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# Visualization of Positioning Data in a Clinical Setting

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Til mamma og pappa



# Abstract

The use of indoor positioning systems (IPS) is seen as a promising way to support coordination of activities in hospitals. Despite this, little work has been done when it comes to how the data from indoor positioning systems should be visualized to the users.

By conducting a case study of a specific work practice at Aker University Hospital in Oslo we have designed visualizations with the aim of investigating the amount of information richness these should have in order to support coordination work. We have also been interested in investigating whether the approach that we have used in this thesis made it possible for the users to use the visualizations in their everyday work, and if it is possible for the users to give informative assessments of them. As little relevant theory exists on how visualizations should be designed we have used methods from the field of usability engineering, and have designed the visualizations as paper prototypes. These have been user tested by test persons with both direct and indirect knowledge about the coordination of activities at the specific work practice.

Our work shows that visualizations that had a high degree of information richness were favored. In addition, the possibility to move between different types of visualizations based on the need for information were seen as especially attractive. The test persons that we recruited were able to give informative assessments of the prototypes, but as these were both tailor-made for a specific work practice and tested using simulated scenarios they had a high learning curve. Based on the results from our work we see usability engineering methods as suitable when designing visualizations, although some of them should be left out or modified to fit in with the project in question.

**Keywords:** visualization, usability engineering, computer-supported cooperative work, coordination, indoor positioning systems, health care



# Preface

This thesis is the result of one year of work, and marks the end of my Master studies in Computer Science with a specialization in Systems Engineering and Human-Computer Interaction. The thesis has been written for the COSTT-project, a multi-disciplinary research project initiated by The Research Council of Norway.

First of all I would like to thank my supervisor, associate professor Pieter Jelle Toussaint, and co-supervisor, Ph.D. Andreas Røsland Seim, for their advice and guidance throughout the year. It has been a pleasure to work with you both.

I would also like to thank the three persons from Aker University Hospital and St. Olavs Hospital who have provided me with information about their work challenges, served as test persons, and have been the main motivation for writing this thesis. I cannot thank you enough for your open and welcoming attitude. Alexander Nossun and Børge Lillebo should be thanked for the discussions we have had on the topic of this thesis in the last year.

I have spent the last year with 13 other Master students at the computer lab Gribb at NTNU. You have all been a great motivation during the year, and I hope we will keep in touch even after we are finished with our studies.

Last but not least, I would like to thank my family and friends for their support during my time as a student - you know who you are. I would not be writing this today if it were not for you.

Trondheim, June 2009

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Hans Petter Eide





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# Chapter 1

## Introduction

We will in this chapter present background information about the problems that hospitals face in relation to coordination of activities. Based on this we present the motivation for our work in this thesis. This motivation is then broken down into the research questions that we seek to find answers to, along with limitations on what we will cover. To give the reader an overview of the contents of the thesis we will in the end of the chapter present the structure of this report.

### 1.1 Background

Hospitals are large and complex organizations, and hospital work often requires concerned effort of a number of roles, actors and organizational units. Efficient patient treatment and resource utilization in such environments require coordination. However, effective coordination of hospital work is difficult in the face of the high complexity coupled with the large variation often found in health care processes.

One promising approach to solving this problem is to develop ICT-solutions that support coordination and collaboration in health care. Traditional workflow approaches have not been successful in doing this. A seemingly more promising approach to support coordination is to develop systems that provide health care workers with awareness.

The latter approach is that of a multi-disciplinary health project named Co-Operation Support Through Transparency (COSTT). The main objectives of COSTT are:

1. To enable flexible “just-in-time” coordination of work in a highly collaborative and dynamic work environment, such as the perioperative domain, with the aim of increasing the efficiency, and to
2. ...achieve this by creating a shared work space that gives all actors involved in the collaboration real-time insight into the work process, for example its progress and possible deviations from the expected course, and to
3. ...derive this insight automatically from samples of data obtained from the work environment by means of sensor and monitoring devices.

COSTT is funded by The Research Council of Norway’s VERDIKT program, and the partners of the project are NTNU, SINTEF, Aker University Hospital, St. Olavs Hospital, Hemit, Sonitor Technologies, and Cetrea.[4]

An important potential data source for the COSTT project is positioning data from indoor positioning systems (IPS). Such systems make it possible to track people and equipment with great accuracy, a capability which is deemed promising for supporting coordination in health care. [12] Nevertheless, there is a lack of literature describing how positioning data from such systems best should be visualized to support its users. This master thesis attempts to provide this insight.

