



# UX Re-Design of an Image Management System in Healthcare

Josefin Andersson

DEPARTMENT OF DESIGN SCIENCES  
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MASTER THESIS



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**LUND**  
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Department of Design Sciences  
Faculty of Engineering LTH, Lund University  
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Interaction Design (MAMM01)  
Supervisor at Lund's University, Faculty of Engineering: Günter Alce  
Supervisor at Bildteknik: Oscar Hallbäck  
Examiner at Lund's University, Faculty of Engineering: Kirsten Rasmus-Gröhn

# Abstract

As incidences of chronic diseases increase, the tools to diagnose, treat and monitor such conditions become more important. Medical imaging technologies, being one of these tools, still face challenges in safe and effective use. At the same time, poor design of medical devices causes errors that could be avoided using proper design methods.

The master thesis is written in collaboration with Bildtechnik, a medical image engineering company that provides hospitals internationally with an image management system, InVision. The scope of the thesis was to redesign InVision using User Experience design principles. The aim was to improve InVision's current functionality and user interface and to examine whether there are additional needs for specific labs that treat heart conditions regarding streamlining, increasing quality of work and reducing unnecessary work created by surrounding systems that could be incorporated into InVision.

An iterative interaction design process was used with a user experience perspective. Primary user needs, behaviours, and current issues with InVision were found by using data gathering methods such as interviews and observations. Ideation was used to render solutions to the issues found during the data gathering. Four iterations of prototypes were created, of which one high fidelity prototype.

Changes to the design were made to support the users' workflow by for example providing more relevant information before, during and after an examination. This helps the users with prioritizing patients, planning and documenting examinations as well as finding specific examinations.

Usability tests were performed with 12 participants which showed that the final prototype was easy to use, with best imaginable usability and good functionality. Points of improvement was also found that can be developed in future work.

**Keywords:** User experience, eHealth, Medical Imaging Technologies, Interaction Design, PCI labs, DICOM, PACS, SCAAR

# Sammanfattning

I takt med att förekomsten av kroniska sjukdomar ökar blir verktyg för att diagnostisera, behandla och övervaka sådana tillstånd viktigare. Medicinsk bildteknik, som är ett av dessa verktyg, står fortfarande inför utmaningar när det gäller säker och effektiv användning. Samtidigt orsakar undermålig design av medicinteknik fel som kan undvikas med rätt designmetoder.

Examensarbetet är skrivet i samarbete med Bildteknik, ett företag inom medicinsk bildteknik, som förser sjukhus internationellt med ett bildhanteringssystem, InVision. Examensarbetets omfattning var att omdesigna InVision med hjälp av designprinciper enligt User Experience. Målet var att förbättra InVisions nuvarande funktionalitet samt användargränssnitt och att undersöka om det finns ytterligare behov hos specifika laboratorier som behandlar hjärtsjukdomar avseende effektivisering, ökad kvalitet på arbetet och minskning av onödigt arbete som skapas av omgivande system som kan integreras i InVision.

En iterativ interaktionsdesignprocess har använts med ett User Experience-perspektiv. Primära användares behov, beteenden och aktuella problem med InVision hittades med hjälp av metoder för datainsamling, som intervjuer och observationer. Idégenerering användes för att komma fram till lösningar på de problem som hittades under datainsamlingen. Fyra iterationer av prototyper skapades, varav en high fidelity-prototyp.

Ändringar av designen gjordes för att stödja användarnas arbetsflöde genom att till exempel ge mer relevant information före, under och efter en undersökning. Detta hjälper användarna att prioritera patienter, planera och dokumentera undersökningar samt hitta specifika undersökningar.

Användbarhetstester utfördes med 12 deltagare som visade att den slutliga prototypen var enkel att använda, med bästa tänkbara användbarhet och bra funktionalitet. Det fanns också förbättringspunkter som kan utvecklas i framtida arbete.

**Nyckelord:** Användarupplevelse, eHälsa, medicinsk bildteknik, interaktionsdesign, PCI-laboratorier, DICOM, PACS, SCAAR

# Acknowledgments

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I would also like to thank Bildteknik, especially my supervisor Oscar Hallbäck and the managing director Mikael Paulsson for the involvement throughout my work and the level of trust shown in me. They have identified the best conditions to enable my work and generously given them to me.

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# List of acronyms and abbreviations

COVID-19	Coronavirus disease 2019
DICOM	Digital Imaging and Communications in Medicine
e-GFR	estimated Glomerular Filtration Rate
FFR	Fractional Flow Reserve
hi-fi	High fidelity
IFR	Instantaneous wave-Free Ratio
IVUS	IntraVascular Ultra Sound
KIC	Cardiovascular Intervention Centre
lo-fi	Low fidelity
NIRS	Near-Infrared Spectroscopy
OCT	Optical Coherence Tomography
PACS	Picture Archiving and Communication System
PCI	Percutaneous Coronary Intervention
SCAAR	Swedish Coronary Angiography and Angioplasty Registry
SUS	System Usability Scale
SÖS	Södersjukhuset
UI	User interface
UX	User experience

# 1 Introduction

*This chapter aims to give the reader a context of the thesis subject. A background is given of the challenges and possibilities of digitalization of healthcare, specifically in imaging technologies and design. Then an introduction to the company Bildtechnik is given and the scope, delimitations and related works are presented.*

## 1.1 Background

Digitalisation of health services has had a profound impact on healthcare according to the Expert Panel On Effective Ways Of Investing In Health and is expected to have an even heavier impact on healthcare in the future, where medical imaging is a part of this digitalisation [1].

Chronic diseases such as cancer and cardiovascular disease has had an increase in incidences, which has led to an increase in affliction and healthcare costs. Lowering the numbers of deaths due to chronic diseases is one of the subgoals of the UN 2030 Agenda for Sustainable Development 17 goals [2].

One possible key in succeeding with this goal is through medical imaging technologies which enable doctors to detect and diagnose such chronic diseases. This saves millions of lives each year and enables earlier diagnoses which reduce overall healthcare costs [3,4]. The economic interest in medical imaging is shown in a growing market, as the global medical imaging market size was estimated at USD 33.69 billion in 2019 and projected to reach USD 43.33 billion by 2027 [3].

However, there are still challenges to digital medical imaging. There is a need to establish digital viewing of images in diagnostic quality, protection of patient data, reduction of errors when creating filmless radiology departments and upholding evidence-based medicine at the same time as providing personalised medicine tailored to the history of an individual patient [5]. Another challenge is the increase in psychological stress induced by healthcare information technology for healthcare professionals [6].

The World Health Organization [7] describes how poor design of medical devices in combination with constricted time and capacity of healthcare professionals lead to medical device errors, potentially causing harm to patients. According to the American Food and Drug Administration (FDA) 9% of medical device errors are directly related to use error. Experts mean that the approach of reducing such errors is to consider everyday use by healthcare professionals and making the products easier to use.

By using principles of user experience (UX) design, systems can be designed to become more usable, enable greater productivity, create a more positive user experience, and avoid harm from use [8].

The company Bildtechnik had prior to this thesis received complaints about their medical image management system InVision. Some users considered InVision to have a poor user interface (UI) and brought up wishes to make InVision better fit in with their workflow. InVision was a finished product but never developed by design methods which is why Bildtechnik brought up the need for a UX redesign.

## 1.2 Bildtechnik

Bildtechnik is a medical image engineering company in Lund that integrates medical imaging, sound, video and patient surveillance to simplify high-quality image management in hospitals [9]. Their solutions work with any brand or model of medical imaging systems or other signal sources. In addition, they are connected to various hospital IT systems such as image storage, picture archiving and communication systems (PACS), electronic health records, radiology and hospital information systems. The company is ISO-13485 certified with TÜV SÜD as notified body.

Bildtechnik's most sold product is InVision, the system that this thesis is based on. InVision is described further in chapter 3.3 *InVision*.

## 1.3 Scope

This thesis describes the prototype development of the InVision user interface according to the interaction design principles and process described by Preece et al [10] with a UX perspective, using both qualitative and quantitative data. The aim of this study was to integrate the design of InVision into the operating procedures of healthcare professionals, just as Bildtechnik previously has integrated InVision with the hospitals IT-systems and imaging systems. The users included was health care professionals at Percutaneous Coronary Intervention (PCI) labs, where blocked coronary arteries are opened up.

### 1.3.1 Research questions

- What flaws do healthcare professionals experience with InVision today and how can these be improved?
- What additional needs do healthcare professionals in PCI labs have that can be integrated into InVision, for example to reduce technology stress, streamline or increase the quality of work?
- What functionalities in InVision are not desirable?
- How can InVision be redesigned to help users avoid unnecessary work by exploring other systems that to some extent overlap with InVision in PCI labs?

## 1.4 Delimitations

This study has been delimited to focus on UX design and has not fully considered other fundamental parts of the development process of medical devices at Bildteknik. The development in this study is partly limited by what is technically possible to achieve but not to how the system is constructed technically today. This study has not considered in full extent what is needed to meet the Medical Device Regulation.

Even though Bildteknik has customers worldwide, the study is limited to Swedish users [11]. Both primary and secondary users have been included but the focus has been on the primary users. Further on, InVision consists of multiple modules but only parts of the entire system have been implemented, being the worklist part of *InVision Control* and *InVision Viewer*. The worklist part of *InVision Control* is where the physicians list and choose the patients to be examined. *InVision Viewer* is the module where patient examinations can be searched for and viewed.

## 1.5 Related works

There have been many research studies regarding UX design since Donald Norman first coined the term in 1995. Although work in the field dates further back in ergonomics with for example Hippocrates providing a description of an optimal surgeon's workplace in ancient Greece [12]. Hippocrates may not have mentioned medical image management systems and there seems to be little to no research on specifically this matter combining UX redesign.

Some reports have been made regarding technology stress at hospitals. Calif et al [6] writes about technology stress of healthcare professionals, where healthcare professionals are reporting psychological stress induced by healthcare information technology. They divide the term technology stress into two parts, the positive techno-eustress and the negative techno-distress. The second research question in this thesis regards techno-distress.

Drummond et al [13] writes about the complexity of existing healthcare structures. They found that the change in one hospital might not provide the same benefit for the same change in another hospital. From this it is clearly important to work with multiple hospitals when discovering the workflow and testing prototypes.

## 2 Design theory

*In this chapter some design theory is presented to give the reader necessary background information. As described above, this thesis is based on the interaction design process described by Preece et al [10] with a user experience perspective.*

### 2.1 User experience design

The international standard on Ergonomics of human-system interaction, ISO 9241-110:2020, defines user experience as a “combination of user’s perceptions and responses that result from the use and/or anticipated use of a system, product or service”. The user experience will be a result of three interacting factors: the user, the system and the context of use.

The user will perceive and response to a system before, while, and after using it. Factors that include the perception and responses are emotions, preferences, comfort, and behaviors. For example, if the user is in a stressed and uncomfortable situation, they might respond to situations in a less thought through way than if they had been in a calmer setting. The user’s psychological and physical state will affect the user experience, like prior experiences, attitudes, skills, abilities, personality, and the context of use. The brand image, presentation, functionality, system performance, interactive behavior, and assistive capabilities of a system will also influence the user experience.

Human-centred design of a system can only handle the parts of user experience that result from the design elements of a system, one cannot design a user experience only *for a* user experience [8].

Preece et al [10] describe how interaction design is usually used as an umbrella term for describing the field of designing interactive products to support the way people interact in their everyday lives, including its methods and theories. Furthermore, UX is more widely used in industry to refer to the profession. However, the terms can be used interchangeably. In this thesis the term UX was used.

UX design is the entire process of designing products that provide meaningful and relevant experiences to users. This include user research, specifying user requirements and designing prototypes that are later evaluated in user tests [14]. The UX design process of this thesis is further described in chapter 4 *Design process overview*.

## 2.2 Normans design principles

When users interact with a new design, they will need to discover how it works, what it does and what operations are possible. Since cognition and emotions are tightly intertwined, the user is likely to have a negative experience of the interaction if the design is hard to discover. Norman offers six psychological concepts that together make up the discoverability of a design: *affordance*, *signifiers*, *constraints*, *mapping*, *feedback* and the *conceptual model* of the system [15]. All these concepts were used in this thesis.

### 2.2.1 Affordance and signifiers

Affordance describes the relationship between the properties of an object and the capabilities of the object's user. The affordance determines how the user can use the object, for example a chair affords support and therefore sitting. Some chairs are too heavy for children to lift and does therefore not afford lifting for children. The prevention of a big chair to be lifted by a child can be considered as anti-affordance.

If affordance can be perceived, they are often described as essentially learned conventions [10]. However, if the affordance or anti-affordance of an object cannot be perceived a signalling of its presence might be required, referring to signifiers. Signifiers communicate what actions are possible and how they should be done. For example, glass affords seeing through but anti-affords passing through, meaning that birds might fly into glass without any signifiers, see figure 2.1 [15].



**Figure 2.1** Hawks painted on the glass to scare birds off and prevents them from flying into the glass, which also works as a signifier for people to communicate that there is glass there [16].



### 2.2.2 Mapping and feedback

Mapping describes the relationship between objects and is an important concept when designing controls and displays. For example, if there are many light switches in a room, the mapping of the switches to lights specifies which switch controls which light. *Natural mapping* can be achieved when using spatial analogies, which will lead to immediate understanding. Many mappings are specific to particular cultures [15].

Feedback describes how the result of an action is communicated. This allows the user to know that the system is working on the user's request. Feedback must be immediate to not annoy the user and informative to be useful. The designer must also be careful to provide enough but not too much feedback as this too can be annoying to the user and the user might choose to ignore all of them [15].

### 2.2.3 Constraints

There are four types of constraints: *physical*, *cultural*, *semantic*, and *logical*. *Physical constraints* limit possible actions and are most effective and useful if they are easy to see and interpret.

*Cultural constraints* refer to what is socially acceptable actions and naturally differ between cultures. For example, most people know how to behave in a restaurant of their own culture even though they have never visited it before. However, they might notice how the same behaviour is frowned upon in a restaurant of a different culture. As culture change, cultural constraints might change with time.

*Semantic constraints* refer to constraints that rely on the meaning of the situation, meaning that the user needs to deal with the environment to interpret the possible actions of an object.

The previously mentioned natural mapping stem from *logical constraints*. Logical constraints do not work upon physical or cultural principles, but on logical relationships between the spatial or functional properties of components the user interacts with and how these components are affected or affect other components [15].

### 2.2.4 Conceptual models

Conceptual models refer to the user's explanation of how something works. The conceptual model is usually highly simplified and does not have to be complete or even correct to be useful. The folders in your computer are an example of an effective conceptual model that is not correct, as there are in fact no folders in your computer. There are often different conceptual models for the same object, as users' understanding and experience might differ, as well as conceptual models they have gotten from other people. Conceptual models can also be created and reinforced by the previously mentioned principles: *affordance*, *signifiers*, *mapping*, *feedback*, and *constraints* [15].

## 2.3 Visual hierarchy

Hierarchy is used to organize from most to least important as well as showing a relationship between blocks of content. Humans process information visually, meaning what first grabs the attention of the users' eye has the highest hierarchy. Each element that then grabs the users' attention is in subordinate hierarchy to the previous. In design, content can be organized in ways to give important elements the highest hierarchy to easily make sense of a design. Important elements can be elements we know the users want or elements of what we want the users to do [17].

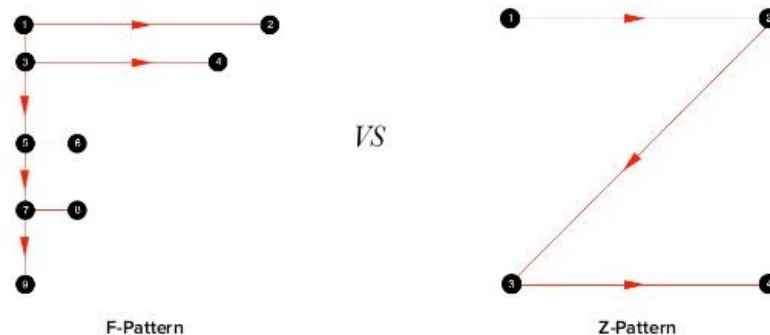
There are several tools to create visual hierarchy. Size can be used as a hierarchy tool as bigger objects demand more attention. Using bold and contrasting colours will demand attention but colour can also be used as a hierarchy tool to create relationships and classes of elements within a hierarchy. Alignment creates order between elements and can simply be used as creating a sidebar column. Alignment can also create more complex hierarchical roles as users expect to find certain elements in specific places in digital systems. Repetition can be used to assign relative meaning to objects. An example of repetition is if links are blue and paragraph text is grey, when encountering blue text, the user can safely assume it is a link. Proximity can create sub hierarchies and associate similar content, by putting objects closer together. Whitespace on the other hand will do the opposite, by including whitespace around an object it will be singled out and separated. Texture and style can be used to draw the eye while setting the theme [18].

### 2.3.1 Hierarchy patterns

Hierarchy patterns are based on movements the eye tend to make when presented a new page. There are two main hierarchy patterns in the western world, the F pattern, and the Z pattern, see figure 2.2. Both the Z and F pattern can be used in the same design on different pages [17]. In parts of the world where text is read from the right the patterns differ but whereas this thesis is based on Swedish users they are not included.

The Z pattern is commonly used in designs that do not contain much text. The eye starts to scan the upper part of the screen from the left and then diagonally down to finish with the lower part of the screen from the right, see figure 2.2.

Contrary, the F pattern is commonly used in design with more text or video content. The eye starts at the top of the screen from the left to the right and then scanning down for clues to what we are searching for. When finding such visual clue, the eyes will scan from left to right and this will continue until reaching the end of the page, see figure 2.2.



**Figure 2.2** Here two common page scanning patterns are shown, to the left is the F-pattern and to the right is the Z-pattern [19].

## 2.4 Typography and colour theory

Typography is the technique of arranging type and its most important function is to make a text readable and easy to navigate in. By using for example different letter size, character spacing, and colour important parts of texts can be brought forward and gives text a structure [20,21].

To increase readability on computer screens sans serif fonts should be used and simple fonts should be used [21]. The Swedish Association of the Visually Impaired (SRF) has compiled guidelines that makes text readable for more people. Text should be no smaller than 12-14 p and italic text should be avoided as it decreases readability. Colour wise, the contrast between the text and the background should be high [22].

Colour theory is a collection of rules and guidelines referring to the use of a colour wheel, knowledge of human optical abilities, psychology, culture and more. Designers can use colour theory to optimize the usability and the user experience through appealing colour schemes. Contrast can be used to catch the users' attention. Different colours can be incorporated to invoke associations that differ in different cultures, for example red signals good fortune in China but mourning in South Africa [23].

## 2.5 Data gathering

Data gathering is a central part of discovering the requirements of users and evaluating prototypes or systems. Data gathering for discovering user requirements should be conducted to collect sufficient, accurate and relevant data. Gathering data during evaluation should include capturing user's reactions and performance with the design [10]. Interviews, observations, and forms have been used in this thesis.

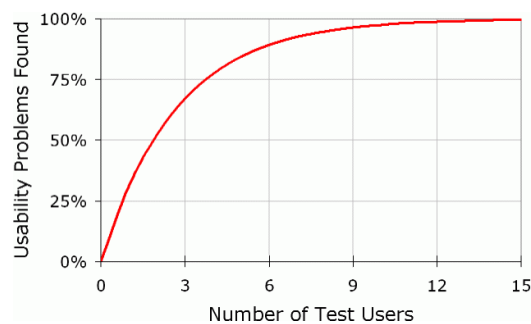
### 2.5.1 Triangulation

Multiple techniques to gather data is often used to attain different perspectives. Apart from using different techniques, triangulation can be achieved by drawing data from different times, places, and people [10]. In this thesis interviews were used to target specific user groups, observations were used to understand the context of the activity and a questionnaire was used to attain the users opinion anonymously during the testing of the final prototype. Triangulation is also useful to make up for drawbacks of individual data gathering techniques [10]. For example, interviews might give more insight about what the users say they do rather than what they actually do. Also, the human mind tends to compensate for its imperfect memory by unconsciously creating details, making it less objective. To compensate for these two drawbacks observations can be used to see first-hand how the user behaves [24].

### 2.5.2 Usability testing

Usability testing is used to test how easy a design is to use for representative users. By observing the use of a design, highly relevant and contextual information can be gathered to avoid flaws and get a vital insight in how well the deign works. To assess the users' behaviour both quantitative and qualitative metrics can be gathered. Some examples of quantitative metrics are time the user takes on a task, success and failure rates and effort. Qualitative metrics are for example users' stress responses, subjective satisfaction and perceived level of effort or difficulty [25].

Depending on the complexity of the design the number of required test sessions can vary. Nielsen [26] writes that the best results, resource wise, comes from testing on only five users but around 15 users are needed to uncover all usability problems. However, there are more ways to increasing the chances of finding usability problems. For example by including users with low digital skills and asking participants to do more tasks [27].



**Figure 2.3** Research has shown that usability problems found in a usability test follows the curve in the figure [26].

### 2.5.3 System usability scale

The System Usability Scale (SUS) is used to assess perceived usability of a system. To evaluate a system using the SUS, a questionnaire is given to a respondent that has recently tested the system. The questionnaire contains ten statements of how the user perceived the system regarding for example the usability and learnability. The statements are scored by a five point Likert scale, ranging from *Strongly disagree* (one) to *Strongly agree* (five) [28].

