencing were clear winners. Our messaging component, on the other hand, still needed attention in areas such as notification prioritization. We also needed to tweak our interruption mechanism so non-urgent notifications would only be shown when radiologists were not working on cases. In addition, we wanted to verify the usefulness of search types for department and role.

We overlaid Axure wireframes onto our medium-fidelity prototype

To avoid heavily investing in high-fidelity development and look-and-feel, we investigated solutions to design gaps and usability issues using special feature cards designed as paper cutouts. These cards wireframed only the interactions we wished to test. Our users played right along, making this method useful for us in evaluating new concepts at this late stage.



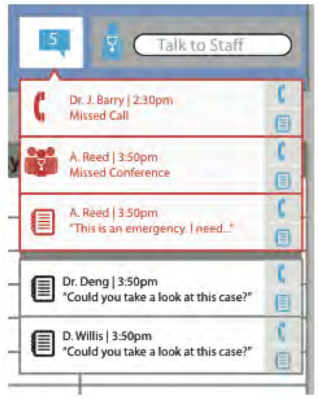
ITERATIVE DESIGN | Design

Feature cards elicited new reactions

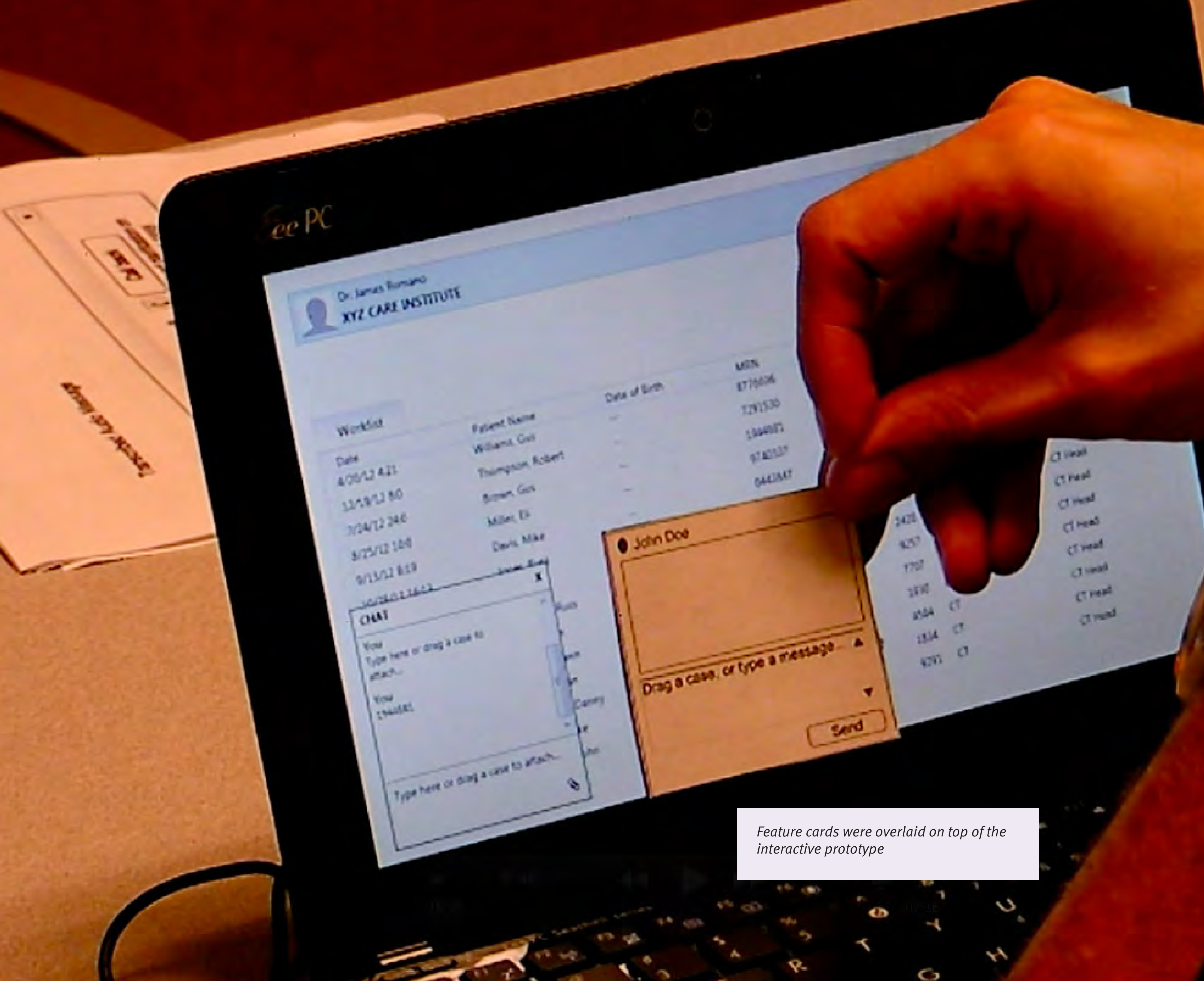
We continued to use regular feature cards in our retrospective interviews to elicit reactions to our prototype and reflections on how it compared with more familiar systems. At this stage, we cared less about whether participants would approve our ideas than that they would be inspired to share key information about their workflows, helping us to perfect our more heavily tested features.