## 1.2 Motivation and Research Questions

In this thesis we have used the Vascular Surgery Department at Aker University Hospital (from here referred to as Aker) as our case. The Vascular Surgery Department at Aker dedicate every Wednesday to three patients that are candidates for a cardiovascular operations. Every patient undergoes tests and examinations performed by physicians, nurses and physiotherapists. The staff at the department refer to this day as the “examination day”, as all examinations that needs to be carried out before a possible operation are done on this day.

The coordination of activities on the examinations days are taken care of by a coordinator. On the examination days a lot of different actors are involved, and these are typically situated in different locations. When deviations occur it is the coordinators job to find out what has gone wrong and how it can be solved.

The main assumption underlying this thesis is that the location of the different actors at a given time make it possible to infer what state of a process they are in. More specifically we are interested in seeing how positioning data

### 1.3. LIMITATIONS

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should be visualized to support the coordinator in her work on the examination days. Based on this we have defined the following research questions:

**RQ1:** Is the approach that we have used in this thesis valid?

**RQ1.1:** Can one assess whether people can use the visualizations in performing everyday tasks?

**RQ1.2:** Are people able to give informative assessments of the different visualizations?

**RQ2:** What amount of information richness, in terms of context information and granularity, should a visualization have in order to support coordination work?

For RQ1 we want to see if our approach for designing the visualizations is valid. We will answer this question by looking at people's view of the prototypes and their interpretation of them. For RQ2 we are interested in the amount of information richness that the visualizations should have in order to support the work of coordinators. We do this by looking at both context information and granularity. We define context information to be the amount of semantical information that needs to be presented in the visualizations to give meaning to the user, and we define granularity as the level of details that needs to be presented in the visualizations for the user to say something about activities that are going on in the moment.

We will in this thesis try to give answers to the research questions. The outcome of the thesis will hopefully give insight into how positioning data best can be visualized to support the work on coordinating activities at the examination days at Aker. If these goals, or part of these goals, are achieved it will hopefully also lead to further investigation on this topic, where both a fully functional system is developed, and the insight gained is utilized in related areas of research.

## 1.3 Limitations

- In this thesis we have used paper based prototyping and tests of these to give answer to the research questions. This means that no functional system has been developed.
- The thesis is based on empirical work with a limited number of people. The reason for this is that we have used a specific work practice as

our case, which in turn meant that tailor-made paper prototypes were made. This made it hard to recruit a large sample of users for the testing of the paper prototypes.

- Securing privacy is an important aspect when introducing positioning systems, especially in health care. We have chosen not to include this aspect, as the focus in this thesis is on visualizations.

## 1.4 Thesis Structure

In **Chapter 2 - Theory** we present the theoretical foundation for this thesis. We will here present history, concepts and theories on visualizations and computer-supported cooperative work (CSCW), and an overview of the possibilities underlying state-of-the-art positioning systems.

In **Chapter 3 - Methodology** we present an overview of the different approaches that can be used when doing research. We have put focus on the research methods that we have chosen to use in this thesis, which is qualitative research through a case study and usability engineering.

In **Chapter 4 - Design of Prototypes** we present the paper prototypes that we have designed in this thesis. Our work will be related to the theory presented in Chapter 2 and to the research methods presented in Chapter 3.

In **Chapter 5 - Results from the User Testing of Prototypes** we present the results from the user testing of the visualizations designed for this thesis, along with the the user's evaluation of the different prototypes.

In **Chapter 6 - Analysis and Discussion** we analyze our results in relation to the research questions that we have defined for this thesis. Our analysis will be related to the theory presented in Chapter 2 when applicable. We also discuss our work in relation to the research methods presented in Chapter 3.

In the final chapter, **Chapter 7 - Conclusion**, we give answers to the research questions and give suggestions for further work on the topic covered in this thesis.

## 1.5 Summary

In this chapter, we have presented the background and motivation for doing this thesis. The reader has been introduced to the organizational challenges related to coordination in hospitals, and we have explained that little work has been done to see how such challenges should be met. For our work, the assumption is that the use of positioning systems is a promising way to reduce these problems. But to do this, we claim that the visualization of positioning data must be presented in a way that supports the user. In this thesis we will use a specific work practice as our case, and look at how positioning data should be visualized to support the coordinator in this practice. We are especially interested in seeing if the approach we have used in this thesis is valid, and to see what information richness the visualizations should have in order to support coordination.