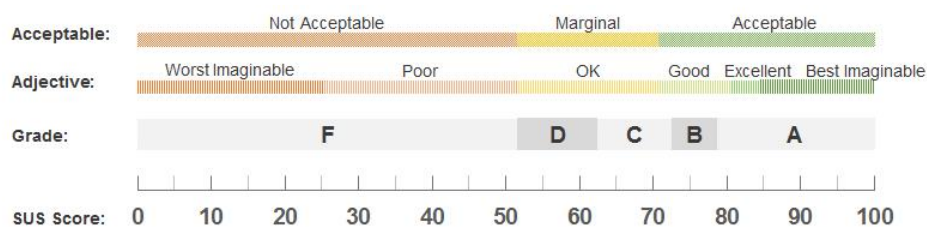
Note that the SUS only assesses the perceived usability and not objective usability. Users are prone to bias when rating their own usability experience and there is usually a difference between how well a user think they did and how well they actually did [29].

### 2.5.4 System usability score

A SUS score can be calculated from the respondents' scoring of the statements. This score will represent a measure of overall usability of the system.

The SUS score is determined by first calculating the score contribution from each statement. For statement one, three, five, seven and nine the score contribution is the respondents scoring minus one. For statement two, four, six, eight and ten the score contribution is five minus the respondents scoring. This means that the score contribution from each statement will range between zero and four. Then, the sum of the ten score contributions is calculated and multiplied by 2,5 which gives the SUS score [28].

The SUS score ranges from 0 to 100 where an average SUS score is considered to be 68. To simplify the interpretation of SUS score different scales have been created. Three examples are by acceptability, adjectives and letter school grading, see figure 2.4 [30].



**Figure 2.4** The SUS score scale together with three interpretations in relation to one another. The three interpretations are by acceptability, adjectives and by letter school grading [30].

## 3 Technical theory

*In this chapter a medical background is given to understand the process of this thesis. A broad explanation of medical imaging is given, then a description of PCI labs to yield a basic understanding of the work environment. Lastly, the InVision system is introduced.*

### 3.1 Medical imaging

Medical imaging refers to different imaging modalities, processes, and techniques to create images of the human body. These images are used for the purpose of diagnosing, treating, and monitoring medical conditions. A multidisciplinary team is required for an appropriate use of medical imaging. Such teams can include radiologists, medical physicists, nurses and biomedical engineers [31,32]. Some examples of medical imaging technologies and techniques are X-ray, magnetic resonance imaging (MRI), nuclear medicine imaging and ultrasound, see figure 3.1 [33].

All medical images must follow certain rules of for example digital image format, file structure and image related information. These international rules are specified by the Digital Imaging and Communications in Medicine (DICOM) Standards [34].



**Figure 3.1** Ultrasound image of a foetus [33].

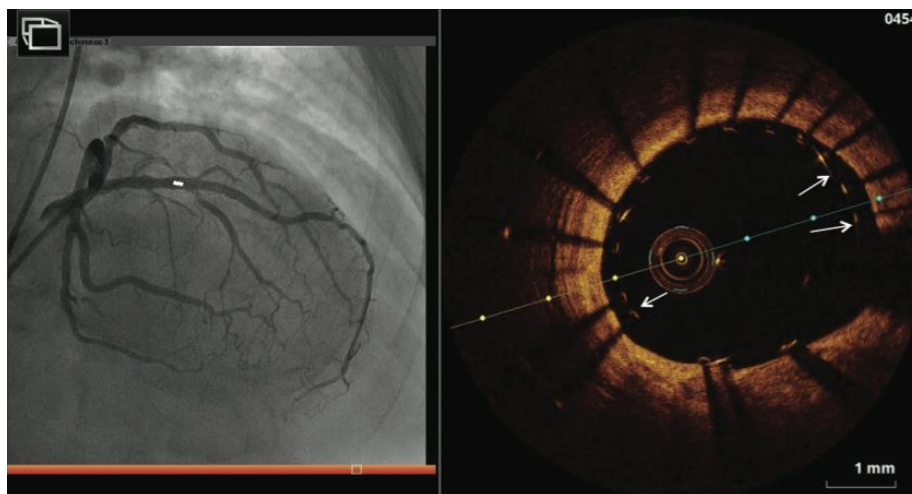
## 3.2 Percutaneous coronary intervention labs

Percutaneous coronary intervention (PCI) is an umbrella term for non-surgical techniques for treating obstructive coronary artery disease, meaning to open blood vessels in the heart that have become narrowed by plaque build-up. PCI is one of the most performed medical interventions. In Sweden around 20 000 PCIs are performed each year at 29 hospitals [35–37].

The examination is performed in special labs, called cardiac catheterization laboratory [38]. These labs can be referred to as PCI labs and for simplicity, they will be referred to as such in this thesis.

PCI labs receive three patient groups: acute patients that have an ongoing heart attack, semi-acute patients where there are signs of risk for a heart attack and planned patients that suffer from for example angina (vascular spasm) [36].

In PCI labs, different diagnostic tools can be used. Angiography is a common method where a dye is injected in the coronary arteries which will make the blood vessels visible through X-ray, see figure 3.2 [39]. Two methods measuring the pressure in coronary arteries are *Fractional Flow Reserve* (FFR) and *Instantaneous wave-Free Ratio* (IFR). Two other methods, *IntraVascular UltraSound* (IVUS) and *Near-Infrared Spectroscopy* (NIRS) use ultrasound to view the anatomy of coronary arteries and their tissue. *Optical Coherence Tomography* (OCT) use light to examine the vascular structure, see figure 3.2 [40].



**Figure 3.2** This figure shows both the angiography image of the coronary arteries on the left (grey) and the OCT image of a cross section of a coronary artery on the right (orange) [41]. In the angiography image the blood vessels supporting the heart with oxygen can be seen as dark grey (in the shape of a human heart).

### 3.2.1 Digital systems

Healthcare professionals manage multiple digital systems in PCI labs to for example administration of patients, maintaining patient safety and to enable examination. Some of these used in Gävle Hospital can be seen in figure 5.2, InVision being one example.

Two systems that play a key role at all PCI labs in Sweden are journal systems and the Swedish Coronary Angiography and Angioplasty Registry (SCAAR). Electronic journal systems are used mainly to document and store patient data. In Sweden there are five big journal systems: *Melior*, *Cosmic*, *TakeCare*, *Systeam Cross* and *Vas* [42].

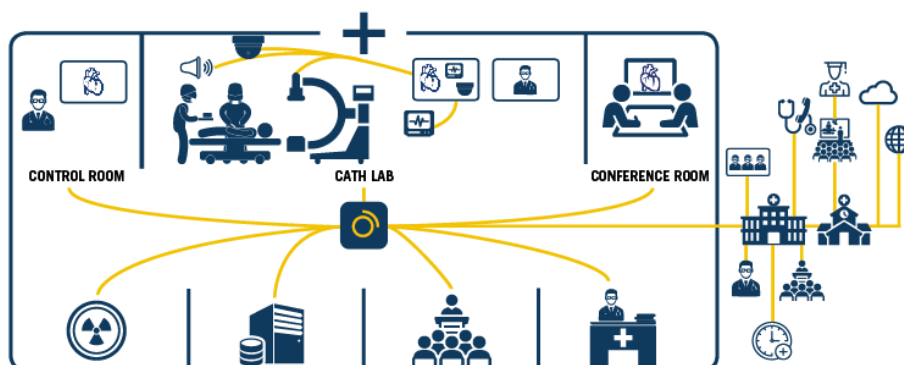
SCAAR is a nationwide register in Sweden, where procedure related information is filled in and stored on all coronary angiographies and PCI treatments. SCAAR can be used in long term follow-ups to contribute to a better healthcare as well as in comparisons between the own hospital and the rest of Sweden. Individual operators can compare their results with other operators and different treatment strategies and new medical technology can be evaluated in the short and long term [43].

## 3.3 InVision

InVision is a complete system for managing medical images. It is classified as a medical device and is primarily a software system. InVision has several features that can also be seen in figure 3.3:

- Recording of video, audio and still images.
- Distribution of images within the department to different monitors, where layouts can be selected for display of multiple image sources.
- Recorded data is saved to the right patient by integration with the hospital and radiology information system (HIS and RIS) and the department's worklist.
- Playback of collected data, in original quality with the possibility to change the playback speed, brightness and contrast in the image.
- Storage of material and patient data, either via PACS or local storage.
- Video conference or video lecture live or with recorded material, within the hospital or to another hospital anywhere in the world [44].





**Figure 3.3** Overview diagram of InVisions functionalities [44].

InVision has six modules, of which each customer can choose what modules to buy [45]. This thesis has focused on *InVision Viewer* and parts of *InVision Control*. The six modules are described further below.

### 3.3.1 InVision Viewer and Control

Recorded images and videos can be replayed and reviewed in the *Viewer* module. They are found by searching for a patient or date in a list. When viewing an examination, that patient's previous examinations can be found. Frame rate, contrast and brightness can be altered to better see details. Reports of the recorded material can be saved and sorted [45].

The *Control* module has multiple functions. It can be used to record images during an examination. The recorded images will be sent to InVision from the imaging modalities, for example an X-ray machine. *InVision Control* can optionally be used as the department's modality worklist. This means that patients are registered in InVision and the imaging modalities retrieves the worklist from InVision. When the examination is about to start, the physician chooses the correct patient in the list the imaging modality retrieves from InVision. The imaging modality will in this way possess the necessary patient information according to the DICOM standards. In case of an emergency, where there is limited time or patient information is unknown, an emergency patient can be registered in InVision. This unknown patient will be retrieved by the imaging modality and the examination can be started swiftly. The necessary patient information according to the DICOM standards can be added afterwards in InVision.

InVision Control can also be used to route live images. This means that the user can choose what images they want to see on what monitor. Live images from different imaging modalities can be routed to monitors in, or outside the lab. Preconfigurable layouts can be used [45].

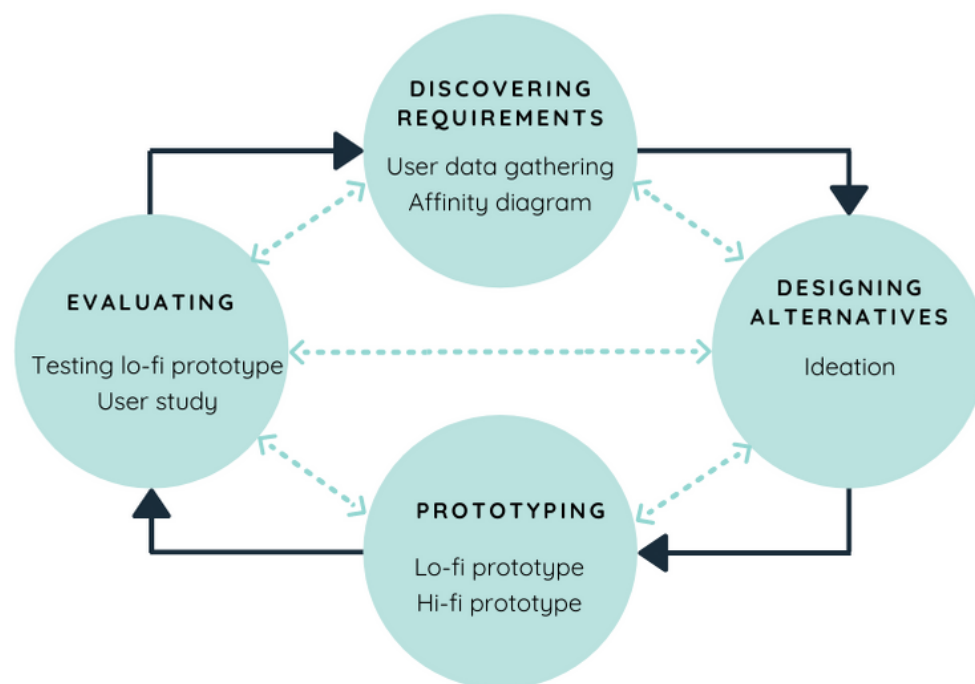
### 3.3.2 InVision Conference, Broadcast, Connect and Proctor

There are four modules that connects two or more parties in different locations, *Conference*, *Broadcast* and *Proctor*. These modules have different uses to fulfil different needs of digital communication. The *Conference* module is used by clients within the same hospital network, one being for example in a PCI lab and one in a conference room. To broadcast examinations to other hospitals, the *Broadcast* module is used. The *Connect* module is used to review recorded material between two or more users, where all users can take control of what to see. The last module is *Proctor* where an expert physician can assist an examination from distance [45].

## 4 Design process overview

*This chapter gives a short description of the design process followed in this thesis, to give the reader an overview. Detailed description of each step in the design process is presented in the following chapters.*

### 4.1 User experience design process



**Figure 4.1** An overview of the design process used in this thesis. Each circle represents one of the four basic activities described by Preece et al with some key words of the steps in this thesis [10]. The dark arrows indicate the main direction of the process, starting with *Discovering requirements*. The light arrows indicate that the iterative design process might go in more directions.

Preece et al [10] describes the four basic activities of UX design as discovering the requirements, designing alternatives to meet those requirements, prototyping the alternative designs so they can be communicated and assessed and lastly, evaluating the product. This should be an iterative process as iteration allows designs to be refined based on feedback. The design process of this thesis had four iterations, with three low fidelity (lo-fi) prototypes and one high fidelity (hi-fi) prototype. The design process described by Preece et al [10] has been slightly modified to fit the prerequisites of this thesis, being for example that InVision was a finished product on the market.

### 4.1.1 Discovering requirements

This is the first step in the design process and it focuses on understanding the target users and the support an interactive system could usefully provide. Data gathering as described in chapter 2.5 *Data gathering* can be used to attain such understanding. In this activity the basis of the products requirements is formed by using the two data gathering methods interview and observation and performing a qualitative analysis of affinity diagram [10].

### 4.1.2 Designing alternatives

The second step in the design process is the activity of designing alternatives. Here, ideas to meet the requirements from the previous step are proposed. This activity can be divided into conceptual and concrete design. Conceptual models are an abstract outline of what can be done and what concepts are needed to interact with a system. Concrete design regards the details such as colours, menu- and icon design. [10]. Ideation was used to generate ideas by using mind mapping and storyboarding.

### 4.1.3 Prototyping

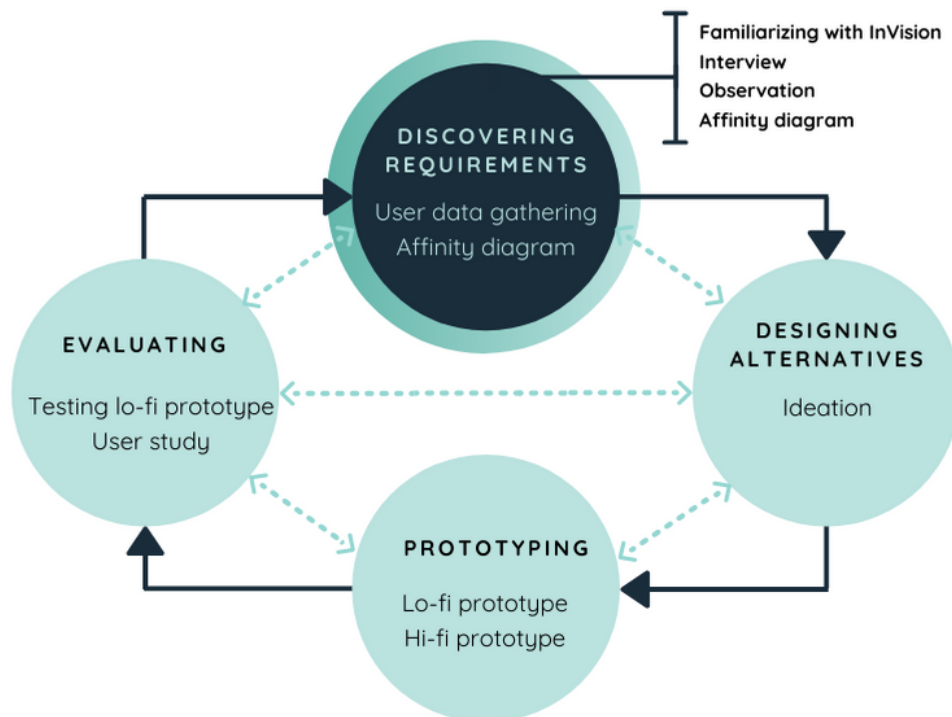
Prototypes are designed to give users the opportunity to interact with the system being designed. In this way, the user can evaluate for example the behaviour, feel, and look of a system. Different kinds of prototypes can be created depending on the system and where in the design process the development is. Simple prototypes can be created with paper while more advanced prototypes can be created using software [10]. Three iterations of lo-fi prototypes were created on paper and one hi-fi prototype was created using a digital prototyping tool.

### 4.1.4 Evaluating

During evaluation, the usability and acceptability of the prototype or system is determined. This activity complements and enhances but does not replace activities of quality assurance or determining if the final product is fit for its intended purpose [10]. The most extensive evaluation was of the hi-fi prototype. It was evaluated in a user study with three methods, testing with scenarios, an interview and a SUS form.

## 5 Discovering requirements

*In this chapter the first activity in the design process is described: discovering requirements. This includes the data gathering methods mainly being interviewing and observing. A description of the two participating hospitals is given in relation to InVision. The findings were analysed by using an Affinity diagram and the process of this methodology is described. The findings of the user needs were lastly summarized and presented.*



## 5.1 Target group

The target group was mainly the primary users of InVision, meaning doctors and nurses at PCI labs. One secondary user was also included, an engineer working at a PCI lab. The engineer had a good understanding and overview of the systems used in the labs and the workflow of the healthcare professionals. Staff at Bildteknik was also included in the discovery phase to attain a broader understanding.

Bildteknik has several customers worldwide and when choosing what hospitals to reach out to three factors were considered:

- Current situation regarding the Coronavirus disease 2019 (COVID-19).
- Strength of the relationship with Bildteknik.
- If they had been open to collaborate during development previously.

Five customers at different hospitals in Sweden and England were contacted and two chose to partake in the study. The PCI lab at Södersjukhuset (SÖS) in Stockholm and the Cardiovascular Intervention Centre (KIC) at Gävle Hospital.

## 5.2 Familiarising with InVision

InVision's user manual was read to gain a basic understanding of the system without taking up time from Bildteknik or hospital staff [10]. Bildteknik provided a test room that was set up as a PCI lab that allowed exploring the system freely.

## 5.3 Interviews

The aim of the interviews was to explore and gain understanding of the users and the users' workflow regarding InVision, surrounding systems to InVision that contribute to double work and if they are experiencing technological stress in their work environment. The interviews also aimed to explore the users' opinions of InVision, how well InVision's different functions fits in to the users' workflow, what is appreciated in InVision and what is not.

Semi structured interviews were held, meaning that a basic script was used to cover the same topics in each of the interviews while probing follow up questions were used freely to gain more new information [10].

In total, nine interviews were held with in total eight people, resulting in approximately 19 hours of audio recordings. A description of the interview subjects and the lengths of the interviews are given in table 5.1 below.

**Table 5.1** Summary of the interviews held in the discovery phase and interview subjects that partook.

<i>Interview number</i>	<i>Title and workplace</i>	<i>Age</i>	<i>Sex</i>	<i>Approximated length of interview</i>
<i>1</i>	Service engineer, Bildteknik	39	Male	2 hours
<i>2-4</i>	Engineer, PCI SÖS	53	Male	Three interviews in total 7 hours
<i>5</i>	Chief physician, KIC Gävle Hospital	52	Female	20 minutes
<i>6</i>	Nurse and coordinator, Cardiac intensive care unit Gävle Hospital	~40	Female	20 minutes
<i>7</i>	One engineer and three nurses, PCI SÖS	53, 58, 39, ~45	Male, Female, Female, Male	1 hour
<i>8-9</i>	Chief physician, KIC Gävle Hospital	63	Male	Two interviews in total 8 hours

### 5.3.1 Formulating questions

First, a list of topics was formulated from the goals within the scope of this thesis. The topics were used to formulate mainly open-ended questions as they are best suited for exploratory interviews but some close-ended questions were also formulated to answer specific questions [10]. Some questions were formulated differently to take into consideration that the two hospitals use different modules of InVision. Following are the topics brought up and some examples of questions to each topic:

- Background
  - Have you worked with any other system similar to InVision?
    - If yes: what did you think of it?
- Exploring the user's workflow with InVision
  - How does InVision help you in your work?
- Double work
  - What information [other than patient ID] do you need to enter into systems [other than InVision] or on paper?
- Technology stress
  - Does your work require you to use multiple digital systems at the same time?
    - If yes: in what situations and what systems?

To explore technology stress, Thorner's tool UDIPA (Evaluation tool for the impact of computer support on the psychosocial work environment) was used. The tool is best used on professions that use computer systems for a large part of their workday and it aims to evaluate cognitive and psychosocial work environment problems. The questions from the short version were used. As all these questions were close-ended, follow up questions were added to get a deeper understanding [46].

### 5.3.2 Notetaking

An ideal interview takes place with two designers and one user, meaning that one designer can focus on asking questions and the other can focus on documenting the answers. But as this thesis is written by only one person, audio recording was used. Some small notes were taken during the interview to help generating relevant follow up questions [24].

## 5.4 Observation

One direct observation was held at Gävle Hospital's PCI lab during approximately 2 hours. During a direct observation, users are observed as they perform activities in their usual environment [10]. Two main users were observed, being two doctors. The other participants were nurses that had no interaction with InVision or any of InVision's surrounding systems in a relevant way. An observation at SÖS could not be performed, as no visitors were allowed into the labs at the time because of their situation with the COVID-19 pandemic.

The aim of the observation was to, as Preece et al [10] writes, complement the interviews and fill in details about how users interact with the system. Especially, to understand the users' workflow better.

### 5.4.1 Framework

Robson and McCartan [47] describe descriptive observations, giving a framework for the observation. This was the base for the framework, modified to serve this thesis better. The framework was also divided into two parts, one that is observed once and one that is observed continuously.