We conducted a survey to pinpoint communication prioritization

Since one of our design goals was to help radiologists prioritize incoming communication, we designed an online survey to assess similarities and differences between their communication priorities. See Appendix E for our survey.



We continued to use feature cards to improve our most successful concepts, such as the prioritized notification panel



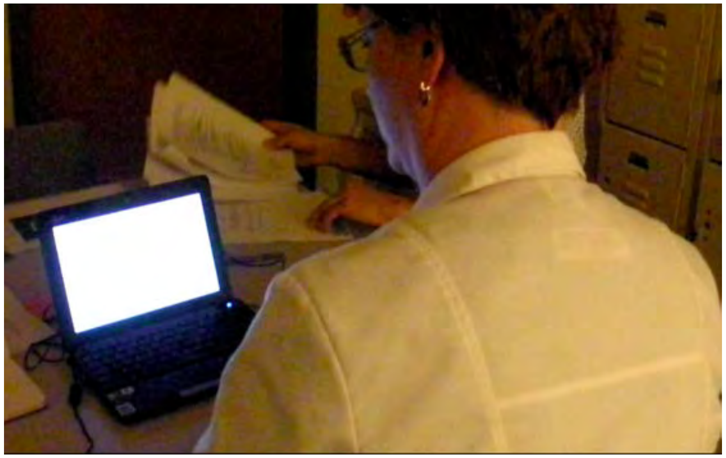
Feature cards were overlaid on top of the interactive prototype

ITERATIVE DESIGN | Evaluation

We attempted to cement time-tested favorite features while exploring new ones and established that radiologists, technologists, and referring physicians all want customizable versions of our solution.

We used:

- C#/WPF on Single Laptop
- Think Aloud Retrospective Interview
- Story Sharing Artifact Models



Meet the Participants

R — Dr. Bernstein is a diagnostic radiologist at St. Luke's Bethlehem. He works primarily on neuro cases and performs non-invasive procedures in this area an estimated 10-30% of the time. He reads 50-60 cases per day. He is in his mid forties.

R — Dr. Ford is a diagnostic radiologist at St. Luke's Bethlehem. He also works on neuro cases, performs non-invasive procedures around 10-30% of the time, and reads 50-60 cases per day. He is in his late thirties.

R — Dr. Truman is a diagnostic radiologist at St. Luke's Bethlehem. He is a generalist, handling around 100 assorted cases daily. He is in his early forties.

T — Janis is a coordinating technologist at St. Luke's Bethlehem. We originally spoke with her at length during our research phase. She schedules and monitors forty technologists on a daily basis. She gave us feedback from a tech perspective as well as roleplaying from a radiologist perspective. She is in her early forties.

We made new discoveries

Dr. Ford said, "I would love to be able to document conference calls automatically." He wanted to insert attempts to communicate with referring physicians into his report automatically with macros. He also wanted to document calls to hold others, e.g. technologists, accountable for their actions. But none of our participants wanted to document statements made during peer consultations for fear of legal implications.