# Chapter 2

## Theory

This chapter describes the theoretical foundation for this thesis. We will use this foundation when we in Chapter 4) present the work that we have done in our thesis. It will also be used in Chapter 6 where we will analyze and discuss how the theories we here present coincide with the the work that we have done.

In this thesis we look at how positioning data best can be visualized to the user. We therefore start by presenting the field of visualization, with an emphasis on its history, its advantages and different methods for visualizing data. The different visualization methods are further described by presenting a proposed taxonomy. The taxonomy covers different types of data that are used in visualizations. We then present the Visual Information Seeking Mantra, which describes different methods of data exploration that should be made available to the end users.

To answer the research questions presented in Chapter 1 it is essential to know how computers can support cooperative work in a clinical setting. We look at this by presenting theory on Computer-Supported Cooperative Work, and will describe commonly used concepts when designing such systems. We supply this by presenting a CSCW system developed for a Danish hospital.

At last a description of state of the art positioning systems is presented, along with a presentation of the specific positioning system assumed to be underlying the prototypes designed in this thesis.

## 2.1 Visualization

### 2.1.1 What is Visualization?

The Merriam-Webster dictionary has the following definition of visualization:

**visualize:** to form a mental visual image

Visualization is a cognitive activity where insight and understanding of something is created in the human mind. The word visualization does not necessarily mean that the data presented is of visual form. Anything that a human can sense can be said to be visualizable. In this thesis however, the focus is on data that is of visual form. Visualizations of such data makes it possible to get an understanding of a set of information by merely looking at it. The advantage is that the viewer with relative ease can get an overview of what meaning the data communicates. Studies also show that visualizations make it easier for the viewer to recall the information that has been presented. Figure 2.1 shows the process of how visual data is interpreted by a human being. Data is first converted into a visual representation. The viewer looks at this presentation, and through cognitive activity forms an understanding of what information the visualization communicates.[25, pp. 5-6]

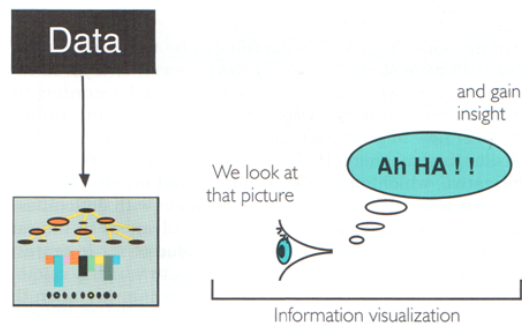


Figure 2.1: The process of gaining an understanding of a visualization. Figure from [25]

The advantages of data visualization have been recognized for centuries. A commonly used example is physician John Snow's use of visualization to track the source of the cholera epidemic that struck London's Soho in 1854. Snow plotted the deaths caused by the epidemic on a map, and found that they all occurred in close proximity to a pump well in Broad Street. By removing the handle of the pump the epidemic soon came to an end.[26, pp. 28-37]



## 2.1. VISUALIZATION

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An excerpt of Snow's map is presented in Figure 2.2. In the figure, black rectangles depict deaths, while the black circles depict well pumps.



Figure 2.2: Snow's visualization of the cholera epidemic in London. Figure from Tufte [26].

Visualizations in itself have nothing to do with computers, but the introduction of computers has changed the possibilities when it comes to make use of them. First of all it is now possible to store huge amounts of data inexpensively. The processing speed of modern computer systems makes it possible to fast and easily access and manipulate such data, and then visualize them on large, high-resolution displays.[25, pp. 6-7]

## 2.1.2 Categories of Visualizations

Depending on the characteristics of the data that is to be presented visualizations can be divided into three broad categories: geovisualizations, scientific visualizations and information visualizations[25, p. 12].

*Geovisualizations* can be said to be a form of visualization where data are binded to maps. An example of such a visualization is shown in Figure 2.3<sup>1</sup>. The figure shows the percentage of unemployed people in the Norwegian workforce in February 2009, divided by county.

*Scientific visualizations* visualize data that are mainly related to physical objects. It will often be possible to extract meaning from such data by comparing visualizations, or by adding, changing or removing parameters to look for emerging patterns. Figure 2.4<sup>2</sup> shows a scientific visualization simulating the progress of a storm.

*Information Visualizations* is mainly used for visualizing abstract concepts, for example information that is not numeric or takes physical form. A subway map is an example of an information visualization. Although the subway stations depicted in a subway map is indeed physical, it is enough to know the concept of subway stations and their relations to visualize such a map. Figure 2.5<sup>3</sup> shows a well known information visualization; the London Tube Map.