Observed once:

- Space: layout of the rooms inside the department.
- Objects: physical elements of the department such as the furniture and machines.
- Actors: the names and titles of the personnel.

Observed continuously:

- Activities: the actors' activities that are related to computer systems and imaging systems.
- Acts: specific individual acts.
- Events: particular occasions, for example meetings.
- Time: the sequence of events.
- Goals: what the participants are attempting to accomplish.



### 5.4.2 Findings of the observation

The findings of the observation were included in the qualitative analysis in chapter 5.7 *Qualitative analysis* together with the findings from the interviews. The findings of the observation are presented here to give the reader a better understanding of the workflow when using InVision.

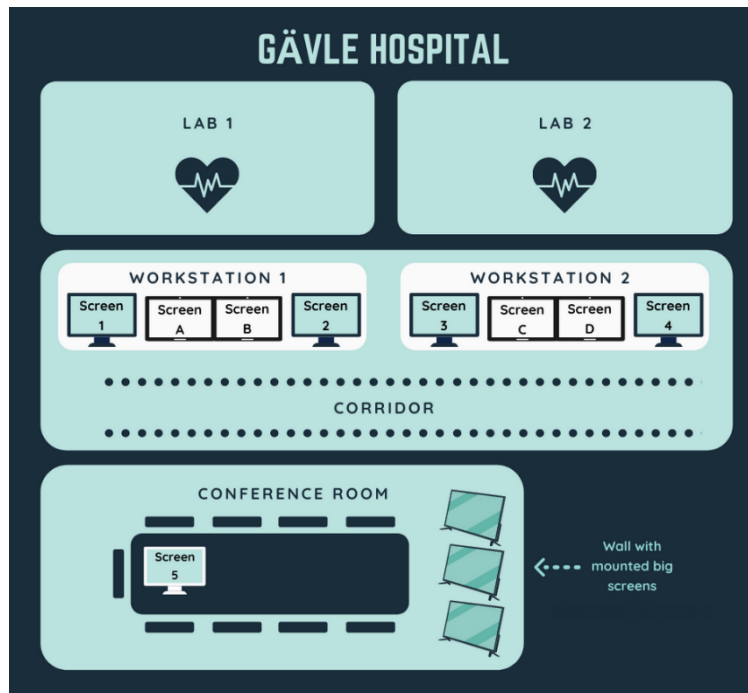
Two physicians performing one examination each were observed. During the observation, the observer sat outside the lab by workstation one, see figure 5.1. Both physicians sat at the same workstation before and after the examination, working at screen number one and two respectively, see figure 5.2. Screen A was only used briefly.

Both physicians acted roughly the same. They both performed one examination at lab one. While the patient was being prepared, the physician that was about to perform the examination prepared at the workstation, using mostly screen two. This preparation consisted of gathering, checking, and entering information in multiple systems. At screen A, the list of patients retrieved from the worklist in InVision could be seen. The current patient's information was sent to the imaging modalities by using screen A, where the examination was marked as started and later as finished. After the examination, the physician came back to the workstation and continued entering information in different systems and dictated the examination.

The systems used were their journal system Melior, SCAAR and InVision. Papers were also printed and filled in by hand. Both physicians went back and forth between the systems a lot, both before and after their examinations. InVision was mainly used for watching images of past examinations. One of the physicians seemed to partially observe the other one's examination from the workstation while working with the images taken from their previous examination.

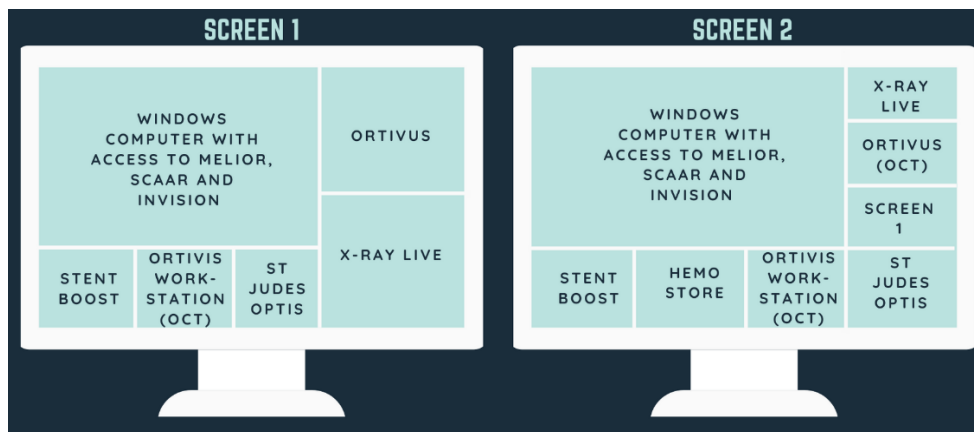
## 5.5 Gävle Hospital

Gävle Hospital has had InVision since 2011, when InVision was first developed. They have had a part in InVisions development from start and continuously been an asset to Bildteknik in form of testing and feedback. The modules used by KIC are *InVision Viewer*, parts of *Control*, and *Conference*. They have multiple clients, meaning an InVision installation on a computer, in different rooms in and outside KIC. They have two clients at each workstation, two clients at each lab, one client in the conference room, multiple clients in their office in connection to the labs and at the Cardiac Intensive Care Unit (HIA).



**Figure 5.1** Simplified overview of KIC at Gävle Hospital, resulting from the observation.

The layout of the KIC was noted during the observation and can be seen in figure 5.1. The two doctors that were observed were both sitting at workstation one, using screen one and two, respectively. In figure 5.2 the many different systems that was presented in split screen was shown. This gave a picture of the many systems physicians use in their daily work.

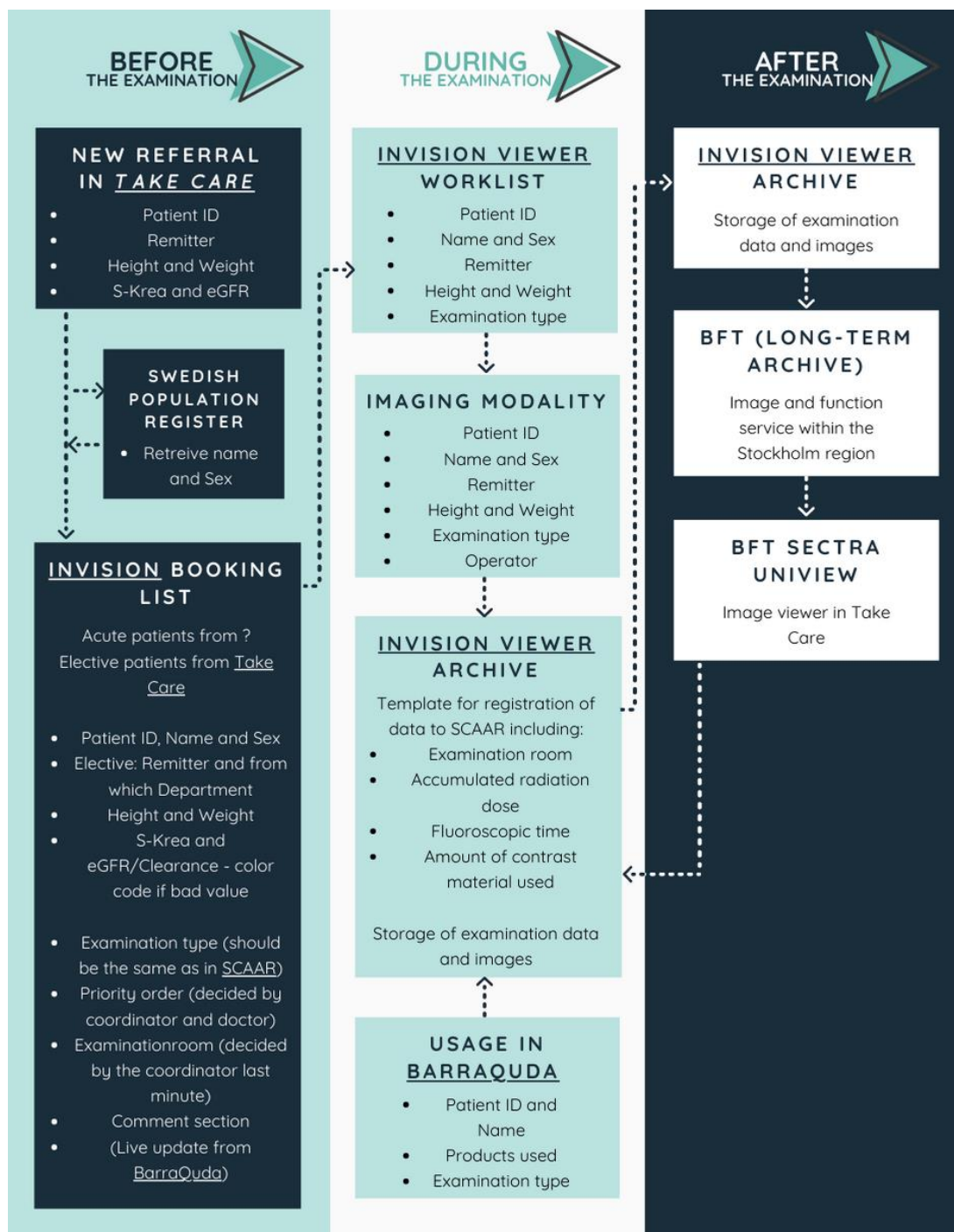


**Figure 5.2** Overview of the programs seen in screen one and two from the observation. These two screens can also be seen at workstation one in figure 5.1. The bigger square in the split screen shows the computer screen while the many smaller squares show different image modalities.

## 5.6 Södersjukhuset

SÖS has had InVision Viewer since 2014 when an acute change of the archiving function and migration of image data was needed. The modules used by SÖS are *InVision Viewer* and parts of *Control*. They have multiple clients in different rooms in and outside the PCI lab. They have three clients in the dictation room, where the doctors can review the image data, make diagnoses, and create reports to be saved in the long-term memory. Two clients in the control room to review old, recorded material during an examination, one client in the conference room, for the doctors when they discuss old cases during rounds. The Cardiac Intensive Care Unit and the Department of Physiology each have one client in their conference room. The Radiology Department and the Hybrid Operating Room each have one client in their operating rooms.

The staff at PCI at SÖS has worked to analyse the work and information flow for a couple of years and the discussion was last brought up in 2018. During interview two to four the information flow they wish to have was discussed and the result can be seen in figure 5.3. In four of the ten boxes, InVision is in the heading, showing what information should be provided to the user in each modality of InVision. The *InVision Booking List* is not an existing module, but something that SÖS requested to be developed during the interviews.



**Figure 5.3** Flowchart over the information flow the PCI lab at SÖS would like to have, compiled from interview two to four. BFT (The Image and Function Service) is a storage service for images and text by Sectra AB [48]. BarraQuda is Bildteknik’s inventory management system that SÖS does not yet have but are looking to incorporate into their workflow.

## 5.7 Qualitative analysis

Thematic analysis was used to identify themes from the interviews and observation. Themes, in this sense, represents important patterns in the data in relation to the study goals [10]. For the thematic analysis, the method of creating an affinity diagram was used.

### 5.7.1 Affinity diagram

Creating an affinity diagram is a method to organize complex problems or large amounts of data. Usually a team is selected, data is broken down into pieces and then put into clusters which will then be given headers. The team will then vote individually, using voting dots, to find clusters that are most important in relation to the design goals. An affinity diagram can be used for multiple reasons. Here, the method was used to identify important themes and connections in the gathered data to be able to focus on factors that would support a successful design from the customer's perspective [49].

The affinity diagram was mainly done according to Weprin [49] with some changes to better suit this thesis. For example, time was not spent to put the pieces of information on written on post-it notes as there was no need to have shorter wording since the writer was the only person handling all the pieces of information. Voting dots was not used either as there was no sense in voting alone. Following is the method used to create the affinity diagram.

All the relevant information regarding InVision, the workflow around InVision and other systems used from the interviews and observation was compiled in a document and the text was coloured with different colours depending on what or who the source of the text was. The document was printed and then cut into pieces, where one piece of paper represented one piece of information.

The clustering was done by placing one piece at a time. The piece was taken and grouped, either with an existing group or a new group. The groups then created categories. Some of the categories had sub-categories and four superior categories were also placed. The result of the categories can be seen in figure 5.4.

**The next step, which is to use voting dots to create a hierarchy of importance for the themes was not used as described above [49]. Instead, three different pieces of paper was put on each need where red pieces were put on needs deemed highly important, green pieces were put on needs moderately important and blue pieces were put on less important needs. This way, it became visually clear which themes were important, as these had many red or green pieces of paper. An image of the finished affinity diagram can be seen in figure 5.4 and the different levels of categories can be seen in**

table 5.2.



**Figure 5.4** Result of the affinity diagram, where the rectangular post-it notes represent categories and the smaller pieces of cut post-it notes represent the modified version of the voting dots. There were three levels of categories, small pink pieces of paper were the superior-, green was intermediate- and blue was sub-categories.

**Table 5.2** Result of the categories when creating the affinity diagram.

<i>Superior category</i>	<i>Intermediate category</i>	<i>Subcategory</i>
InVision overview		
User interface	<ul style="list-style-type: none"> <li>Visibility</li> <li>Icons</li> <li>Readability</li> <li>Intuitive functions</li> </ul>	
InVision Viewer	<ul style="list-style-type: none"> <li>Data storage</li> <li>View patient examinations</li> <li>Report function</li> <li>Functions</li> </ul>	<ul style="list-style-type: none"> <li>DICOM</li> <li>Book patient</li> <li>Edit patient data</li> <li>Search for patient</li> <li>Duplication of work</li> <li>Help guide</li> </ul>
InVision Control		
InVision Conference		
Technology stress		
Booking list		

**Of the seven superior categories in**

table 5.2, three were chosen to go forward with: user interface, *InVision Viewer* and the worklist part of *InVision Control*. These three were chosen because they were deemed most important to redesign in the altered version of *voting dots*. The other superior categories were naturally precluded. *InVision Conference* and the rest of *InVision Control* were precluded as only one of the two hospital uses them. Therefore, the risk of the result only benefiting one type of workflow was deemed high and time restraints of this thesis also played part in this preclusion.

Technology stress was precluded from this thesis as the two physicians that were interviewed separately agreed that it was not a problem in their workspace.

The booking list was precluded, not because it was deemed unimportant to the workflow of the users of InVision but because it would generate a big project that could not fit in within the boundaries of this thesis. The booking list is not an existing module in InVision and would have to be designed from square one. Additionally, the needs of Gävle Hospital and SÖS for the booking list were not consistent and in some parts contradictory.

### 5.7.2 Needs

Described below are the categories (and subcategories) deemed most important, with some of the key needs.

#### 5.7.2.1 *User interface*

There is a need for good visibility of functions that are frequently used and information about the patient, together with good readability. This applies to the normal case but stems from physicians working under pressure when dealing with acute patients. This is also the reason of the need for a more intuitive use and icons. One example of how the UI is unintuitive is that the functions in the upper bar sometimes are clickable and sometimes not. When for example viewing the list of old examinations, the user must click “Cancel” in the lower right corner to enable the functions in the upper left bar to go to the worklist. There is also a need to give some parts of the UI more space on the screen, while other parts that are not as important can be given less space on the screen.

#### 5.7.2.2 *InVision*

It is important that InVision remains being a modularly built system, so that hospitals can choose what they will buy and use. There is a need to bring back the function that could prohibit InVision from being closed. The reason for this is that when using modalities like Conference, one client in a conference room connects to the clients at the lab. If the clients in the lab are closed, the Conference module will not work as intended, causing at best an inconvenience and at worst a failed conference since the user does not know why the Conference module is not working.

#### 5.7.2.3 *Viewer – Search for patient*

Some different needs have been found when choosing a patient from the history list. When searching for a patient that has a history of multiple examinations, SÖS has expressed the need for patient to only show up once in the list. A wish is to have a separate page for this. Now each examination shows up in the list. Gävle Hospital and SÖS has the need to easier search for a patient when knowing only the approximate date. As described in chapter 5.7.2.7 *DICOM*, there is a need to have more DICOM-tags, including when searching for a patient. SÖS has the need to see examination type, modality and institution where the examination was performed. Gävle Hospital agrees that examination type could be useful. Karlstad Central Hospital contacted Bildteknik, saying that the manufacturer’s model name would be more useful than the current study description, a DICOM tag that two out of three of their modalities does not provide. Both SÖS and Gävle Hospital agree that there is still only a need to search for name, ID number and date.

#### 5.7.2.4 *Viewer – View patient examination*

There is a need to gain a better overview of old examinations connected to a patient. To gain a better overview both SÖS and Gävle Hospital agree that more information about the examination could be displayed, with an option to filter for certain examinations. SÖS expressed the need for the old



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examinations and the overview of the images for the chosen examination to take up a greater space on the screen. Gävle hospital disagrees, meaning that the current layout is good enough.

#### 5.7.2.5 Viewer – Edit patient data

Concerns regarding changing patient data has been raised. There is a need to be able to change all the patient data. Gävle Hospital expressed the need for safety regarding this, meaning that only some super users should be able to change the patient data and that log-files should be saved when editing a patient, to enable backtracking if a faulty change would be made.

#### 5.7.2.6 Viewer - Report function

Gävle Hospital has a need for an upgraded report function that is easier to use. This could be accomplished by for example creating templates for the reports. SÖS on the other hand does not use the report function since they use Take Care and are in no need for such an upgrade.

#### 5.7.2.7 DICOM

There is a need for InVision to collect information about more DICOM tags, this is something SÖS, Gävle Hospital as well as Karlstad Central Hospital has expressed. The need stems from two reasons. The current DICOM tag that is being displayed when searching for a patient is not always given from the imaging modalities and additional information is needed. Specific DICOM tags would provide a foundation for information transfer between for example the journal system and SCAAR.

#### 5.7.2.8 Journal systems and SCAAR

There is a need to transfer information from the journal system the hospital uses, to InVision and then further to SCAAR more conveniently. Ideally, this would be done automatically which could be a technical difficulty. Both SÖS and Gävle Hospital fill in information in their journal system and SCAAR before as well as after examinations. Both have expressed that there is a need to collect information at one place to avoid searching for information in different systems and that a template for the information in InVision could fulfil that need.

#### 5.7.2.9 Help guide

Gävle Hospital has expressed the need for a module that would increase the patient safety by providing a checklist or instruction video for instruments or methods that are potentially harmful to the patient and rarely used. SÖS expressed the same need but questions if InVision is the right place as they only use *InVision Viewer* outside the lab. A better system to include this feature could be Bildteknik's stock management system *BarraQuda* that is used inside the lab during an examination.

#### 5.7.2.10 Duplication of work

Unnecessary work in this sense refers to actions that must be done multiple times that could be avoided. For example, filling in the same information in multiple systems because the systems do not communicate.

SÖS says that InVision adds unnecessary work that could be avoided. If some patient data could be imported from their journal system to InVision the users would not need to create a paper copy of that information. Gävle Hospital says that InVision has reduced the unnecessary work, in the sense that they

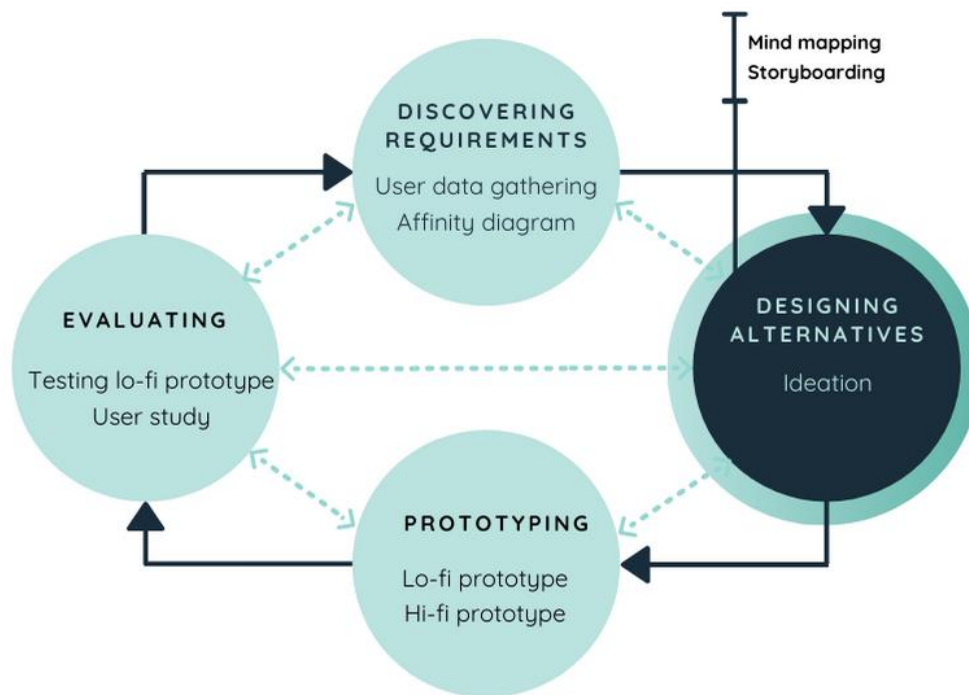
## Discovering requirements

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had to fill in the patient ID to each modality before using InVision. Though, they do agree with SÖS that if some patient information could be transferred from the journal system to InVision, that would increase the efficiency. There is also a need to have a simple and fast way to import examinations from other hospitals.