We answered more design debates

Dr. Bernstein and Janis both agreed that radiologists do not need default lists like frequent contacts when attempting to contact a colleague through the system. Dr. Bernstein said, "We are small people. We know who we work with." But when looking for anyone in a particular department, role and department-based search was deemed essential. Some participants declined calls gracefully using the indicated text box and Send button, forcing those of us in favor of removing this feature to reconsider. We also received strong positive feedback for a drag-and-drop attachment wizard with a choice between attachment types: key images, the report impression, or the entire case. Finally, the complications of indicating multiple levels of urgency and the differences in types of urgency between providers again pointed toward the simple, effective solution of a binary urgent/not-urgent option for sending and receiving communications.

Our test revealed many technical glitches. In terms of design, one participant wanted to revisit a previously closed instant message, but could not. In technical terms, participants caused two notifications to load instead of one by double-clicking.

According to Janis, technologists' mobility means they would not be good candidates for the desktop solution we are developing. However, Janis thought technologists would benefit from a mobile instant messaging version of our solution.

ITERATION 5

Finalizing our designs

High-fidelity interactive prototype

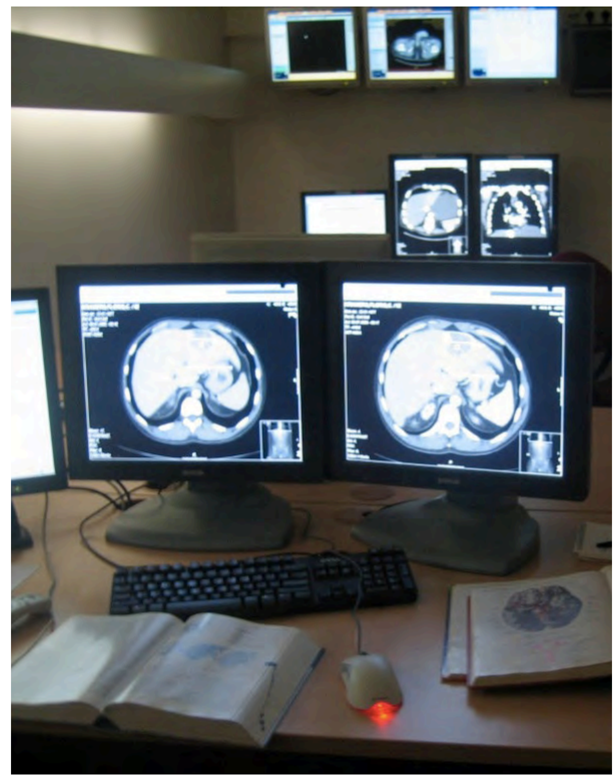
We incorporated feedback from all previous iterations into a new C#/WPF prototype designed for dual monitors.

Addressing close-to-final usability issues and scope concerns, we created our eighth prototype—based on Adobe Illustrator wireframe mockups—in C#/WPF. We finalized our prototype's feature list, recognizing that certain details still needed usability testing. We tested our prototype to ensure it would support radiologists' workflow and manage interruptions while seeming discoverable and accessible.

We designed for two monitors to help users multitask

We had initially chosen to design for a single-monitor system to account for the lowest common denominator: a laptop-friendly version of PACS such as GE's PACS-IW. However, we found radiologists struggling to multitask in this comparatively restricted environment. So, we designed our eighth prototype to work on a dual-monitor system.

After the promising results of our previous tests, we felt confident about the solution we presented to users at this stage.



We measured success with rapid desirability testing

Research conducted by Lindgaard et al [9] shows how the appeal of a website's visual interface can affect positive or negative feelings towards a product within 50 milliseconds of seeing it—less time than it takes to read a single word. Users who initially experience a negative reaction are more likely to find fault with an interaction regardless of actual usability and value.

For our fifth iteration, we chose to evaluate the user experience of our prototype with rapid desirability testing. Usually, such studies consist of users quickly viewing and reacting to interfaces. However, most radiologists are long-term product users. So, we waited until the end of each Think Aloud session to ask our participants for their slightly better informed opinions on desirability. We were thereby able to better assess their overall satisfaction with the experience.

We used two questionnaires to measure the desirability of our interface.