## 6 Designing alternatives

*In this chapter the ideation is described. Both mind mapping and storyboarding was used. The process of the two methods is described. The 13 mind maps are shown, and two storyboards are presented to the reader.*



## 6.1 Ideation

Creation of mind maps and personas was used as methods during ideation process. Other useful methods like sketching and brainstorming were set aside for two reasons. The project had a complex and varying user flow, and the project was done by only one person and not a group.



**Figure 6.1** Photo taken of the tree model mind maps written in Swedish. The 13 focus areas are positioned in the middle of each tree with clouds around them. Problems within the focus area are drawn as the first leaf with a circle around. Ideas of solutions are drawn as second leaves.

### 6.1.1 Mind mapping

The tree model was used where the focus areas were positioned in the middle and problems within the focus areas were drawn as leaves from the centre. From these leaves, ideas of solutions were drawn as second leaves [50]. The mind map helped create a better overview of the result from the affinity diagram described in section 5.7.1 *Affinity diagram*. It also worked to generate ideas and led forward to the next step, storyboarding. The result of the mind mapping is displayed in figure 6.1.

### 6.1.2 Storyboarding

Storyboarding can be used during ideation to get a better understanding of the interaction between the user and the system, to explore concept ideas and understanding both the technical environment and the social environment [51]. The method was used in the ideation process as an exploratory element but did not generate much further insight. Two scenarios inspired from the observation and the interviews were created in the digital tool Canva. The result can be seen in figure 6.2-3.



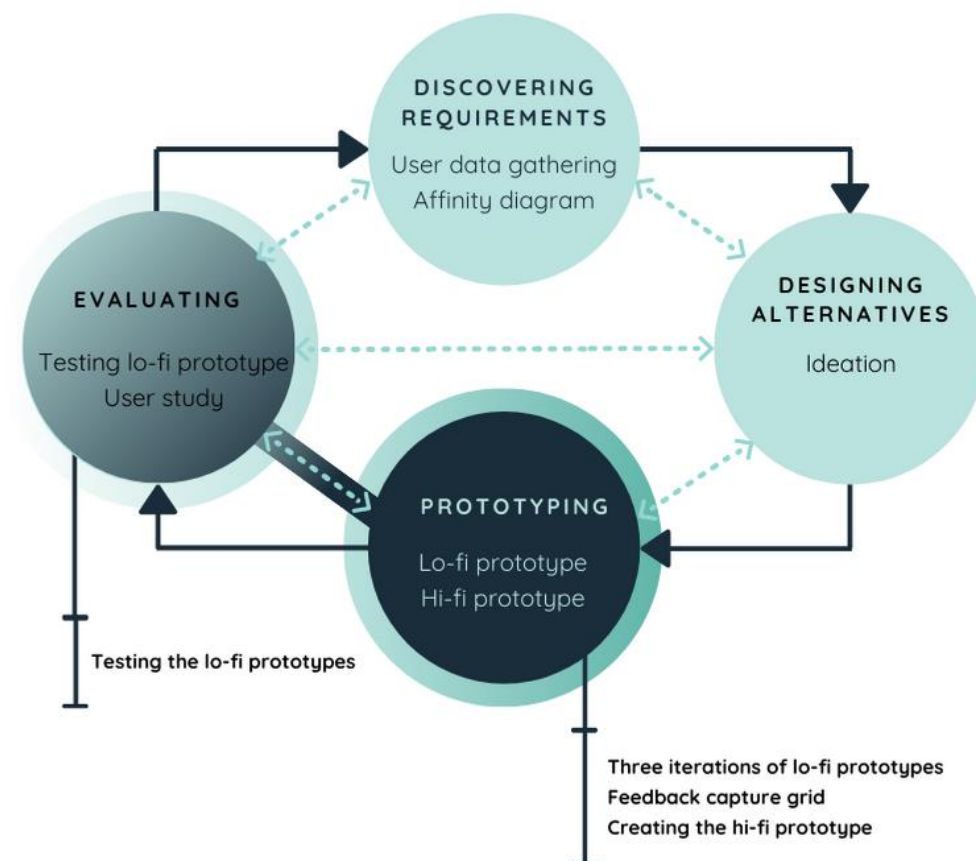
**Figure 6.2** Storyboard of the usage of parts of the InVision Viewer functionality.



**Figure 6.3** Storyboard of parts of the InVision Viewer, Connect and Broadcast functionality.

## 7 Prototyping

*In this chapter the prototyping phase is described, together with the evaluation of the low-fidelity prototype. This is a good example of the iterative process in the design process which is manifested in the figure below. First the process of the low-fidelity prototypes is presented, followed by examples of the low-fidelity prototypes compared to the original designs of InVision. The testing of the high-fidelity prototype is described together with the findings. The changes from the low-fidelity prototype are presented together with examples of the high-fidelity prototype.*



## 7.1 Low fidelity prototype

Lo-fi prototypes are used partly because they are quick and easy to make, meaning that the designer can focus on the design and not a static prototype since changes are easy to make. Lo-fi prototypes are likely to generate more feedback from the tester since they recognize that the prototype did not take much time to create and is far from done, while a polished and seemingly finished prototype might discourage the tester to give negative feedback. Not putting a large amount of time into a prototype will also make the designer less attached to the design [52].

### 7.1.1 Process

The lo-fi prototype was created in three iterations, all on paper. During the first iteration, rough sketches were created. These were shown to Bildteknik staff and open discussions were held. This was done to test if it was technically possible and how to incorporate different needs into the design. With the feedback from Bildteknik staff, new prototypes were created during the second iteration. Before the testing at SÖS and Gävle Hospital, a pilot test was performed with a well experienced UX designer which led to some changes in the third iteration.

### 7.1.2 Changes from the current InVision design

Features that were chosen to be less visible or take up less space on the screen was the InVision logo, the remaining storage space and some of the video playing functions, compare figure 7.5-6. The video playing window was also given less space as most images are quadratic.

Other features were chosen to be more visible. For example, the different module buttons were placed as folders as opposed to accessing them through a home screen. Features that were hidden in top bar menus were also placed as folders and some were placed as icons, for example a trash bin for removing images, and an export icon for exporting images. Thumbnails were given more space to see a greater number of them at once.

On the explicit request of the interviewees new features were added to the lo-fi prototype. In the archive, searching by a range of dates was added, see figure 7.4. A sterner warning popped up when closing the system was added (the two versions can be found in Appendix A). More columns were added in three places: the worklist, in the patients' medical history and in the archive, see figure 7.2, 7.4 and 7.6. All these columns aim to give the user relevant information for their workflow and get a better overview of the patient and the upcoming or finished examination. An example is the column added in the worklist (see figure 7.2) shows the patients estimated Glomerular Filtration Rate (e-GFR). It was at this point unclear how this value would be generated. It could either be calculated in InVision which could bring regulatory issues for Bildteknik to comply with the Medical Device Regulation. Or it could possibly be retrieved from another system.

New features were also added by analysing the result from the observation and the interviews. To ease the workflow of checking the patients' medical history before starting the examination, a history button

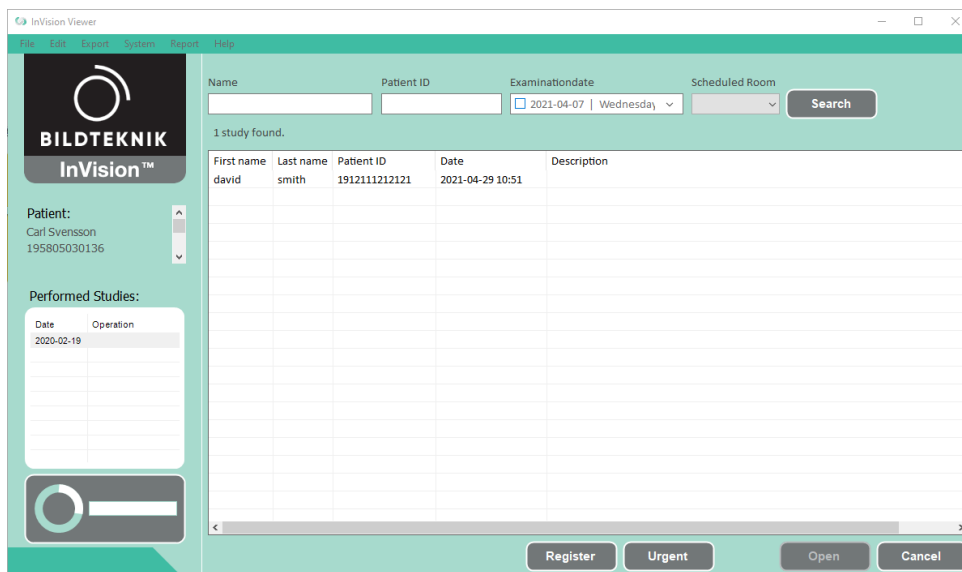


is placed in the worklist, taking the user directly to the patients' past examinations. This means that the user does not have to manually search for the patient going back and forth between InVision and another system to check the patient information.

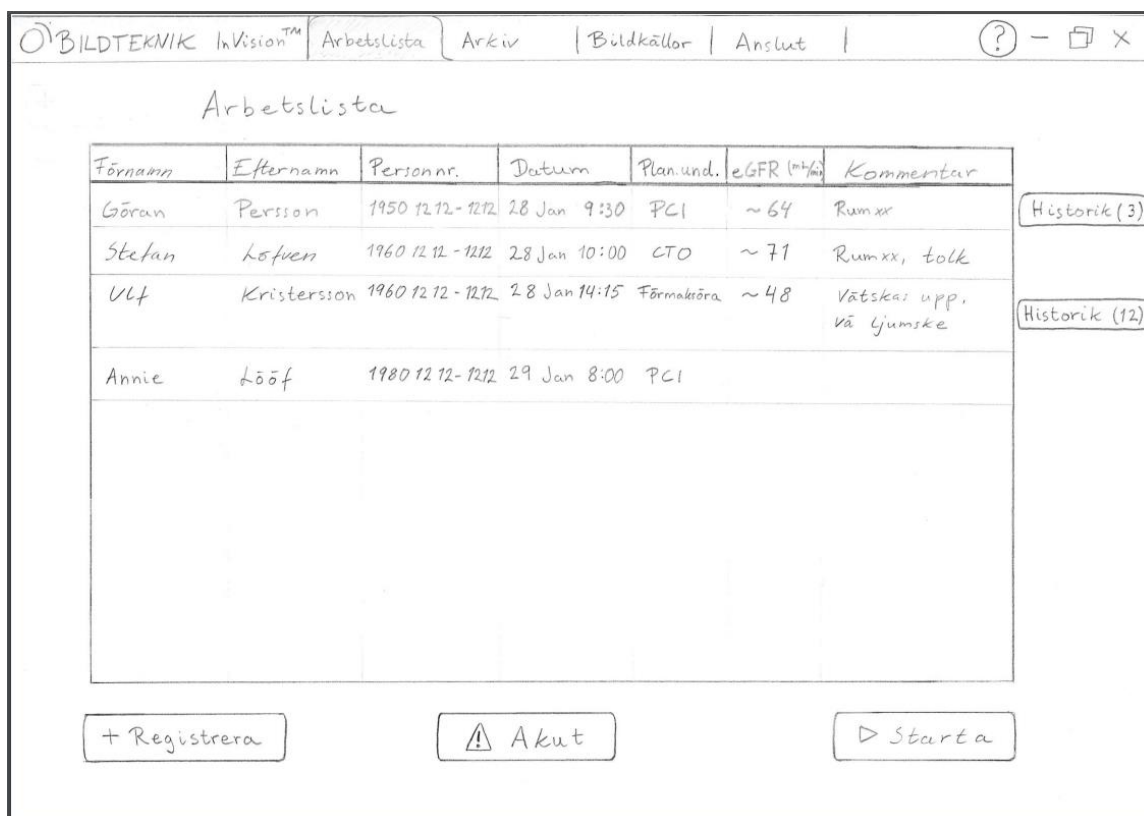
In the archive, searching by using more filters were added to make it easier to find examinations where the user does not have the patient information. When viewing a patient's past examination, the play functions were changed to more resemble big video viewing websites like YouTube and Netflix.

Below are some of the lo-fi prototypes shown. Before the lo-fi prototypes in figure 7.2, 7.4 and 7.6, the corresponding view of the original design is shown in figure 7.1, 7.3 and 7.3. The rest of the final lo-fi prototype can be found in *Appendix A*.

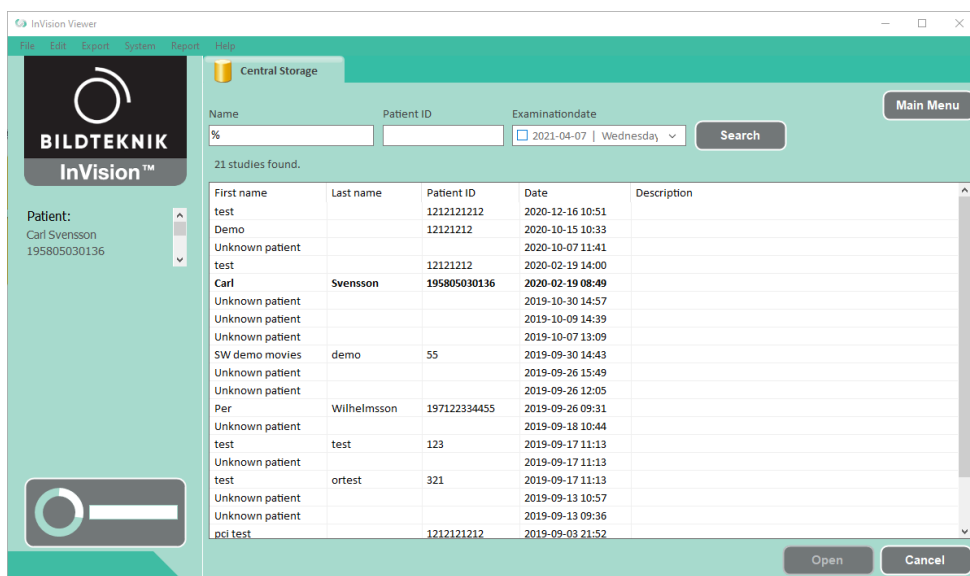
## Prototyping



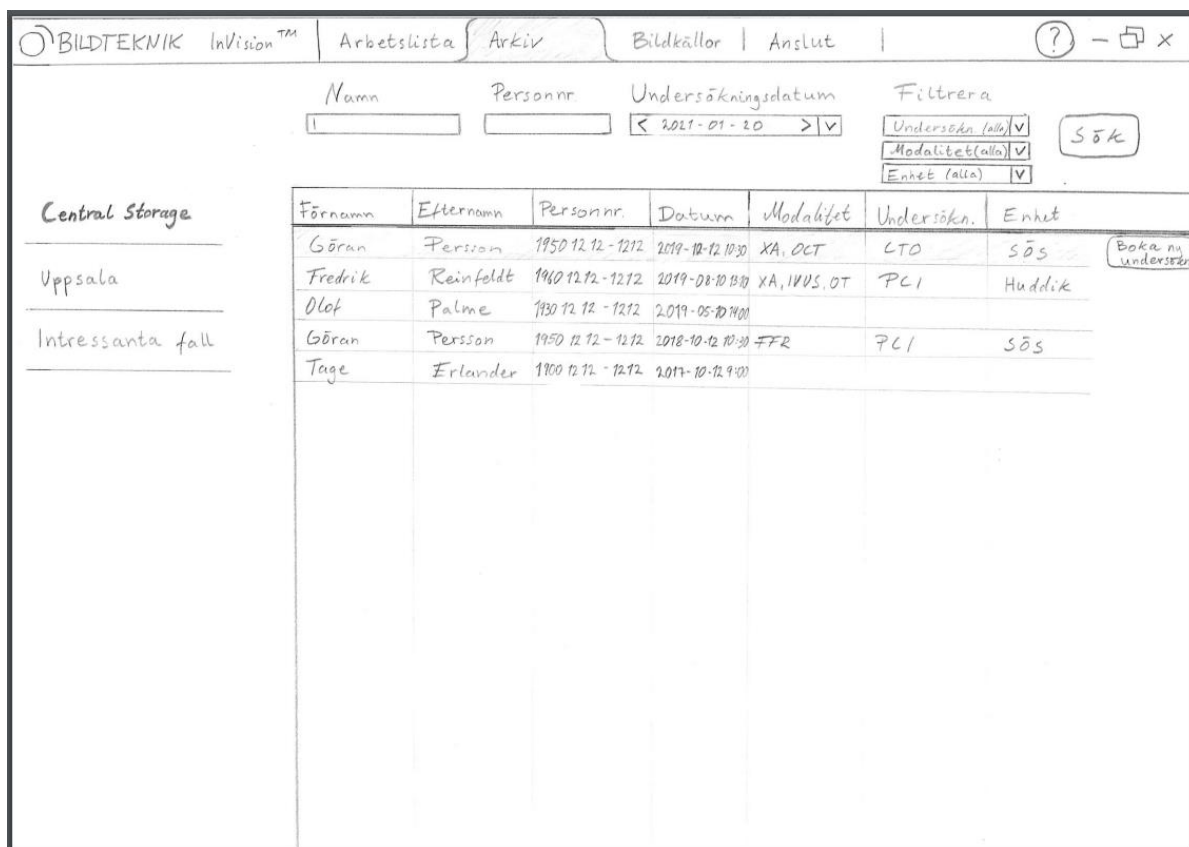
**Figure 7.1** InVision's current design showing the worklist. Here, an examination can be searched for or registered. To go to any other view, one must click "Cancel", then it will be able to choose what to do from the drop downs in the top bar. The lo-fi prototype of this view is shown below in figure 7.2.



**Figure 7.2** The lo-fi prototype of the tab *Worklist*. Here, the booked patients can be seen. Examinations can be registered. A registered examination can be started and in an acute situation and unregistered examination can be started.

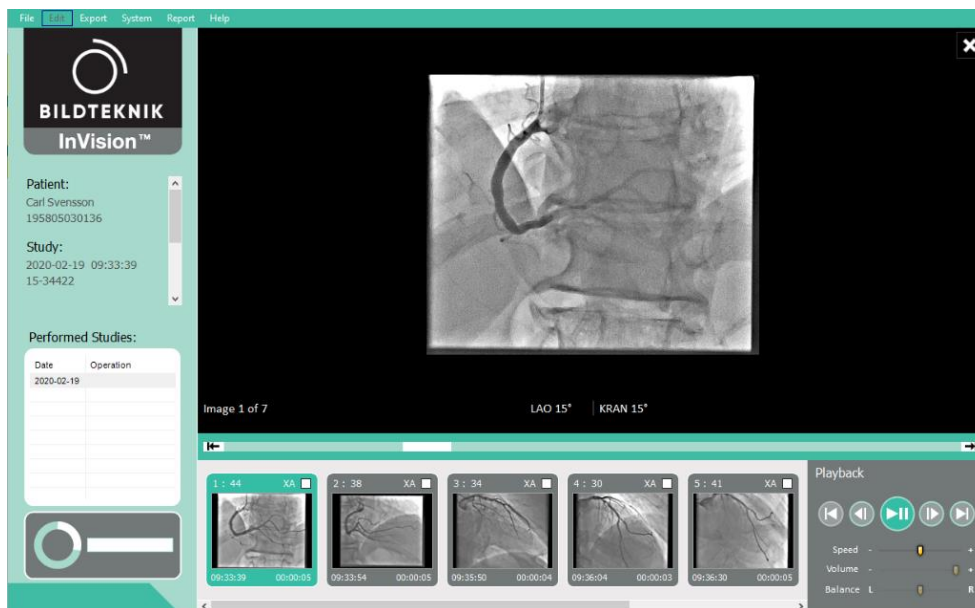


**Figure 7.3** InVision’s current design showing the archive. Here a patient can be searched for by their name, patient ID or examination date (not interval). To register a new patient, one must first click “Cancel” to enable the top bar drop downs where you can go to the view in figure 7.1.



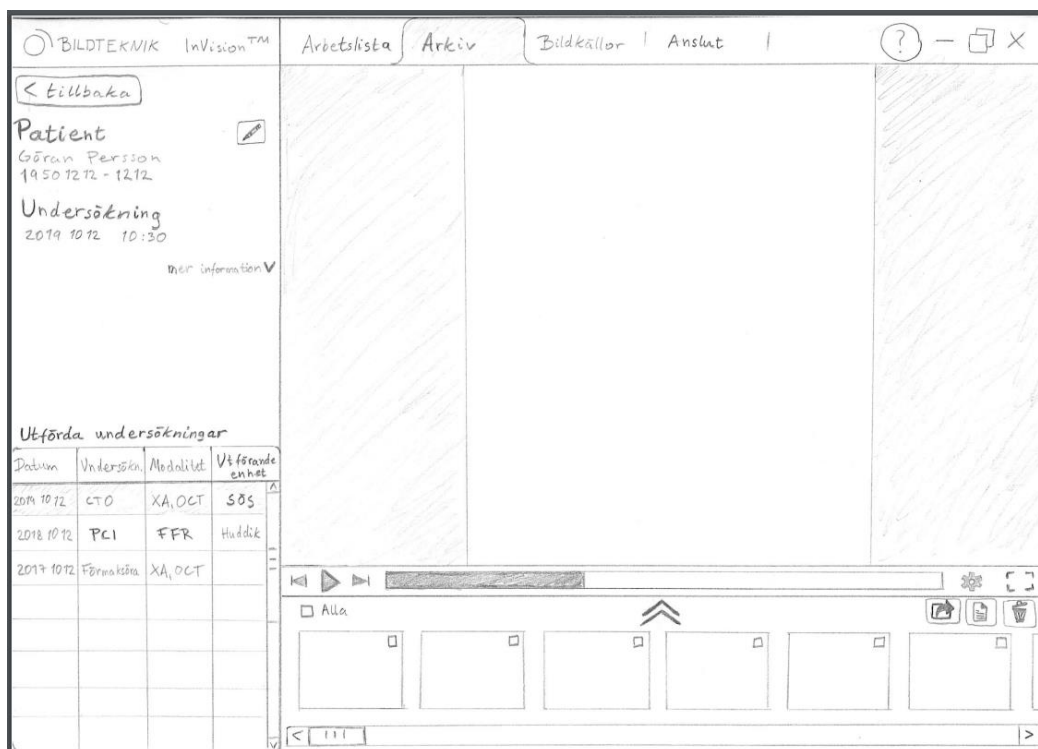
**Figure 7.4** The lo-fi prototype of the tab Archive. Here, the finished examinations are found. A search function with multiple options can be found in the upper part of the screen. Folders of which examinations can be placed are to the left.

## Prototyping

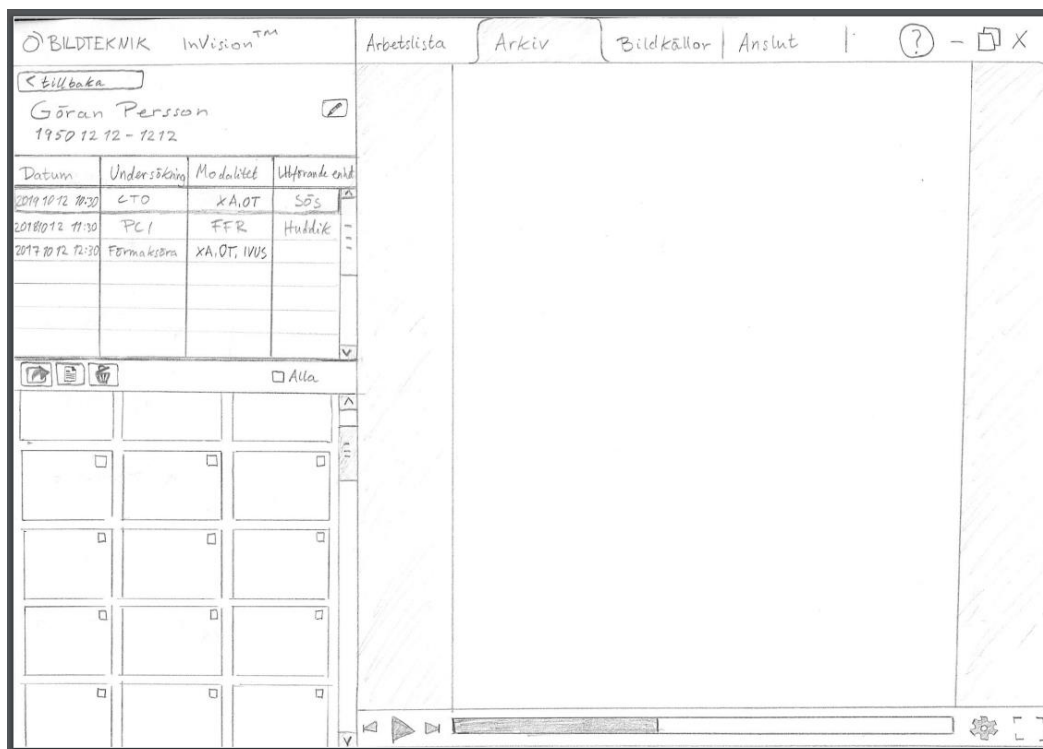


**Figure 7.5** InVision's current design showing a patient's past examination. Here most of the drop downs in the top bar are active.

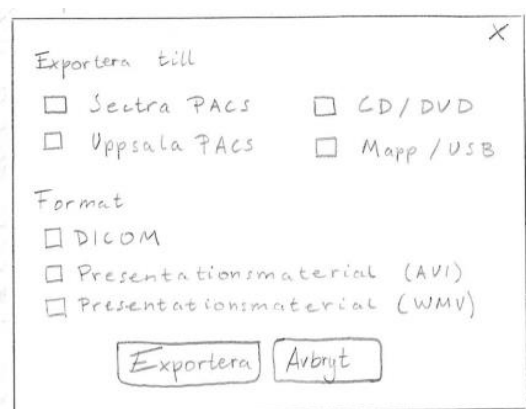
To the left the patient information together with more past examinations are seen together with remaining storage in the lower left corner. In the lower right corner, the play buttons are placed. To the right of them the thumbnails are placed.



**Figure 7.6** Version A, showing one patient's examination. Here the patient information can be seen in the upper left corner. In the lower left corner past examinations with the same patients can be found. To the right is the image currently viewed, with multiple thumbnails in the lower right part. More thumbnails can be shown by pressing the two arrows going upwards.



**Figure 7.7** Version B of the lo-fi prototype, showing one patient’s examination. Here the patient information can be seen in the upper left corner. Below, past examinations with the same patients can be found. In the lower left corner, the thumbnails are shown together with functions relating to the thumbnails. To the right is the image currently viewed.



**Figure 7.8** Pop-up window when pressing the export button in figure 7.7.



**Figure 7.9** Pop-up window when pressing the question mark in the full widow. The remaining storage was moved to this place, instead of always having it visible.

## 7.2 Testing the low fidelity prototype

Friis Dam and Yu Siang [53] describe how to test prototypes to gather feedback and maximize learning. The methods described were used to choose relevant test participants being mainly the primary users and to attain the right information by creating questions beforehand that should be answered during the test. A feedback capture grid was used to structure feedback.

The purpose of testing the lo-fi prototype was to test the usability, see if the right information was shown in the right places, if any functionality was missing and get positive and negative feedback. For views where there were multiple versions of the lo-fi prototypes, it was used to decide what version to go forward with in the hi-fi prototype.

Two tests were performed on the final lo-fi prototype. One test was performed remotely via the digital meeting tool, Zoom with a male chief physician at Gävle Hospital, 63 years old. The second test was performed at SÖS together with three test participants at once. One of these test participants was a male engineer, 53 years old. The other two were female nurses, 40 and 58 years old, respectively. Both tests could not be performed in person because of temporary visitor restrictions at Gävle Hospital due to the COVID-19 pandemic.

In the first test, the tester opened an image series of the lo-fi prototypes that had been scanned to attain digital copies. The tester shared her screen with the participant and asked the participant to share their mouse. This allowed for the tester to switch between the images in the series when seeing what the participant “clicked” on with his mouse. To record the test, the test participant was asked for consent of recording the screen together with the audio.

In the second test, the paper versions were brought to the participants and when the participant would “click” on something on the paper, the tester would switch between the papers. The test participants were asked separately if recording of audio was permitted by them. After approval, their audio was recorded. Notes were taken where audio would not be sufficient, when for example referring to something by pointing. Video was not recorded as safe distance was kept due to the COVID-19 pandemic, it would therefore have been difficult to record close enough to see the prototype as the lo-fi prototype was moved between the participants.

During both tests, the purpose of the testing was presented first, being mainly to test the usability, and get both positive and negative feedback about the design. Four scenarios were presented, and the participants were asked to perform certain tasks. Then alternative versions of one view were presented. The design was discussed further in a semi structured interview, discussing for example if the right information is shown, placement of functions and if the icons are intuitive.

A feedback capture grid was used to organize the feedback collected from the testing. The result is presented in table 7.1.

Table 7.1 Result of the feedback capture grid from the lo-fi testing.

<i>Likes</i>	<i>Criticism</i>
<ul style="list-style-type: none"> <li>• Mainly intuitive icons.</li> <li>• Positive to the shorter and sterner warning message when closing the application.</li> <li>• If e-GFR would be calculated when manually filling in height, weight and creatinine.</li> <li>• History button in the worklist, as it is easy to find and allows the user to see if and how many past examinations there are.</li> <li>• Function to put examinations in different folders.</li> <li>• When deleting images, they are not deleted immediately.</li> <li>• The columns when viewing old examinations is good, with mentioned additions.</li> <li>• Free text column in the work list.</li> <li>• Gävle Hospital liked design B most while SÖS liked design A most.</li> </ul>	<ul style="list-style-type: none"> <li>• Do not need filters when searching for a patient.</li> <li>• Settings icon to easier find the remaining storage.</li> <li>• Want bank holidays and week numbers included in the calendar.</li> <li>• Deleting images should be hidden for some users, a suggestion that only the client in the dictation room has this function.</li> <li>• Do not want “aggressive” pop ups when closing the program since they restart the computer every morning at SÖS.</li> <li>• Instead of a scroll bar, pages would be better when going through thumbnails.</li> <li>• Want to see more information about an examination since they usually only check the images in the latest examination.</li> <li>• Preferred the setup of the play buttons before.</li> <li>• Displaying/calculating estimated e-GFR might not be relevant since it is calculated in TakeCare.</li> </ul>
<i>Questions</i>	<i>Ideas</i>
<ul style="list-style-type: none"> <li>• How will e-GFR be filled in?</li> <li>• Do I need to press “search” when searching for a patient?</li> <li>• What will happen when starting an acute examination? (They will always try to fill in the information they know to get the right information to the imaging systems, like name and patient ID. They would want to only fill in the patient ID and that the patients name and sex is picked up from the Swedish population register.)</li> </ul>	<ul style="list-style-type: none"> <li>• Filter on age and sex when searching for patients.</li> <li>• Checkbox to anonymize data when exporting.</li> <li>• See if an examination is in a study or special folder when viewing examinations (not necessary to see which).</li> <li>• Add patients by priority in the worklist, since they do not know what time an examination will take place. The priority should be close to the examination type (column wise).</li> <li>• Colour code information on the worklist, for example if the patient is going to have, has started or has finished an examination, if the patient is regarded as acute, subacute or elective or is planned for another day.</li> <li>• Want to know department and bed number the patient is at in the work list.</li> <li>• See why an examination was interrupted in the worklist.</li> <li>• Give the X-Ray remittance in the worklist since it is used to prioritize the patients. Pick it up automatically (like Sectra) and notify the user if the remittance is for a patient of the day or the following day.</li> </ul>

## 7.3 High fidelity prototype

The hi-fi prototype was developed by using the web-based prototyping tool Figma. The changes from the lo-fi prototype are described below.

### 7.3.1 Changes from the low fidelity prototype

The InVision logo was moved from the upper left corner to the right as the logo was deemed less important than the tabs. This would correspond better with the eye scanning patterns presented in the theory, as the eye scans from left to right. A settings icon was added in the top bar, as it was not intuitive that an icon with a question mark would hold both information and configuration.

In the archive, the filters in the lo-fi prototype were changed to filters for sex and age, see figure 7.12. The date search function was refined with week numbers and red days.

In the worklist, patients are sorted by priority instead of time, see figure 7.13. A column was added with which department the patient is at and in which bed number. How e-GFR will be filled in was not implemented as this needs to be investigated further, discovering if it is possible for Bildteknik to calculate it or if the value should be retrieved from another system, as mentioned in chapter 9.3 *Technically not viable at this moment*. The X-ray remittance that would be useful when prioritizing patients was added as a link to a PDF file. How this PDF file will be retrieved and if it should be updated also has to be further investigated.

Version B (see figure 7.7) for viewing the patients' examination was chosen. The rationale for this was that the screen size is utilized better since most images shown are quadratic, see figure 7.14. The reason why the physician at Gävle Hospital preferred design A more was because this would change the design less, as most people are uncomfortable with big changes. This was considered but disregarded in this case since the thumbnails are still visible and will therefore likely not affect the workflow negatively.

When viewing a patient, having pages instead of a scrollbar for the thumbnails was also disregarded as three out of four people did not prefer this option. Two more columns were added in the patient history, a field for comments and a field for if the examination is added to one of the folders in the archive, for example if the examination is included in a particular study, see figure 7.14. The option to anonymize the view was added to allow users to share their screen with digital communication tools. The function to anonymize material when exporting was also added. It was raised that the play buttons of the original design were preferred over the lo-fi prototype which was why they were brought back but the icons of skipping forward or backwards in the sequence was differentiated from the icon of skipping forward or backward between sequences by different colours.

What should happen when trying to close InVision was hard to decide as Gävle Hospital and SÖS had strong and almost contrary needs. It was therefore decided to make this configurable as it was not possible to find a satisfactory compromise.



### 7.3.2 Changes in relation to design theory

The changes made from the current InVision design stem from both findings of the interviews and from design theory. Here the changes in relation to the design theory are presented.

*Signifiers* have been used to signal *affordance*. For example, all buttons that afford a drop-down menu have an arrow pointing down to signify this to the user. *Mapping* was used in the sense of spatial mapping to relate buttons to their functions. For example, all buttons regarding the thumbnails such as exporting or deleting images was placed in proximity to the thumbnails. The buttons regarding changing or temporarily anonymizing the view was placed by the patient information. *Feedback* was used for example during exporting images, where a message saying “Exporting” together with a symbol showing how much had been exported and then the message “Done” when the images was exported. Several *constraints* were set to guide the user. An example of a physical constraint is that depending on where the user chooses to export images, the system will choose what format the images are exported in, as these two factors are partially depending on each other.

The function to start, pause, resume, and stop an examination is an example of a *conceptual model*. This is, as described in the theory, a highly simplified model. Clicking pause in the system does not pause the real examination nor does it affect the imaging modalities. But it enables solving some technical difficulties in the system (described in chapter 8.5.1 *Feedback*) and enables users to keep track of and prioritize examinations.

To create visual hierarchy, typography and colour was used as described in chapter 7.3.3 *Typography and colour theory* below. The Z pattern was used when placing important information and buttons in the screen where the user views a patient, as it has little text. For the screens with more text like the worklist and the archive the F pattern was used when placing information and buttons. In these two views little information is placed in the bottom of the screen with the most important parts placed in the upper and left part of the screen. Alignment was used as users expect to find certain elements in the same place. Compare for example the video bar in figure 7.14 with video viewing services like YouTube and Netflix. The play button together with skipping functions was placed to the left while the full screen button and a button with more functions regarding the video was placed to the right.

### 7.3.3 Typography and colour theory

To fulfil the need for high readability only one font was used, with mainly 14 or above as font size. The font size of 12 was used only as information about the thumbnails where a bigger font would not fit. To compensate for the smaller font size, character thickness was increased.

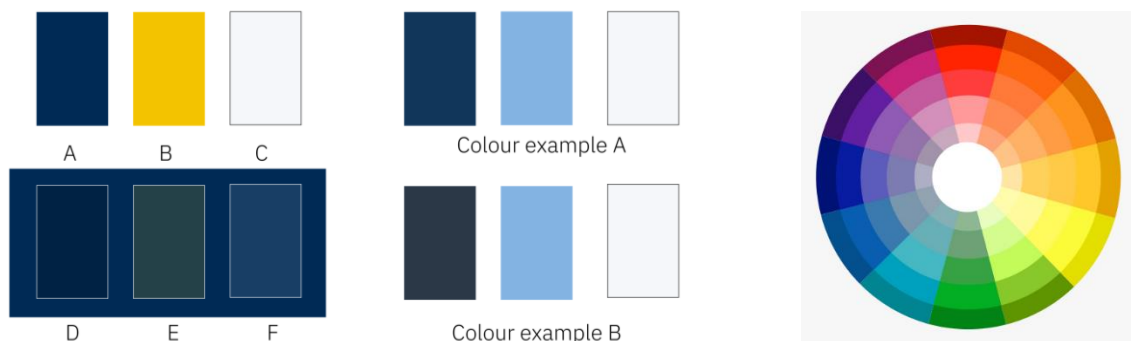
Character thickness and font size was used to create structure between different text. For example, all headers of tables have the same thickness and size, whereas the text in the tables have another.

Mainly three colours were used in the design. Dark blue, yellow, and white, see figure 7.10. These colours can be found in Bildtechnik’s brand colours but were chosen not only for this reason as is described further in this section.

The dark blue was chosen as background for three reasons. Blue is said to reflect calm, safety and reliability, which corresponds well with what the system should signal and is therefore the colour the

user sees most of on the screen [54]. As for example radiology labs have low lighting it would be distracting to have a bright screen in the lab. The third reason is that X-ray images and ultrasound images have light details with a dark background. Having a dark background in the design with light text and buttons conforms with this.

The blue and yellow makes for a complementary design as they are contrasting colours, see figure 7.11, and therefore maximizes the contrast which was expressed as a need from the user [23]. It was used to draw the eye to certain areas, such as small buttons and the chosen folder at the top bar. The white is used in text to maximize contrast to the dark blue and therefore readability, and also for bigger buttons used regularly that do not need extra attention.



**Figure 7.10** Samples of the colours used in the design. A, B and C are the base colours. D, E and F are used as highlighting colours in the tables. The two colour examples, A and B to the right are used in versions only to show the participants.

**Figure 7.11** Colour wheel showing that the warm yellow (B in figure 7.10) is a contrast colour to the dark blue (A in figure 7.10) [55].

Two other colour combinations were explored by creating only a few of the views to show to the test participants as examples, see figure 7.10. Colour example A, where the yellow was exchanged to light blue and one where both yellow was exchanged to light blue and dark blue were exchange to a medium grey colour.

Below is a selection of views from the hi-fi prototype presented. The rest of the hi-fi prototype as well as the two versions with different colouring is shown in Appendix B.

Arbetslista Arkiv Bildkällor Anslut InVision™

Namn:  Personnummer:  Undersökningsdatum: 2021-03-04 - 2021-03-18 Filterera Ålder Kön Renia arkiv

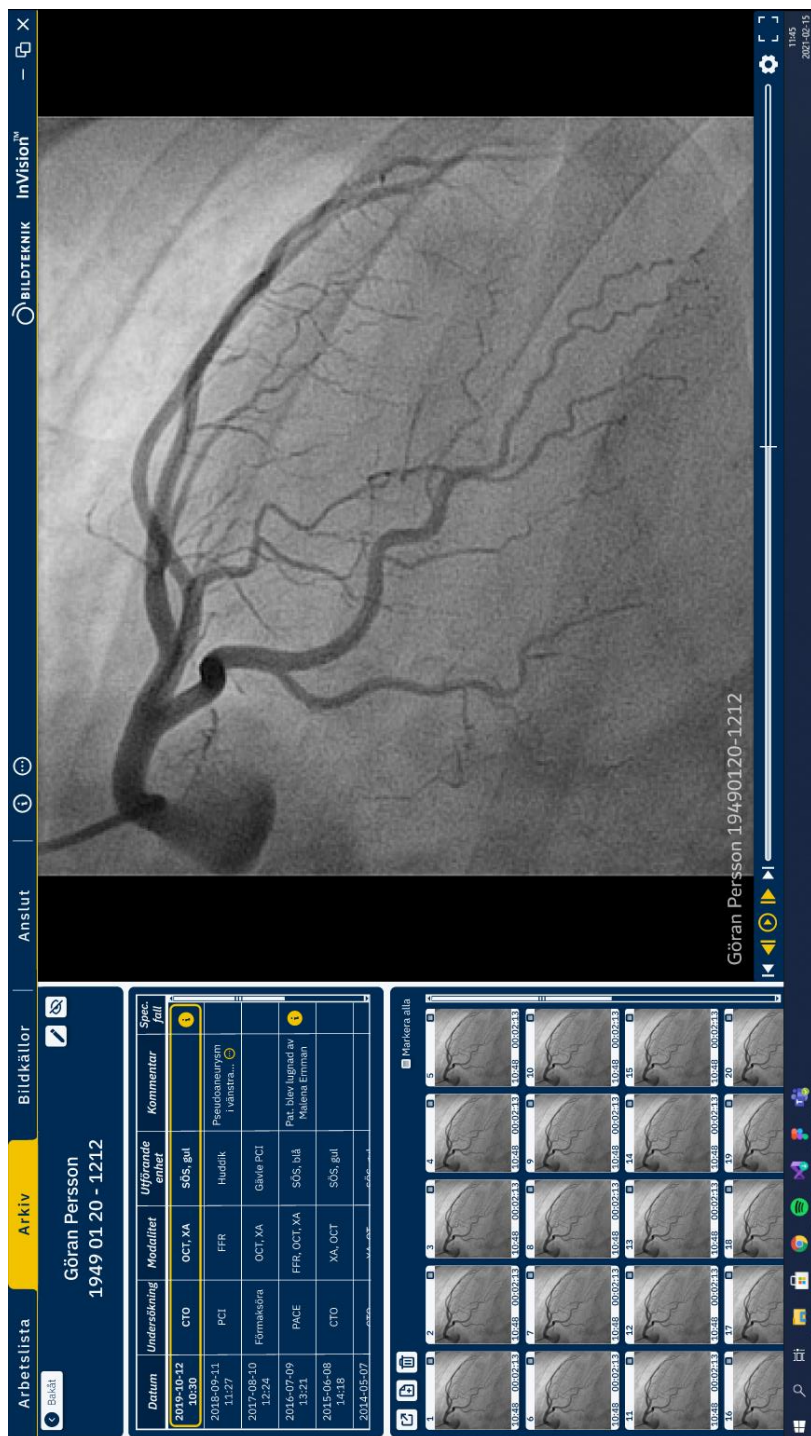
Förnamn	Efternamn	Personnummer	Datum	Modalitet	Undersökning	Enhet	Kommentar
Stefan	Löfven	1957 07 21 - 1313	2021-03-18 10:30	OCT,XA	CTO	SOS, gul	
Fredrik	Reinfeidt	1965 08 04 - 1313	2021-03-18 9:30	FFR	PCI	Huddik	
Göran	Persson	1949 01 20 - 1212	2021-03-17 15:20	OCT,XA	Formaköra	Gävle PCI	Studie xxx
Ingvar	Carlsson	1934 11 09 - 1919	2021-03-17 14:50	FFR,OCT,XA	PACE	Gävle PACE	
Nils Daniel Carl	Bildt	1949 07 15 - 1818	2021-03-17 10:30	XA, OCT	CTO	SOS, blå	
Ingvar	Carlsson	1934 11 09 - 1919	2021-03-17 08:30	OCT,XA	CTO	SOS, gul	Läng pat (2,03 m)
Olof	Palme	1927 01 30 - 1010	2021-03-16 23:07	FFR	PCI	Huddik	
Thorbjörn	Fälldin	1926 04 24 - 1616	2021-03-16 14:10	OCT,XA	Formaköra	Gävle PCI	
Ola	Ullsten	1931 06 23 - 1717	2021-03-16 12:45	FFR,OCT,XA	PACE	Gävle PACE	Intressant fall pga xxx
Tage Fritjof	Erfander	1901 06 13 - 1212	2021-03-16 11:10	XA, OCT	CTO	SOS, blå	
Bo Osten	Undén	1886 08 25 - 1515	2021-03-16 09:10	OCT,XA	CTO	SOS, gul	
Per Albin	Hansson	1885 11 28 - 1616	2021-03-16 07:45	FFR	PCI	Huddik	
Axel	Pehrsson-Brannstorp	1883 08 19 - 1313	2021-03-15 18:55	OCT,XA	Formaköra	Gävle PCI	
Felix	Hamrin	1875 01 14 - 1818	2021-03-15 15:00	FFR,OCT,XA	PACE	Gävle PACE	

Alla fall  
Uppsala  
Intressanta fall  
Forskningsprojekt xx

**Figure 7.12** Final prototype of the *Archive* where the history of the examinations can be seen. The archive tab is marked with yellow as this is where the user is located. The folders of examinations are to the left. All functions for searching are placed in the upper screen. One could go to any examination by double clicking on the row. Here, Stefan Löfven’s examination is marked with yellow, clicking once on any other examination would mark that row.