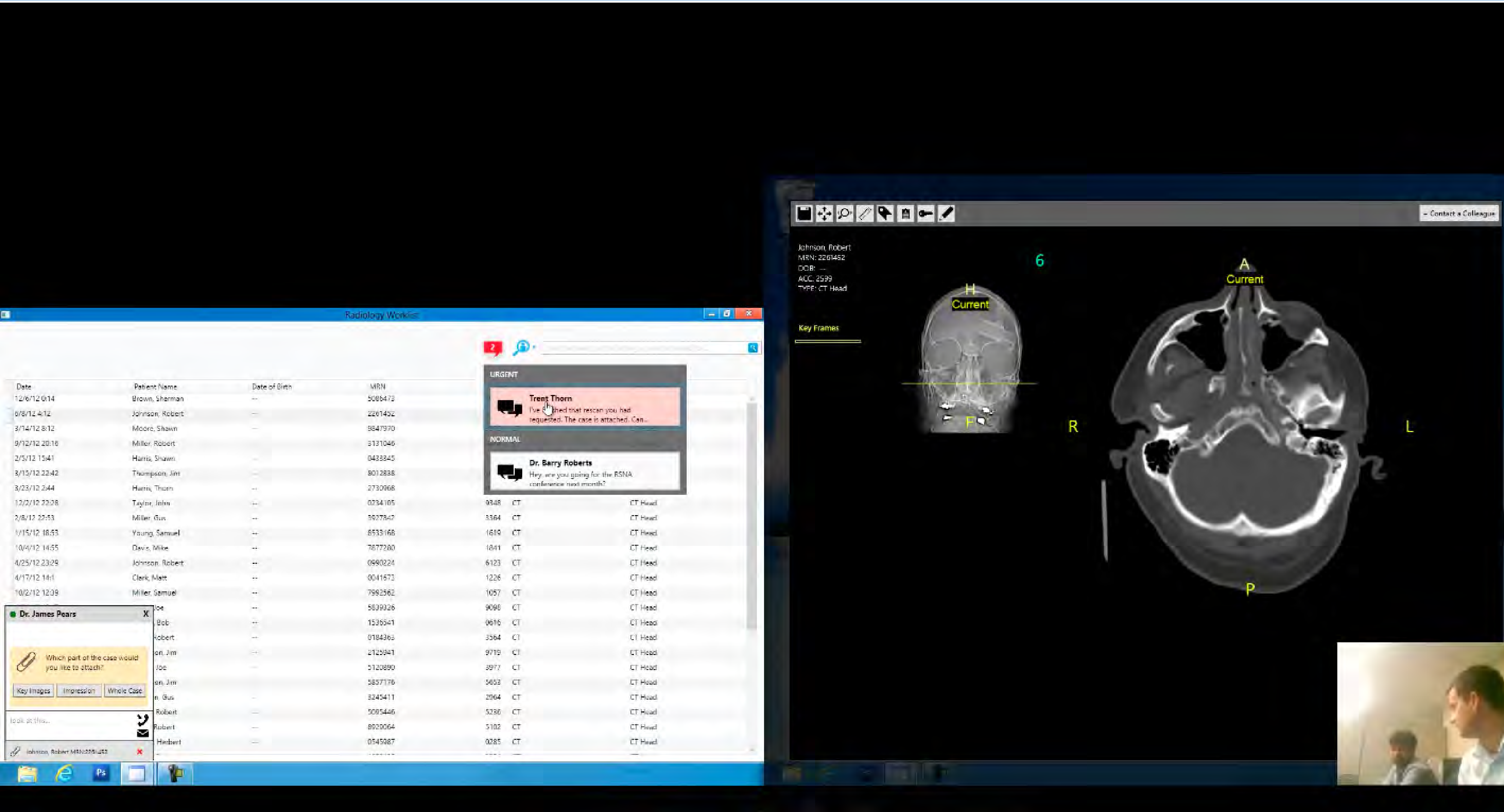
Product reaction questionnaire

Microsoft researchers developed Product Reaction Cards [10] to assess whether their product affected users as their findings indicated it should. Product Reaction Cards contain a variety of positive and negative adjectives from which users are asked to select the five that best describe the product.

Based on Product Reaction Cards, our modified Product Reaction Questionnaire omitted some of Microsoft's adjectives and added some from our research findings. A full list of the words we evaluated with can be found in Appendix E.