Prio	Planerad undersökning	Förnamn	Efternamn	Personnummer	eGFR (ml/min)	Avdelning/sängnummer	Remiss	Historik	Kommentar
Startad	CTO	Annie	Löf	1983 07 16 - 1616	71	HIA, säng 4	Öppna	Öppna (0)	Lab xx
1	PCI	Göran	Persson	1949 01 20 - 1212	64	HIA, säng 7	Öppna	Öppna (1)	Laby Y, Tolk
2	Färdskåpa	Stefan	Löven	1957 07 21 - 4313	68	HIA, säng 2	Öppna	Öppna (0)	
3	PCI	Ebba	Busch	1987 02 11 - 1919	47	Huddik	Öppna	Öppna (2)	Väntas upp, vä lumske, positiv Covid-19...
4	PCI	Nyamko	Sabuni	1969 03 31 - 1818	63	Avdelning 5	Öppna	Öppna (3)	Studia xxx
5	CTO	Ulf	Kristersson	1963 12 29 - 4313	64		Öppna	Öppna (1)	Lång pat (2,03 m)
6	Välj	Jonas	Sjestedt	1964 12 25 - 1010	+	Beskiva	Öppna	Öppna (0)	
7	Välj	Jimmie	Akesson	1979 05 17 - 1616	+	Beskiva	Öppna	Öppna (1)	Rädd för nålar, Tolk
8	Välj	Per	Balund	1971 07 03 - 4717	+	Beskiva	Öppna	Öppna (0)	
9	Välj	Isabella	Lövin	1963 02 03 - 1212	+	Beskiva	Öppna	Öppna (3)	Bor i Gävle
10	Välj	Olof Anders	Wedin Johansson	1961 06 24 - 4515	+	Beskiva	Öppna	Öppna (1)	Planerad för lördag
Avslutad	PCI	Göran	Hägglund	1959 01 27 - 1616	72	HIA, säng 16	Öppna	Öppna (1)	Lab xx, Tolk
Avslutad	PACE	Håkan	Juholt	1962 09 16 - 4313	65	HIA, säng 3	Öppna	Öppna (0)	
Avslutad	CTO	Mona	Sahlin	1957 03 09 - 1818	80		Öppna	Öppna (1)	

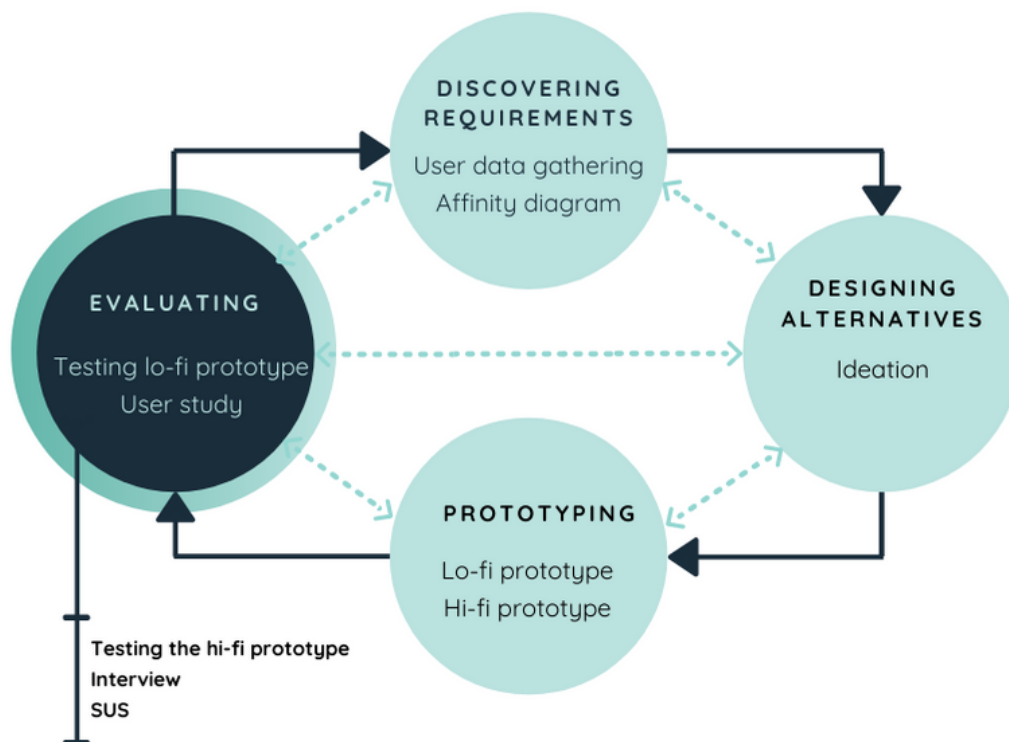
**Figure 7.13** Final prototype of the *Worklist* where the history of the examinations can be seen. The worklist tab is marked with yellow as this is where the user is located. Two buttons to either start an acute examination or register a new is placed in the upper right part. The list of the registered and prioritized patients' examinations is found in the table. The row of the started examination has a yellow hue. The rows of the finished examinations in the bottom of the table have a white hue. The marked examination has a start button at the right side of the table. Several columns can be seen with the functions and information requested. Patient's past examinations (if there are any) can be seen by clicking the History button of their row.



**Figure 7.14** Final prototype of the view of an examination. The patient information can be seen in the upper left corner. Below are the other past examinations in a table. In the far-right column, the user can hover over the yellow i-icon to see in what folder in the archive the examination is. Below are the thumbnails with associated functions above them. Most of the window shows the image with the play buttons placed to the left, so as to be in close proximity to the thumbnails.

## 8 Evaluation

*This chapter describes the last step in the design method, evaluation of the high-fidelity prototype. This was done in the form of a user study, conducting a usability test, interviews and a system usability questionnaire. It was performed to gather both quantitative and qualitative data on how well the prototype was designed in relation to the thesis' research questions. The result of each part in the evaluation is presented.*



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## 8.1 Participants

The user study was conducted with 12 participants that were divided into three groups based on their experience of PCI labs and InVision, see table 8.1 . Of the participants, three had been involved throughout the entire design process and six participants were first involved in this final step.

Group A contained four participants that work daily at PCI labs with InVision or have a good understanding of the workflow and InVision.

Group B contained four participants that have some understanding of the workflow of PCI labs. Two of the participants were medical students halfway through their education who had both visited PCI labs but never used InVision or any equivalent. The other two participants were employees at Bildteknik who have also visited and performed jobs for PCI labs regarding InVision. These two participants were included to not only test the design but also if they could see technical difficulties in implementing the design.

Group C contained four participants that had no understanding of PCI labs and had never used InVision or any equivalent. All the participants do office work and are therefore used to working in digital systems.

## 8.2 Setup

To assess the users' behaviour both quantitative and qualitative measurements were gathered. Quantitative metrics were gathered by recording the screen as well as sound. Parameters measured were failure rates and effort, more specifically how many clicks the user took, how many of these clicks did not lead the user towards completing the task and instances of confusion.

The qualitative metric of subjective satisfaction and perceived level of difficulty was gathered by a SUS form, described in chapter 2.5.3 *System usability scale*. One additional question was added regarding if the user feels that the system fits in to their workflow. This question was added as it was a central part of the design process. The questions were translated from English to Swedish as to avoid language barriers, as all the test participants' first language was Swedish. The SUS form given can be found in *Appendix C*. Group B and C was asked to not answer the 11th question as they did not have enough insight into the workflow.

## 8.3 Procedure

Background information was given to the participants, informing them that it was the last prototype in the design work of this thesis and that the testing was done with the purpose of evaluating the usability of the design. The participants were asked to give their consent to recording of the screen and audio. If the test participants said yes, the recording was started.

To get familiarized, they were first asked to explore the system by clicking around as they wished and think aloud as they did. Then four scenarios were given. After the scenarios were completed the test participant was asked general questions about the design and asked to give feedback and thoughts on the design freely. Lastly the test participant was asked to fill in the SUS-form.

With the participants from SÖS, an open question interview was also conducted where the participants were asked to discuss their impression of the new design and points of improvement together.

## 8.4 Quantitative results

The quantitative data was collected by reviewing the recorded test. Four parameters were quantified for each task of each scenario, see table 8.2. Number of clicks to complete the task, number of wrong clicks, failure rate and instances of confusion was counted. Wrong clicks were counted when the participant would try to click on something that would not lead them to or towards completing the task. Confusion was counted when the participant seemed confused about what to do, how to do it or what to click on. Confusion was not counted when the participant was simply scanning the screen during a reasonable amount of time. The participant was considered to have failed the scenario when there was so much confusion that the participant could not complete the task within a reasonable amount of time without guidance from the test designer.

**Table 8.1** Participants in the user tests. The participants from group A are named a1-a4, group B are named b1-b4 and group C are named c1-c4.

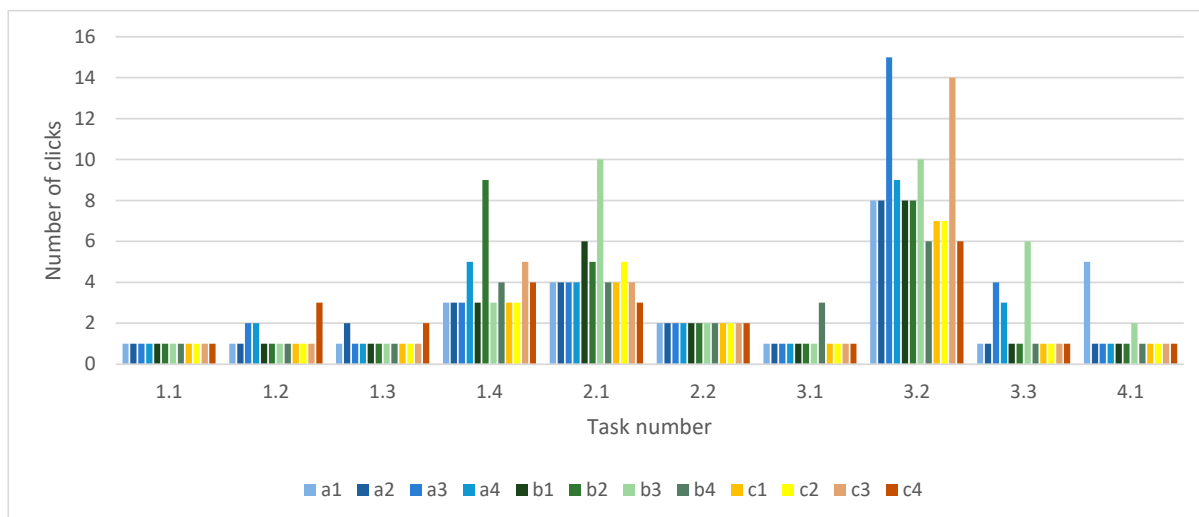
<i>Participant</i>	<i>Title and workplace</i>	<i>Age</i>	<i>Sex</i>
<i>a1</i>	Nurse, PCI SÖS	58	Female
<i>a2</i>	Nurse, PCI SÖS	39	Female
<i>a3</i>	Engineer, PCI SÖS	53	Male
<i>a4</i>	Chief physician, KIC Gävle Hospital	63	Male
<i>b1</i>	Medical student, Lund University	24	Male
<i>b2</i>	Medical student, Lund University	25	Female
<i>b3</i>	Service engineer, Bildteknik	51	Male
<i>b4</i>	Service engineer, Bildteknik	39	Male
<i>c1</i>	Unit manager, municipality	29	Female
<i>c2</i>	Development secretary, municipality	29	Male
<i>c3</i>	Payroll administrator	60	Female
<i>c4</i>	Engineer, car industry	63	Male



The scenarios and associated tasks the test participants were asked to perform are presented below in table 7.2. The result of the quantitative results is presented below in figure 8.1-4. The tasks are named after scenario number and task number. For example, task number three in scenario number one is named 1.3. The participants are named according to table 8.1.

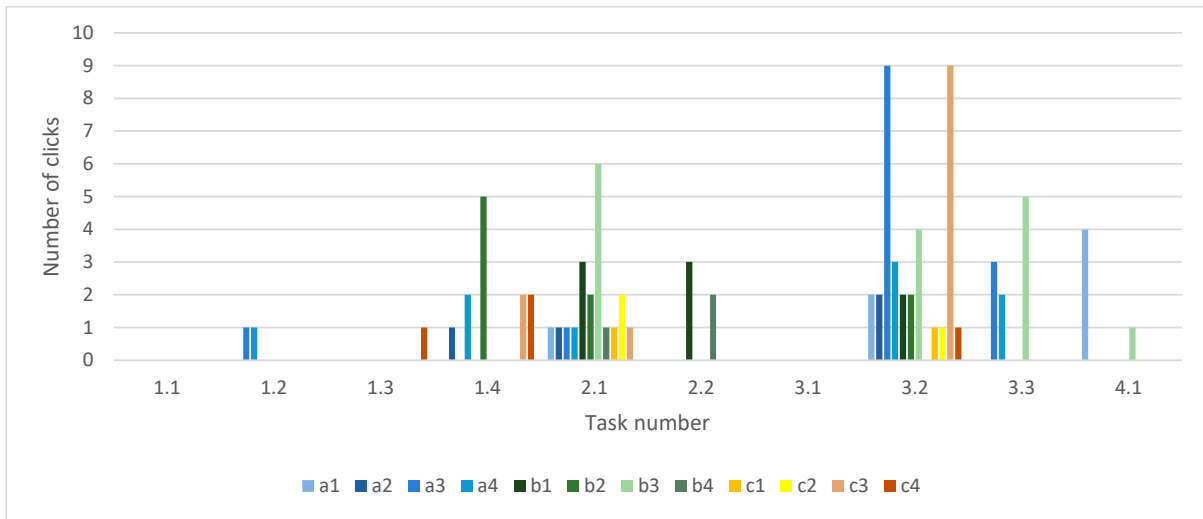
**Table 8.2** The four scenarios of the user study with the tasks to each scenario.

Scenario	Tasks
1.	<ol style="list-style-type: none"> <li>1. Go to the list of today’s patients that are going to be examined.</li> <li>2. You are about to do a PCI on Göran Persson and you want to see his former examinations.</li> <li>3. You want to go back to the work list.</li> <li>4. Do you see any alternative ways?</li> </ol>
2	<ol style="list-style-type: none"> <li>1. You want to search for a patient in the examination history, but you only know that the examination was done between the 17<sup>th</sup> and the 18<sup>th</sup> of march.</li> <li>2. You have found Göran Persson and you want to open his examination.</li> </ol>
3	<ol style="list-style-type: none"> <li>1. You want to see another of Göran Persson’s old examinations.</li> <li>2. You want to export the three first images to Sectra PACS.</li> <li>3. You want to edit the patient information.</li> </ol>
4	<ol style="list-style-type: none"> <li>1. You are in a digital meeting using Microsoft Teams. You want to share the screen and therefore anonymize so the viewer cannot see that it is Göran Persson.</li> </ol>

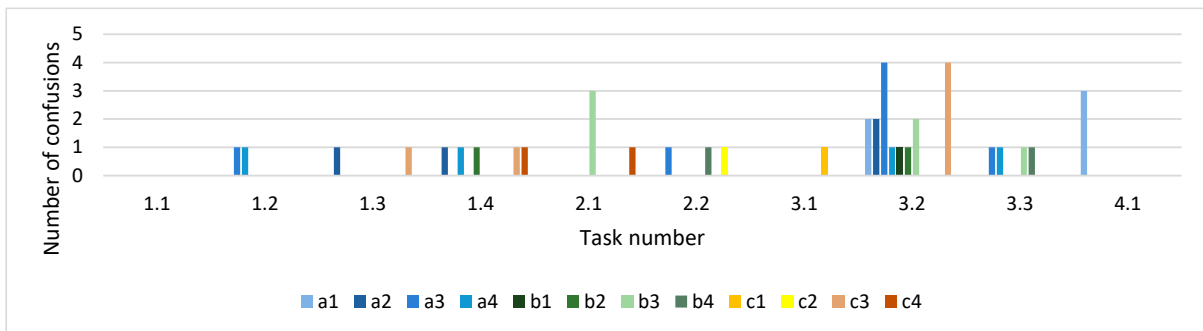


**Figure 8.1** Number of clicks to complete each task. Each column in the chart represents one user.

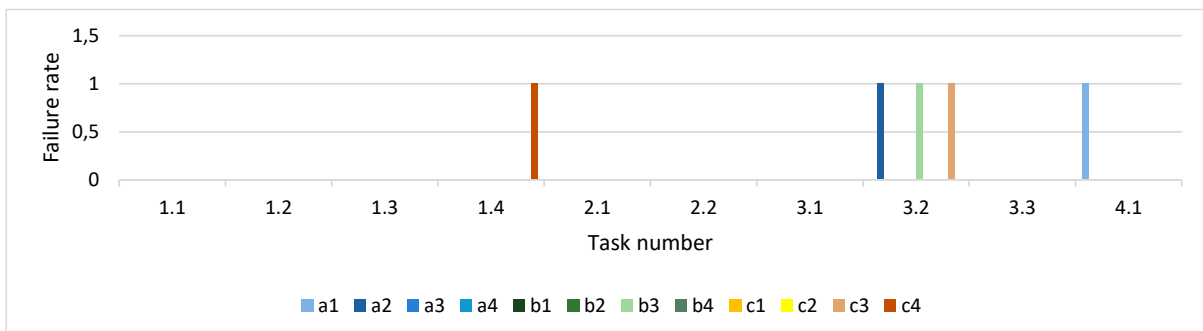
## Evaluation



**Figure 8.2** Number of wrong clicks during the completion of a task. A wrong click was defined as a click that would not lead them to or towards completing the task. Each column in the chart represents one user.



**Figure 8.3** Number of confusions completing each task. Confusion was considered when the participant seemed confused about what to do, how to do it or what to click on. Each column in the chart represents one user.



**Figure 8.4** Failure rate when performing each task. A participant was considered to have failed the task when there was so much confusion that the participant could not complete the task within a reasonable amount of time without guidance from the tester. Each column in the chart represents one user.

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## 8.5 Qualitative results

### 8.5.1 Feedback

Qualitative results were gathered during the test where the participants were encouraged to think aloud. Below is the feedback given by the participants.

- **Positive feedback**
  - Overall:
    - Most of “the design is very logical and easy”.
    - “I think I did all of the tasks easily because the design is very reasonable.”
    - Icons are said to be “good and intuitive”, “easy to learn”, “logical” and “grouped well”.
  - Worklist:
    - The user directly gets an overview if there is any history of the patient.
    - Being able to start, pause, resume, and stop an examination is a good function.
    - Marking examinations as started solves technical issues such as editing patient information when an examination has been started. When Bildteknik functions as the modality worklist, patient information can be edited in InVision before an examination (as it should be) but should not be edited when the examination has started as this will cause failure in connecting images to the right patient and study. This happens since the imaging modalities retrieve patient information from InVision.  
Marking an examination as started would prohibit this failure if a restriction on editing patient information is set. The image modalities would access the patient information first when the examination is started in InVision.
    - The suggestion of retrieving the X-ray remittance automatically and giving the user some sort of notification was liked by both SÖS and Gävle Hospital.
    - “Columns fit nicely with our workflow”.
  - Viewing an examination:
    - “The screen looks nice when viewing a patient and good information is shown”.
    - Having the play buttons close to the thumbnails make it easy to work with.
    - The Export window is much “better than the old design”, as it is just a small pop-up window and not an entire new window which can be confusing.
    - The “Done” message after exporting images.
- **Negative feedback**
  - Overall:
    - The tab Connect (Anslut) might need to be divided into multiple tabs as it is a rather big tab. Participants agree with the suggestion that the user should first choose where to connect and then how to connect.
    - The configuration icon should be hidden from the user.

- Having the column for last name before the first name would agree better with other systems (would like to have the following order: date, patient ID, last name, first name).
- Worklist:
  - It is unclear that the comments are only for the day and will not be stored.
  - Maybe the history button should change name to performed examination for those who are finished.
  - The start button is too far away, would rather like to start an examination by double clicking on the patient.
  - It is easy to miss the row of the examination that was started.
- Archive:
  - Searching for an interval is not entirely intuitive.
- Viewing an examination:
  - Cannot edit patient information of an archived examination since it might be sent to other systems for storing. Should only be able to change for a recently finished and not yet archived examination.
  - When exporting images, have radio buttons and not check boxes as there can only be one choice.
  - Regarding the button for going back. The Swedish word “bakåt” means back, but in the sense of up in a system according to one of the participants. Using the word “tillbaka” which also means back would be better suited as a “go backwards” button.
  - The eye icon used when anonymizing the screen should be the other way around, crossed over when the screen is anonymized, not when to anonymize it.
  - The “Done” message after exporting should specify more, for example, “3 images exported to Sectra PACS”.
  - When exporting some formats, anonymize should be filled in automatically.
  - The report icon is misleading with the cross/plus sign, some participants thought it meant to add images to the examination.
  - It was not clear to all participants that anything on the screen changed when clicking the anonymizing button.
  - How do you export to Uppsala or put an examination in a folder?
- **Points of improvement**
  - Worklist:
    - Would like to have acute patients stand out in some way in the work list.
    - Would like to have date and time for booked patients, both SÖS and Gävle Hospital agreed.
    - Merge the archive and the worklist to be just one list of examinations (given by Bildteknik staff).
    - Would like to have a drop-down list in the comment column (together with free text). This becomes a memory list when writing comments and is easier

- 
- read later. Would also like to get information from the X-ray remittance into the comment column automatically.
  - Some of the examinations are rarely done, those usually have a guide of how to prepare and perform them. It would be useful to have a link to a PDF in InVision when one of these are planned.
  - Would like to be able to search for a patient that is booked. This would be useful if a patient comes in acute and has been booked before. Searching using the patient ID only would be sufficient.
  - Deviating e-GFR should be marked in some way to stand out.
  - If the X-ray remittance should be retrieved automatically it would be useful to know if the X-ray remittance is acute or sub-acute or elective. Somewhere on the screen there should be stated if there are remittances waiting to be prioritized in InVision. May also like to export the priority made in InVision to the remittance system.
  - Archive:
    - Would like to filter on modality type and examination type in filters.
    - When choosing a time interval, it would be useful to be able to click and drag over the dates you would want to be marked.
  - Viewing an examination:
    - Make the check boxes to mark the thumbnails bigger.
    - Would want to hold shift and be able to select many images at once.
    - When exporting images and anonymizing the data for a study there is a need to be able to change fields of the patient (to fill in for example test subject number, study number, and keep some parts of the patient information).

Confusions arose around the inconsistency of not being able to click on the row of a patient in the work list but in the archive. Confusion also arose when marking images to be exported as the check boxes were too small to notice for many of the users. As they were so small it was also not clear whether they were filled in. Small moments of confusion in group C arose around the difference of an examination and a patient and some questions were asked to understand the workflow of PCI labs better. When editing patient information, some confusion around if the patient information of all the examinations would be changed or just the latest, which was a good question and had not been thought through all the way.

The colours of the design were appreciated by the majority of the participants. Partly because the yellow made for good contrast to the dark blue background. The feedback gotten was that the dark blue could be toned down to a more neutral colour.

One participant liked the aesthetics of the grey/blue tones, as it gave a calmer impression. Though, it was also said that the stronger contrast of blue and yellow makes it easier to find what is clickable and therefore more “user friendly”. The participant added, “in these kinds of systems it is more important that it is user friendly”.

Four participants liked the aesthetics of the dark blue/light blue, but the low contrast between the two colours made it harder to find important buttons, similarly to the grey and blue design.

One participant did not like the yellow as it was “garish” and gave the “impression that it was an older system”. Another participant said it was too much colour overall and should be toned down to look more professional. Contrary, a third participant said that yellow is a warning signal to him, which is good for example the button “Start acute”.

### 8.5.2 SUS score

As described in chapter 2.5.3 *System usability scale*, the SUS score ranges from 0 to 100 where an average SUS score is 68, see figure 8.5 [30].

The SUS score was calculated from the ten first questions of the SUS-form that was handed out. The eleventh question was naturally left out from the calculation of the SUS. The result is given group by group in table 8.3.

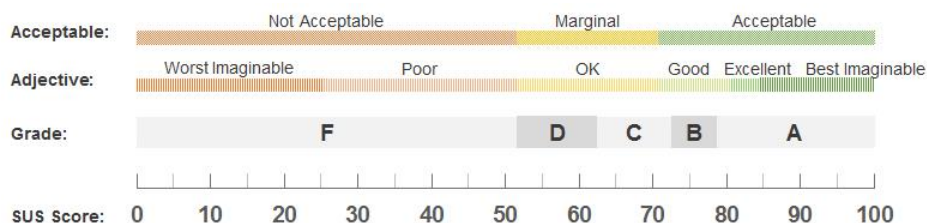


Figure 8.5 Above are three interpretations of SUS score [30].

Table 8.3 Result of the SUS score from each test participant and the group mean.

Group	Test participant 1	Test participant 2	Test participant 3	Test participant 4	Group mean
A	90	82.5	100	95	<b>91.875</b>
B	90	97.5	87.5	90	<b>91.25</b>
C	85	90	97.5	100	<b>93.125</b>

The statements that were overall rated in the most positive way was number two and eight. This means that participants almost fully agreed with “I found the system very cumbersome to use” and fully disagreed with “I found the system unnecessarily complex”.

On the other hand, the two questions the participants rated in the most negative way was number four and five. All participants did not rate that they fully disagree with “I think that I would need the support of a technical person to be able to use this system”. Neither did all fully agree with “I found the various functions in this system were well integrated”.

### 8.5.3 Workflow

The eleventh statement that was added to the SUS form was “*I feel that InVision’s functions fit well into my workflow*”. It was only answered by users that work daily at PCI labs. Others were deemed unfit to answer since they do not know the workflow.

**Table 8.4** Result of the added question in the SUS form where one corresponds to “Fully disagree” and five corresponds to “fully agree”.

	<i>List of individual results</i>	<i>Mean</i>
<b>Group A</b>	5, 5, 5, 4	4.75

## 9 Discussion

*In this chapter different parts of the thesis are discussed to give nuance and reflection upon the work. The design process and user study are discussed from different points of views. The parts of the high-fidelity prototype that are not technically viable at the moment of writing this thesis are described, together with future work.*

### 9.1 Design process

As described in related works, Drummond et al [13] found that the complexity of existing healthcare structures means that a positive change in one hospital might not provide the same benefit for another. Because of this, it was important to work with participants from more than one hospital when discovering requirements. Only two out of the five hospitals Bildtechnik deemed most likely to partake chose to do so. This might have been because of the strained situation in the healthcare because of the ongoing COVID-19 pandemic combined with a low priority to redesign InVision's UI.

Having more than one participant and more than one workflow provided good triangulation together with a few other factors. Different professions were used in the data gathering: nurses, physicians, and engineers. This provided different entry angles to the workflow. A physician could give a more detailed description of the preferred UI while a nurse could give relevant points of patient safety and an engineer had a deeper insight in the technical details of the systems, making it possible to give an understanding of the connecting systems to InVision.

Three different methods to gather data were used which also provided different perspectives. The observation provided an understanding of the workflow that was not attained through the many and lengthy interviews. The interviews however did provide an insight into InVision's points of improvement and new functions. The SUS questionnaire used in the user study allowed the participants to be anonymous, which hopefully provided true answers. Although it is possible that the participants that were all friendly and polite did not want to give a bad grade as to not upset the writer.

During the interviews, the participants were encouraged to go off topic. This generated much data that needed to be sorted through in the affinity diagram, which was time consuming. However, it allowed the subject to think freely and not be limited in what needs they expressed. This showed as needs that could be met by an entire new product or module in InVision were discovered.

The design process was conducted by only one person and not a team of different individuals and professions which had its advantages and disadvantages. It was likely more time and cost efficient to



be alone. Design decisions were made quickly as there was no need for discussion. There was neither any time spent on updating different parts of the team on the progress.

Although, being a design team would have given broader competence, more perspectives, and opinions. It is possible that the design is biased towards the writer. An example is the affinity diagram as the voting dots could not be performed. It is worth to mention that the design has been discussed on several occasions with Bildteknik staff. However, one could argue that as there were less opinions in the design team, the opinions of the users were given more room.

The ideation was rather lean and could have been elaborated. This had to do with time restraints, as the data gathering process took longer than expected. To elaborate ideation, more cycles of ideation could have been done to refine the suggested solutions at the end of each branch in the mind mapping. These suggestions could also have been discussed together with Bildteknik staff to utilize their expertise.

During the interviews, no physician at SÖS was available. The engineer being interviewed passed along relevant questions to physicians. Unfortunately, this meant that there was no one to represent SÖS in the matter of technology stress as this was not deemed to be of great importance. At Gävle Hospital most of the interviews were conducted with one physician. One more physician was requested to get more than one perspective on the technology stress. As both physicians independently agreed that technology stress was not an issue in their work environment the matter was not further investigated.

## 9.2 Evaluation

The user study was constructed to give insight in how well the prototype fits in to the PCI lab workflow and to uncover any significant issues. According to Nielsen [26] testing on only five users is the most resource efficient way to discover most usability problems. The usability test was performed on four participants that work in PCI labs. As this was the final test for the hi-fi prototype, as many usability problems as possible was wanted to be discovered, so the testing was performed on additionally eight participants. Looking at the results in figure 8.1-4, the participants from group A performed the tasks in similar ways as group B and C. The same can be seen in the SUS form. In the interviews some additional comments were given from group B and C, but the most valuable insights came from group A. It is therefore questionable if it was needed to test on twelve participants. Maybe it would have been more useful to have one more iteration of a prototype and only test on group A, as the tests and following analysis was time consuming.

Other types of testing could have been performed to generate insight in the hi-fi prototype in comparison to the current design of InVision. One example is *Within-Subject Protocol*, where participants test both UI's to determine which one is preferred [56]. This type of testing was disregarded as new participants would have needed to be found as the participants of the design process likely would have been biased towards the new design. During the ongoing COVID-19 pandemic, it was deemed too difficult to attain enough relevant participants as there was a ban on visitors on many hospitals in Sweden and many healthcare professionals were under a lot of pressure, including PCI labs. It would also have been challenging to create scenarios that would suit both UI's and still evaluate the many new functions added to the hi-fi prototype.

The hi-fi prototype had a lot of functions that had not been implemented. This made it somewhat hard to test the users' workflow as for example starting and stopping an examination was not possible. It was however not reasonable to implement all functions and modalities of InVision during the limited time of this thesis. As written in chapter 5. *Discovering requirements*, only *InVision Viewer* and the worklist part of *InVision Control* was implemented as these were deemed most important to redesign.

The testing could have been improved to better resemble the natural environment of using InVision. For example, the test should have been performed with a screen the size of the users regular viewing station, as the prototype was designed for. Some of the test persons used a laptop which has a significantly smaller screen which made the text and icons smaller. The test could also have been performed in the room where the user usually views images to get the correct lighting and to include some outside distractions. This would give a more realistic result of the usability test.

One main request from the participants was to change the design as little as possible. Changing as little as possible would mean that the users would not have to re-learn the system. It was hard to find the balance to not change too much of the existing design but at the same time keeping an open mind of what the design should be as to not get stuck in old patterns. The design has changed a lot in some respects which showed in the usability testing as there was not any significant difference between the results of group A compared to group B and C. On the other hand, none of the old functions have been removed. Comparing the current design in figure 7.1, 7.3 and 7.5 to the corresponding views in figure 7.12-14, one can still recognize similarities. Further on, you could argue that new users will learn the new design of InVision quick, as there was little difference in the test results between the participants that had used the system before and the participants that had not, together with the fact that a lot from the current design is kept which should mean that the participants that have used InVision before should be more familiar with the system.

### 9.2.1 Test results

Looking at the test results there is a clear relationship between rising age of the participant and their failure rate and number of confusions. There is also a connection between the age and number of wrong clicks. It probably comes as no surprise that age and comfort in digital systems is related in many cases. According to Kane [57] testing showed that peoples' ability to use websites declined by 0.8% per year between the age of 25 and 60. All participants under the age of 39 had a failure rate of zero, however two of the seven participants over the age of 39 had a failure rate of zero. Younger participants are likely to have more experience with using different digital systems. They will therefore adapt faster to new ones and find patterns that resemble systems they have used before.

Looking at the results, one can see that task 3.2 was hardest to complete, regarding all four parameters. Why so many struggled to mark and export three images had to do with the small checkboxes in combination with the screen that was smaller than intended. Some people also struggled to find the export button, after being flustered with marking the images. The issue of marking images can be solved by using a screen size that the design is intended for, making the checkboxes larger and finding alternative ways to achieve the goal. There were two alternative ways that the participants tried and could be implemented. Pressing the Ctrl key and marking multiple images by using the arrow keys or by clicking and dragging the mouse.

Task 2.1 generated many wrong clicks and task 1.4 generated many confusions. In task 2.1 almost every participant tried to search for an interval by first clicking on the first date the interval should span from. What would happen by doing this is that only the date chosen is searched. What they should have done is first click in the square where the current interval begins, to choose where they would like the interval to begin. Most of the participants quickly understood that this is what they must do. The UI could nonetheless benefit from discovering other options. Task 1.4, where the participants were asked if they could find alternative ways to a specific patient's past examinations generated confusion in five of the participants. However, most of these participants had no to little issue with finding the past examination in the task before, making this a lesser of a concern as the important thing is that they easily can find a patient's past examinations.

Judging from the results, it was fairly intuitive to navigate between the different tabs, find a patient's former examinations and opening them, and to navigate the different functions when viewing a patient, apart from exporting images. None of these tasks generated much confusion or wrong clicks.

### 9.2.2 SUS results

Each one of the mean SUS scores from the three groups ends up in the highest category in all three interpretations of SUS score in figure 8.5. Looking at the individual scores all are well above the mean SUS score of 68 and end up in the grade A or "Excellent" to "Best imaginable" as adjectives.

This could be because most of the test participants had a personal relationship with the tester as group B and C mainly consisted of acquaintances and co-workers. However, when comparing the mean of group A which is 91.875 it is only marginally lower than group B and C's mean that is 92,188.

Looking at the individual questions of the SUS questionnaire, the two statements that was rated most positively had to do with the system being easy and not unnecessary complex to use. Since this is a system that is occasionally used in high stressed situations and by multiple people, it is important that the system is perceived as easy to use. The statements rated most negatively had to do with needing technical support to use the system and whether the systems' functions were well integrated. It could be mentioned that all participants in group A answered that they fully disagreed that they would need technical support, so this result could have to do with the participants in group B and C not understanding the workflow of a PCI lab. Whether the systems' functions are well integrated might be more serious, as one participant in group A answered that they almost fully disagree. Another participant in group A answered that they fully agree so there seems to be a disagreement within the group. One explanation to the low score might be the inconsistency of how to go to patient's past examinations in the worklist and in the archive.

The added statement regarding the workflow that was only answered by group A also had good responses. Of course, participants from both hospitals have had big influence on the design, but they have also had conflicting needs and wishes. This points towards that this design could fit well into other hospitals workflows as well but would need further user testing to be confirmed.

There are possible sources of errors associated with the test, SUS and the prototype itself. Since the prototype had limitations in what elements the user could interact with or not the experience of using the prototype is limited. Additionally, when clicking outside any element that is not clickable, the

prototyping tool Figma will briefly highlight clickable elements. This could give the user a hint on how to move forward and therefore improve the test results. Further, this could interfere with the test persons experience of the usability of the system.

### 9.3 Technically not viable at this moment

Some of the needs expressed by the users are not technically viable at this moment. The solutions to some of the needs would need a great deal of development. This does however not mean that it cannot be implemented in the future, but it should be carefully considered if the cost of doing so is justifiable.

A patient's examination history cannot be retrieved from other hospitals through InVision. It is possible to retrieve them on request if the other hospital also have InVision, but it does not happen automatically.

e-GFR cannot be calculated in InVision and it can neither be retrieved from another system at this moment. There are challenges with both options. If InVision would calculate the e-GFR it might make InVision classified as a higher safety risk according to the Medical Device Regulation [58]. This could mean that Bildtechnik would have to implement costly methods to be in compliance with the Medical Device Regulation. If InVision would only retrieve the e-GFR from another system this might not be necessary, but development challenges could arise if the system calculating e-GFR is not fit to communicate with other systems.

The X-ray remittance cannot be retrieved to InVision at this moment. Here, the question of what will be sufficient arose. If it is enough to retrieve it just once as a PDF or if it should be updated as the X-ray remittance is updated. It is also not entirely answered if InVision should retrieve it automatically and notify the user or if the user should manually retrieve it.

Pausing and then resuming an examination could prove demanding. InVision can work as a modality worklist and the main drawback of a modality worklist is their passive nature. When a modality, for example an X-ray machine has pulled the patient information from InVision this data cannot be deleted or edited [59]. What might prove difficult is to have the two parts of the examination, the one before and the one after the pause, to be seen as one examination according to DICOM standards.

### 9.4 Future work

During this thesis, the focus has been on the functionality of the system. Some thought has gone into the UI as well, but this could be further developed. Especially as participants said the colour choice was "user friendly" but did not look aesthetically appealing or professional. Different colour combinations could be explored, and more colours could be used to create more depth in the program. Other UI elements such as buttons and font could also be evaluated further to possibly make the system more enjoyable to the eye.

Coming back, for the last time, to Drummond et al [13] describing what might provide a benefit to one hospital, might not provide the same for another. It would be interesting to test the hi-fi prototype on

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other hospital's PCI labs. It could be tested on other hospitals in Sweden that does not have InVision already in their workflow to evaluate how well InVision could be incorporated and if the functions in InVision would be useful. It could also be tested on PCI labs in other countries. Some of the added functions might not be useful for hospitals in other countries. This could partly have to do with other standards of procedure and other systems used. For example, other countries use other journal systems. Cultural differences might also affect how well the hi-fi prototype is perceived. One of Bildteknik's biggest sale regions is the United Arab Emirates [11]. As Arabic is read from right to left, the Z and F pattern described in chapter 2.3 *Visual hierarchy* might not representative of these users' eye scanning pattern.

Looking at the feedback from the evaluation, the participants still see possibility of improvement. There are many smaller adjustments that could be made to the hi-fi prototype and it would serve Bildteknik to make at least one more iteration before implementing the design. There are also questions that remain unanswered, that would need to be answered to successfully implement the design of the hi-fi prototype. Some examples are given below:

- How should and can information be transferred to SCAAR?
- What should happen in the UI when an examination is started, paused, and finished?
- How should e-GFR be transferred or calculated and viewed in the UI?
- In what order should thumbnails be listed? Chronologically or listed in what modality and then time?
- How to add examinations to folders? The original idea was to do it after an examination, but it should also be possible to edit afterwards.

This thesis also generated the possibility of a new concept for Bildteknik, a booking list that would be incorporated in InVision. The booking list would display the list of patients for today and possibly some time ahead. It could be used instead of the whiteboard where planning of the different lab rooms and personnel is done today. The booking list could also give information of the patient's information and status. It could also be used as a communication tool between the PCI lab and other departments such as HIA where patients are normally brought from before and taken to after an examination.

The needs for a booking list come mainly from SÖS. Looking at the information flowchart in figure 5.3, implementing the hi-fi prototype could serve as an interstage between the whiteboard and the booking list. The needs of information stated in the flowchart are fulfilled by the hi-fi prototype, however there are other needs such as making it suitable for a large screen. The implementation could at least serve as an evaluation of the information before developing the booking list.

## 10 Conclusion

*In this final chapter the conclusions this thesis generated are presented in the form of answers to the research questions.*

### **What flaws does healthcare professionals experience with InVision today and how can these be improved?**

The frustrations regarding InVision were mainly about the UI being unintuitive and providing insufficient information. Both an intuitive UI and provision of relevant information can be created by principles of UX design. By understanding the context of which the system is used and the users' needs, relevant information to provide the user with was found. When designing the UI, design principles such as Normans was followed. Usability testing of the prototypes determined the usability of the final prototype to be the best imaginable.

### **What additional needs do healthcare professionals in PCI labs have that can be integrated into InVision, for example to reduce technology stress, streamline or increase the quality of work?**

As mentioned, there was a need for more information relevant to the workflow to be shown in InVision. Displaying information such as e-GFR, the X-ray remittance, planned examination type and whether any patient has been paused will provide necessary tools for the user to prioritize examinations. Displaying where patients are and free text comments that can be filled in by other departments will serve as a communication tool between departments, for example by eliminating the need for some calls between PCI labs and cardiac intensive care units.

Having relevant information about past examinations, both when searching for them and viewing them will make reviewing old examinations easier and more time efficient. Having a more flexible way of searching for a patient will enable physicians to easier find past examinations. Utilizing the screen better when viewing an examination will make it easier to get a better overview of the patient and their past examinations and thereby faster to find images of interest.

### **What functionalities in InVision are not desirable?**

None of the current functionalities in InVision was deemed undesirable.

### **How can InVision be redesigned to help users avoid unnecessary work by exploring other systems that to some extent overlap with InVision in PCI labs?**

By incorporating information into InVision from other systems, unnecessary work can be avoided and a more streamlined workflow can be created. As described above, by incorporating e-GFR and the X-ray remittance, prioritizing patients become more streamlined. If information from InVision could later

be transferred to SCAAR and maybe even the journaling system, it would save physicians time for each examination.