System usability scale

We also wanted to measure the user experience of our interface from a more holistic perspective. A 2004 study [11] showed that the simplest available questionnaire, known as the System Usability Scale (SUS), not only yielded the most reliable results but also was the most comprehensive in terms of overall user experience. Please see the SUS survey in Appendix E.

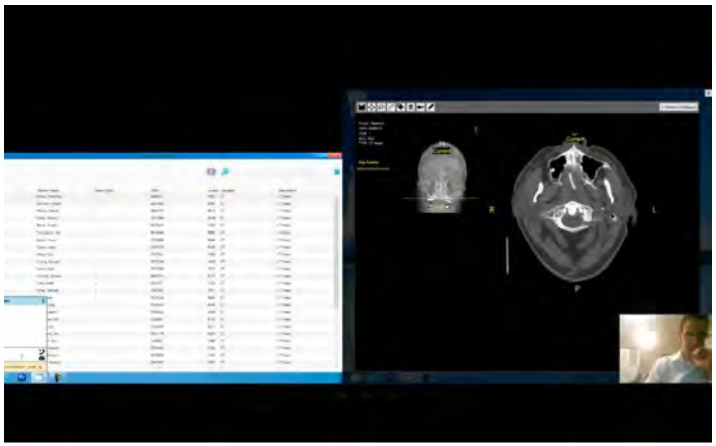


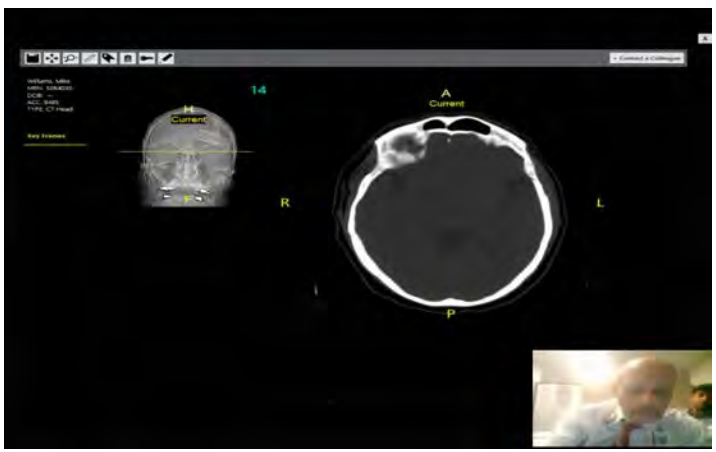
Prototype was tested in an environment similar to the radiologists' actual reading room

We tested our prototype at increased fidelity and asked participants to evaluate it. Participants described it as fast, efficient, convenient, time-saving, and easy-to-use.

We used:

- C#/WPF on Dual Monitors
- Think Aloud, Retrospective Interview, Usability Aspect Reports
- Story Sharing, Rapid Desirability Testing





Meet the Participants

Dr. Farnsworth is an attending radiologist and department head at UWMC. He completed our drag-and-drop tasks with remarkable ease and in unexpectedly ingenious ways, preferring to use asynchronous instant messaging almost exclusively to complete all tasks. He is in his mid fifties.

Dr. London is an attending radiologist at UWMC. He speaks eloquently of interaction issues in current radiology communication flow and has prototyped his own non-integrated system similar to our earlier patient timeline concept from speed dating. He is in his mid thirties..

Dr. al'Fatir is a resident at UWMC. He gushes about how efficient our prototype could make him. He is in his early thirties.

Derek is Director of Imaging I.T. at UWMC and spends many of his days finding new ways to implement GE's RIS/PACS to increase radiology efficiency. He is in his early fifties.

What worked and what didn't?

Entire interface
Participants raved about the usefulness of the interface. Dr. London said, "This is incredibly valuable." Dr. al'Fatir said, "Case attachment is a beautiful feature, because it is really useful. It's really painful to look for cases. And the text part was beautiful. Like, just texting them. I think it's a lot of nice stuff. I love it."

Case sharing
Case sharing was, as always, a hit with participants. Dr. London said, "It's absolutely outstanding. Not only for radiologists, but for clinicians in the ED and elsewhere."

Asynchronous messaging
Participants felt the integrated nature of messaging made it more appealing than other available asynchronous communication. Dr. al'Fatir said, "We have a pager, but it's not on your screen. You cannot attach. So, this is beautiful." When asked if asynchronous messaging should be detachable from the worklist or accessible elsewhere, Derek cautioned, "It would be more useful to have messaging integrated with the RIS." Also, one participant thought the envelope icon representing "Send Asynchronous Message" meant the message would be sent to the recipient's email inbox.

Case attachment
Case attachment and its wizard were applauded. Dr. al'Fatir said, "I think it's perfect. You don't have to look for the case." Dr. Farnsworth used the feature intuitively and extensively, actually believing it was already part of his current system—which is was not—commenting, "Drag and drop is pretty straightforward." However, one participant asked that the case indication be attached along with the impression for clarity's sake.

Priority
Participants were satisfied with the sufficiency of two levels of communication prioritization—urgent and non-urgent. Dr. al'Fatir told us, "Oh, yeah. This is nice, because you want to see which one to look at."

Radiologists found our prototype strongly desirable

From this test, we learned that despite lingering issues at the fringes of our scope, our prototype was highly desirable to the radiologists for whom we had designed it. In our Product Reaction Questionnaire, the top two adjectives our participants selected to describe our collaboration and communication tools were "efficient" and "time-saving." Runners-up were **"convenient," "easy-to-use," "fast," and "useful."** In addition, participants gave our system an average System Usability Scale (SUS) score of 91.25. (Across SUS tests, the top 10% of scores sit above 80.3, meaning that users of our solution are highly likely to recommend it to friends. [12])

Lack of Recent Communication Access
Participants continued a trend of forgetting the names of people to contact in our scenario tasks. While we attributed this to the distraction of testing a new interface, we felt that with their regular workflow distractions, it could be useful to give users access to recent communication within the messaging inbox and/or people search.

Opaque border around case continues to confuse
Participants did not understand the reason for the opaque border around a case. This opaque border was a vestige of an earlier prototype which tested real-time image conferencing as a closed session, and should not be implemented in a developed version of our solution.

Flashing PACS message notification
Participants continued to feel that the notification flash in PACS was not noticeable enough. They asked for it to be slower and more distinctive, particularly should their sound ever be disabled, when noticing the flash would be the only way for participants to respond to an urgent call.

RECOMMENDATION

Conferencing and integration have high value

Participants consistently and emphatically desired our conferencing tool, stating that it could change their entire workflow overnight. We found that its direct integration with PACS made it easier to use and fit the way radiologists currently read cases. As with many of our features, we believe that the simplicity of the conferencing tool adds to its value. The tool is intentionally restricted to highlighting and cursor sharing features because radiologists saw it as a briefing tool and expressed concern over the professional and legal implications of collaboratively annotating images. Based on both the strong positive reaction this tool generated and the multiple rounds of evaluation that it endured, we feel confident about its value and maturity.

Integration differentiates Synaptic's asynchronous messaging from other offerings

Constant phone interruptions were the first thing we noticed in the field. They plagued almost every reading room we visited, so it was no surprise that radiologists often requested the ability to exchange asynchronous messages. However, the true value of our asynchronous messaging tool lies in its integration with our other tools in a cohesive RIS/PACS communication ecosystem. This true integration differentiates our product from other enterprise messaging offerings and lays the groundwork for GE to provide a more effective workflow solution, facilitating case-centric conversations, simple case attachment interactions, and availability indication directly linked to current work status. Radiologists saw great potential here for eliminating notification-related phone calls and prioritizing incoming communications.

Drag and drop is intuitive

Our case drag and drop attachment feature consistently tested well with participants, particularly once we answered their request for the ability to attach specific case components: key images or the report impression. Radiologists found this feature simple, effective, and generally intuitive. When case components are attached, the receiver temporarily opens them over his worklist without obscuring cases currently open in PACS. However, despite positive feedback, we see scope for future work in this area.

People Search is desirable—role-based search, too

Radiologists strongly desired our people search tool and preferred the one-on-one communication it would afford to group conversation within specific cases. This tool is designed for in-hospital networks and was useful for participants who often spent time searching for colleagues on premises. Most radiologists were content with being able to search for people by name, but technologists asked for role-based search.