By enabling the user to anonymize the screen, it becomes easy for the user to share past examinations with other healthcare professionals over digital communication tools without the risk of compromising patient information.

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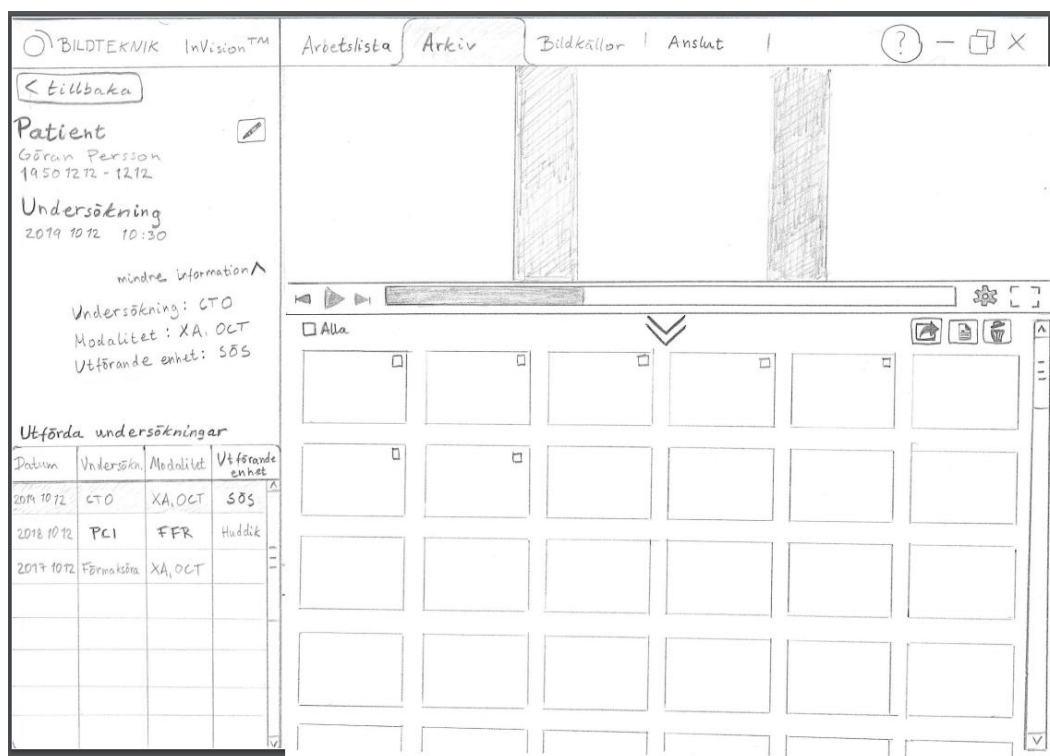
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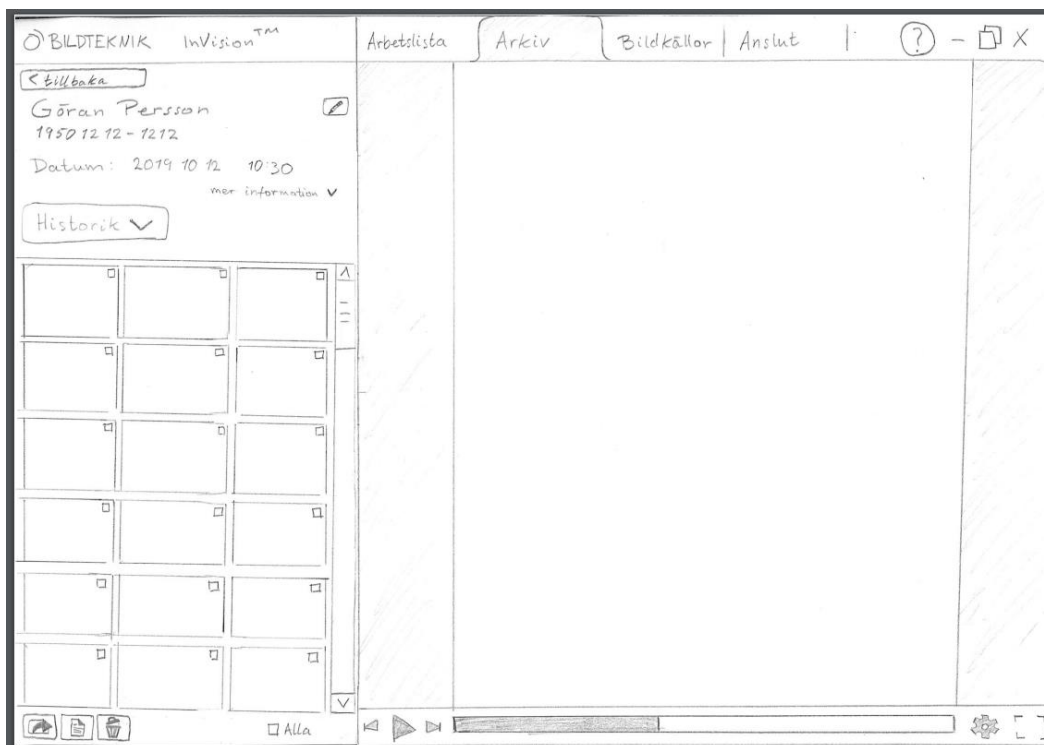
# Appendix A - Low fidelity prototype

## Versions of viewing the patient

Below is version A of the lo-fi prototype, showing one patient's examination. Here, the arrows in figure 7.6 have been clicked to show more thumbnails.

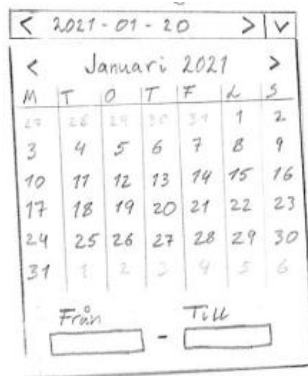


Below is version C of the lo-fi prototype, showing one patient's examination. The difference from version B in figure 7.7, is that past examinations can be found by clicking the "History" button. This allows for more thumbnails to be viewed.



## Drop down menu

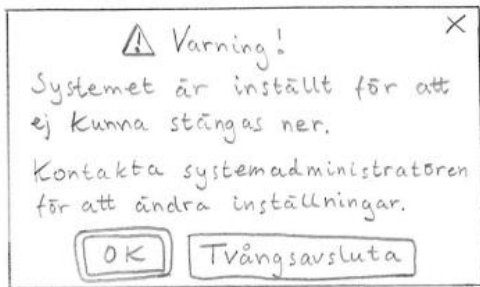
The drop-down menu of choosing date or date interval of examinations the archive (see figure 7.4):



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## Pop-up window

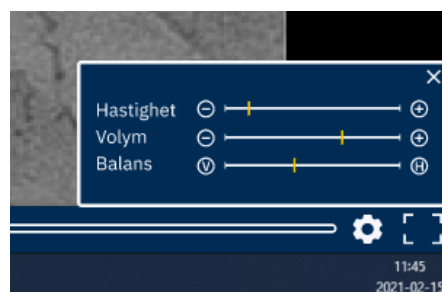
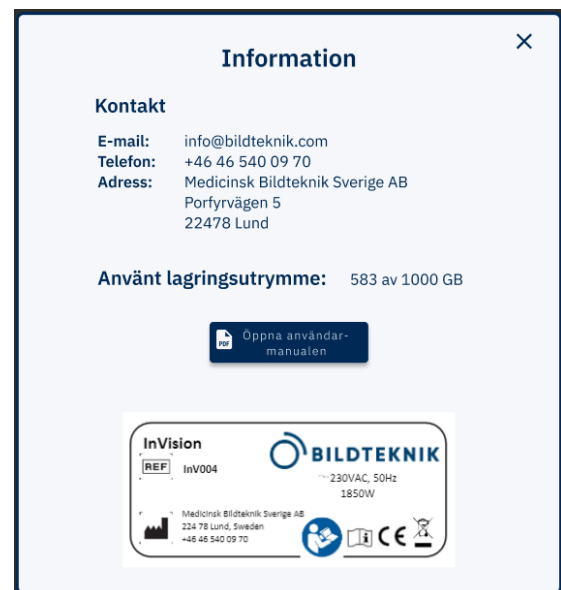
Below are the two versions of sterner pop-up windows designed to prevent the user from closing the system.



# Appendix B – High fidelity prototypes

## Pop-up windows

Below, to the left is the window that pops up when clicking the export button when viewing a patient. To the right is the window with information that pops up when clicking the question mark in the design. Below these two, in the middle are the controls for image and sound which come up when clicking the gear icon.





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## Date interval

Below is the flow of choosing what interval of dates to search for in the Archive (see figure 7.12). To the left the pre-set interval is shown. When clicking the early interval box, the middle figure will come. The right figure shows when the user has clicked on the 17<sup>th</sup> of march in the calendar.



## Colour versions

Below follows six figures. Three figures of the grey/light blue version and three figures of the dark blue/light blue version. In each version, the view of past examinations, the archive and the worklist is presented.

The screenshot displays a medical software interface with a patient history table on the left and a large angiogram image on the right. The patient's name is Göran Persson (1949-01-20 - 1212). The table lists various examinations from 2014 to 2019, including CTO, PCI, Formaksöra, and PACE, with details on the modality, performing unit, and comments. Below the table is a grid of 20 thumbnail images representing past examinations. The main image is a large angiogram showing a coronary artery with a stenosis. The interface includes navigation buttons and a timeline at the bottom.

Datum	Undersökning	Modallitet	Utförande enhet	Kommentar	Spec-fall
2019-10-12 10:30	CTO	OCT, XA	SÖS, gut		
2018-09-11 11:27	PCI	FFR	Huddik	Perforationsaneurysm i vänstra...	
2017-08-10 12:24	Formaksöra	OCT, XA	Gävle PCT		
2016-07-09 13:21	PACE	FFR, OCT, XA	SÖS, blå	Pat. blev lugnad av Malena Erman	
2015-06-08 14:18	CTO	XA, OCT	SÖS, gut		
2014-05-07					

Arbetslista Arkiv Bildkällor Anslut

BILDTÉKNIK InVision

Namn Personnummer Undersökningsdatum Filtrera  
 2021-03-04 2021-03-18 Alder Køn Rensa sökfil

Alla fall Uppsala Intressanta fall Forskningsprojekt xx

Förnamn	Efternamn	Personnummer	Datum	Modalitet	Undersökning	Enhet	Kommentar
Stefan	Löfven	1957 07 21 - 1313	2021-03-18 10:30	OCT, XA	CTO	SÖS, gul	
Fredrik	Reinfeldt	1965 08 04 - 1313	2021-03-18 9:30	FFR	PCI	Huddik	
Göran	Persson	1949 01 20 - 1212	2021-03-17 15:20	OCT, XA	Förmaksöra	Gävle PCI	Studie xxx
Ingvar	Carlsson	1934 11 09 - 1919	2021-03-17 14:50	FFR, OCT, XA	PACE	Gävle PACE	
Nils Daniel Carl	Bildt	1949 07 15 - 1818	2021-03-17 10:30	XA, OCT	CTO	SÖS, blå	
Ingvar	Carlsson	1934 11 09 - 1919	2021-03-17 08:30	OCT, XA	CTO	SÖS, gul	Lång pat (2,03 m)
Olof	Palme	1927 01 30 - 1010	2021-03-16 23:07	FFR	PCI	Huddik	
Thorbjörn	Fälldin	1926 04 24 - 1616	2021-03-16 14:10	OCT, XA	Förmaksöra	Gävle PCI	
Ola	Ullsten	1931 06 23 - 1717	2021-03-16 12:45	FFR, OCT, XA	PACE	Gävle PACE	Intressant fall pga xxxx
Tage Fritjof	Erlander	1901 06 13 - 1212	2021-03-16 11:10	XA, OCT	CTO	SÖS, blå	
Bo Östen	Undén	1886 08 25 - 1515	2021-03-16 09:10	OCT, XA	CTO	SÖS, gul	
Per Albin	Hansson	1885 11 28 - 1616	2021-03-16 07:45	FFR	PCI	Huddik	
Axel	Pehrsson-Bramstorp	1883 08 19 - 1313	2021-03-15 18:55	OCT, XA	Förmaksöra	Gävle PCI	
Felix	Hamrin	1875 01 14 - 1818	2021-03-15 15:00	FFR, OCT, XA	PACE	Gävle PACE	

11:45 2021-02-15

Arbetslista Arkiv Bildkällor Anslut

BILDTÉKNIK InVision

Arbetslista Starta akut Registrera ny

Prio	Planerad undersökning	Förnamn	Efternamn	Personnummer	eGFR (mL/min)	Avdelning/sängnummer	Remiss	Historik	Kommentar
Startad	CTO	Annie	Löf	1983 07 16 - 1616	71	HIA, säng 4	Öppna	Öppna (0)	Lab xx
1	PCI	Göran	Persson	1949 01 20 - 1212	64	HIA, säng 7	Öppna	Öppna (12)	Lab yy, Tolk
2	Förmaksöra	Stefan	Löfven	1957 07 21 - 1313	68	HIA, säng 2	Öppna	Öppna (4)	
3	PCI	Ebba	Busch Thor	1987 02 11 - 1919	47	Huddik	Öppna	Öppna (0)	Vätskas upp, vä ljumske, positiv Covid-19...
4	PCI	Nyamko	Sabuni	1969 03 31 - 1818	63	Avdelning 5	Öppna	Öppna (5)	Studie xxx
5	CTO	Ulf	Kristerasson	1963 12 29 - 1313	64		Öppna	Öppna (1)	Lång pat (2,03 m)
6	Välj	Jonas	Sjöstedt	1964 12 25 - 1010		Beräkna	Öppna	Öppna (0)	
7	Välj	Jimmie	Åkesson	1979 05 17 - 1616		Beräkna	Öppna	Öppna (12)	Rädd för nålar, Tolk
8	Välj	Per	Bolund	1971 07 03 - 1717		Beräkna	Hemma	Öppna (0)	
9	Välj	Isabella	Lövin	1963 02 03 - 1212		Beräkna	Hemma	Öppna (3)	Bor i Gävle
10	Välj	Olof Anders	Wedin Johnsson	1961 06 24 - 1515		Beräkna	Öppna	Öppna (1)	Planerad för lördag
Avslutad	PCI	Göran	Hägglund	1959 01 27 - 1616	72	HIA, säng 16	Öppna	Öppna (12)	Lab xx, Tolk
Avslutad	PACE	Håkan	Juholt	1962 09 16 - 1313	65	HIA, säng 3	Öppna	Öppna (3)	
Avslutad	CTO	Mona	Sahlén	1957 03 09 - 1818	80		Öppna	Öppna (1)	

11:45 2021-02-15

Arbetslista Arkiv Bildkällor Anslut BILDTEKNIK InVision

Bakåt

Göran Persson  
1949 01 20 - 1212

Datum	Undersökning	Modalitet	Utförande enhet	Kommentar	Spec-fall
2019-10-12 10:30	CTO	OCT, XA	SÖS, gul		
2018-09-11 11:27	PCI	FFR	Huddik	Pseudoaneurysm i vänstra...	
2017-08-10 12:24	Förmaksöstra	OCT, XA	Gävle PCI		
2016-07-09 13:21	PACE	FFR, OCT, XA	SÖS, blå	Pat. blev lugnad av Malena Erman	
2015-06-08 14:18	CTO	XA, OCT	SÖS, gul		
2014-05-07					

Markera alla

Göran Persson 19490120-1212

11:45 2021-02-15

Arbetslista Arkiv Bildkällor Anslut BILDTEKNIK InVision

Namn Personnummer Undersökningsdatum Filtrera

2021-03-04 2021-03-18 Ålder Kvin Rensa sökfält

Alla fall

Uppsala

Intressanta fall

Forskningsprojekt xx

Förnamn	Efternamn	Personnummer	Datum	Modalitet	Undersökning	Enhet	Kommentar
Stefan	Löfven	1957 07 21 - 1313	2021-03-18 10:30	OCT, XA	CTO	SÖS, gul	
Fredrik	Reinfeldt	1965 08 04 - 1313	2021-03-18 9:30	FFR	PCI	Huddik	
Göran	Persson	1949 01 20 - 1212	2021-03-17 15:20	OCT, XA	Förmaksöstra	Gävle PCI	Studie xxx
Ingvar	Carlsson	1934 11 09 - 1919	2021-03-17 14:50	FFR, OCT, XA	PACE	Gävle PACE	
Nils Daniel Carl	Bildt	1949 07 15 - 1818	2021-03-17 10:30	XA, OCT	CTO	SÖS, blå	
Ingvar	Carlsson	1934 11 09 - 1919	2021-03-17 08:30	OCT, XA	CTO	SÖS, gul	Lång pat (2,03 m)
Olof	Palme	1927 01 30 - 1010	2021-03-16 23:07	FFR	PCI	Huddik	
Thorbjörn	Fälldin	1926 04 24 - 1616	2021-03-16 14:10	OCT, XA	Förmaksöstra	Gävle PCI	
Ola	Ullsten	1931 06 23 - 1717	2021-03-16 12:45	FFR, OCT, XA	PACE	Gävle PACE	Intressant fall pga xxx
Tage Fritjof	Erlander	1901 06 13 - 1212	2021-03-16 11:10	XA, OCT	CTO	SÖS, blå	
Bo Östen	Undén	1886 08 25 - 1515	2021-03-16 09:10	OCT, XA	CTO	SÖS, gul	
Per Albin	Hansson	1885 11 28 - 1616	2021-03-16 07:45	FFR	PCI	Huddik	
Axel	Pehrsson-Bramstorp	1883 08 19 - 1313	2021-03-15 18:55	OCT, XA	Förmaksöstra	Gävle PCI	
Felix	Hamrin	1875 01 14 - 1818	2021-03-15 15:00	FFR, OCT, XA	PACE	Gävle PACE	

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Arbetslista Arkiv Bildkällor Anslut 🔔 🔄 BILDTEKNIK InVision™ 🏠 ✖

Arbetslista ⚠️ Starta akut ➕ Registrera ny

Prio	Planerad undersökning	Förnamn	Efternamn	Personnummer	eGFR (mL/min)	Avdelning/sängnummer	Remiss	Historik	Kommentar
Startad	CTO	Annie	Löf	1983 07 16 - 1616	71	HIA, säng 4	Öppna	Öppna (0)	Lab xx
1	PCI	Göran	Persson	1949 01 20 - 1212	64	HIA, säng 7	Öppna	Öppna (12)	Lab yy, Tolk <span>🔔 Starta</span>
2	Förmaksöra	Stefan	Löfven	1957 07 21 - 1313	68	HIA, säng 2	Öppna	Öppna (6)	
3	PCI	Ebba	Busch Thor	1987 02 11 - 1919	47	Huddik	Öppna	Öppna (2)	Vätskas upp, vä ljumske, positiv Covid-19...
4	PCI	Nyamko	Sabuni	1969 03 31 - 1818	63	Avdelning 5	Öppna	Öppna (5)	Studie xxx
5	CTO	Ulf	Kristersson	1963 12 29 - 1313	64		Öppna	Öppna (1)	Lång pat (2,03 m)
6	VRI	Jonas	Sjöstedt	1964 12 25 - 1010			Beräkna	Öppna	
7	VRI	Jimmie	Åkesson	1979 05 17 - 1616			Beräkna	Öppna (12)	Rädd för nålar, Tolk
8	VRI	Per	Bolund	1971 07 03 - 1717		Hemma	Beräkna	Öppna (0)	
9	VRI	Isabella	Lövin	1963 02 03 - 1212		Hemma	Beräkna	Öppna (3)	Bor i Gävle
10	VRI	Olof Anders	Wedin Johnsson	1961 06 24 - 1515			Beräkna	Öppna (1)	Planerad för lördag
Avslutad	PCI	Göran	Häglund	1959 01 27 - 1616	72	HIA, säng 16	Öppna	Öppna (12)	Lab xx, Tolk
Avslutad	PACE	Håkan	Juholt	1962 09 16 - 1313	65	HIA, säng 3	Öppna	Öppna (1)	
Avslutad	CTO	Mona	Sahlén	1957 03 09 - 1818	80		Öppna	Öppna (1)	

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## Appendix C – System usability form

The SUS form below was used in the user study to evaluate the hi-fi prototype. The form consists of the 10 standard questions of a SUS form translated to Swedish and one added question to evaluate how well the design fits in with the workflow at PCI labs.

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## SUS-enkät (System Usability Scale) - InVision

Dina svar är anonyma och gäller den design av InVision som du just testat.

	<b>Håller inte med alls</b>				<b>Håller med helt</b>
1. Jag tror att jag vill använda InVision regelbundet.	1	2	3	4	5
2. Jag tycker att InVision är onödigt komplext.	1	2	3	4	5
3. Jag tycker att InVision är enkelt att använda.	1	2	3	4	5
4. Jag tror att jag behöver stöd av någon teknisk kunnig person för att kunna använda InVision.	1	2	3	4	5
5. Jag tycker att de olika delarna i InVision är välintegrerade.	1	2	3	4	5
6. Jag tycker att det är för mycket inkonsekvens i InVision.	1	2	3	4	5
7. Jag tror att de flesta snabbt skulle lära sig detta system.	1	2	3	4	5
8. Jag tycker att InVision är besvärligt att använda.	1	2	3	4	5
9. Jag känner mig trygg i att använda InVision.	1	2	3	4	5
10. Jag kommer att behöva lära mig många nya saker innan jag blir produktiv med InVision.	1	2	3	4	5
11. Jag känner att InVisions funktioner passar väl in i mitt arbetsflöde.	1	2	3	4	5