Notification Badge and combination of alerts are effective

Changing the color of the notification badge was extremely effective in making radiologists aware of incoming communications. In addition, a combination of sound alerts and pop-ups were also effective for urgent communications.

Two priority levels suffice but could be further customized

Through trial and error, we found that two priority levels—urgent and Non-urgent—were enough to satisfy most radiologists' needs. We designed the sender side so that urgency can be indicated for each individual message. Here, we found the greatest potential for urgent cases arriving from the ED or the OR. We also feel that in the future, radiologists and their I.T. support staff should be given the ability to define custom priority levels and rules.

Mobile extensions would be desirable

Although mobility of radiologists was one of our findings, we prioritized a desktop solution over a mobile version. However, we feel that parts of our solution—for example, people search, notification, and asynchronous messaging—would easily extend to a mobile version designed for radiologists away from their desks. Again, radiologists frequently move between different hospital sites and shifts, logging into multiple workstations every week or even every day. Establishing RIS/PACS as the radiologist's point of contact ensures he is reachable wherever he logs in. We believe that a mobile RIS/PACS solution will play a strong role in radiologists' future workflow, and therefore that an integrated communication interface would take advantage of that solution.

One technologist suggested that a mobile version would be more useful to technologists than a desktop version because technologists need to remain available while frequently away from their desks.

Aside: Participants occasionally expressed doubts about a mobile solution. For example, one radiologist said that she would rather not be available for communication when away from her desk. However, others liked to stay on top of their communications even when not at work.

Liaisons could benefit from messaging

Although our solution does not currently support communication between radiologists and the referring physicians who are outside of their RIS/PACS networks, it does support communication between radiologists and RIS/PACS-enabled liaisons who help them to get hold of referring physicians. Currently, radiologists and their liaisons discuss incoming and outgoing communications using handwritten Post-it notes, in-person interruptions, and even phone calls. The asynchronous features of our solution, along with added call-forwarding functionality, could represent major improvements in efficiency between radiologists and their liaisons.

One final wish for GE

Throughout our research and evaluation, we were consistently asked to provide better access to patient data in radiology systems. We watched radiologists log into multiple systems per case to search for patient data. The time and productivity overhead was significant. More importantly, radiologists worried that improperly integrated patient data was dangerous and shared anecdotes of near-lethal incidents. When we asked testing participants to look at a case or study, the first thing they asked for was patient data. Repeatedly, they asked us to prioritize patient data over other information, including communication information.

During our exploration phase, we developed a vision called the Patient Timeline. This vision was our attempt to visualize integrated patient data from multiple systems into a single, familiar-feeling dashboard. Not only did radiologists respond strongly to this idea, but they also expressed frustration at how much time they usually spent collecting this information. Simply having one login for all these systems would have a strong impact. Deeper integration would have a significant, positive impact on radiologists' workflow, diagnostic accuracy, and overall satisfaction. We recognized that our research was not sufficiently attuned to this need, so we were unable to pursue this vision. However, we encourage GE Healthcare to consider this topic for future research, both internally and with future MHCI Capstone Projects.

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Synaptic

CONCLUSION

ABOUT THE HCII

OVERVIEW

The Carnegie Mellon Human-Computer Interaction Institute is an interdisciplinary community of students and faculty dedicated to research and education in topics related to computer technology in support of human activity and society. The Masters program is a rigorous 12-month curriculum in which students complete coursework in programming, design, psychology, HCI methods, and electives that allow them to personalize their educational experience. During their second and third semesters, the students participate in a substantial Capstone Project with an industry sponsor.

The Capstone Project course curriculum is structured to cover the end-to-end process of a research and development product cycle, while working closely with an industry sponsor on new ideas that may work with their existing human-to-machine technology. The goal of this 32-week course is to give each student the opportunity for a "real-life" industry project, similar to an actual experience in a research/design/development setting.

Company sponsors benefit from the innovative ideas produced by the students, to fix existing systems or reach into new markets. Some companies also use this project as a recruiting tool, offering industry positions to the top producers in their project team.

For questions about the content, or to learn how to sponsor a project please contact:

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WellSpan York Hospital

APPENDIX

On Disc:

A. Design specifications
B. Exploration ideas and sketches
C. Prototypes and wireframes
D. Report and presentations
E. Evaluation results

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