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<sup>1</sup>From <http://www.ssb.no/arbeid/kart01-arbeidsledige.gif>. Accessed 2009.04.29.

<sup>2</sup>From [http://redrock.ncsa.illinois.edu/image\\_89video.html](http://redrock.ncsa.illinois.edu/image_89video.html). Accessed 2009.04.29.

<sup>3</sup>Excerpt from <http://www.tfl.gov.uk/assets/downloads/standard-tube-map.gif>. Accessed 2009.04.29.

## 2.1. VISUALIZATION

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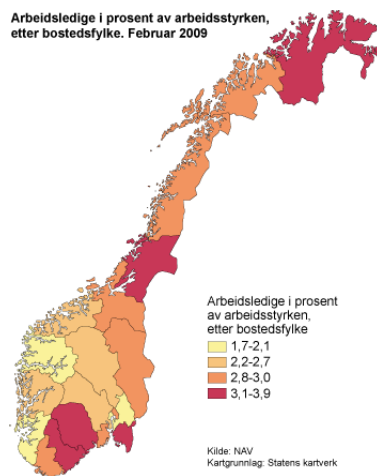


Figure 2.3: Example of a geovisualization.

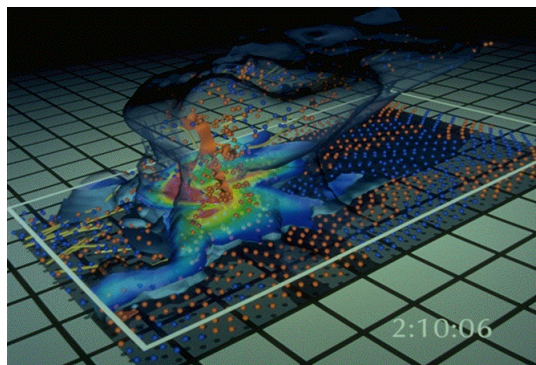


Figure 2.4: Example of a scientific visualization.

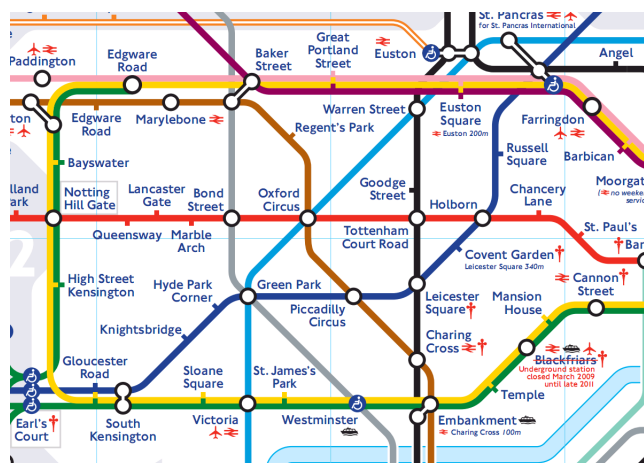


Figure 2.5: Example of an information visualization.

### 2.1.3 Representation Methods for Different Data Types

Schneiderman[21] has proposed a taxonomy that covers nearly all types of data that can be visualized. For each of the categories in the taxonomy Schneiderman gives advice on how to visualize the data and list user tasks that common to each visualization. Schneiderman's categories can be said to be a more detailed description of the different visualization methods presented in section 2.1.2. Below we present the categories in Schneiderman's taxonomy. For each of the categories we also present examples of relevant visualizations from the field of health care.

#### 1-dimensional

1-dimensional data types are linear data which are sequentially organized. When designing for 1-dimensional visualizations, important factors to include are font type, font size, colors, and choices about how to provide overview, scrolling and selection. An example of a 1-dimensional visualization is a list of persons that are scheduled for operations on a given day in a hospital.

#### 2-dimensional

Planar or map data are 2-dimensional, and can be visualized in a number of different ways, for example as geographical maps and floor maps. From such maps, viewers will often want to find objects that are located near each other, objects contained in other objects, and paths between different objects. Counting objects, filtering objects of interest and getting details on demand (further described in section 2.1.4) are also common user tasks for such visualizations. Design decisions to be made for such visualizations include the size of the different objects, their color and their opacity. Although the maps in themselves will be laid out 2-dimensionally it will often be necessary for the users to navigate between different layers. An example of a 2-dimensional visualizations is a PDA showing a map of a hospital, where it is possible to zoom in on certain parts to get a more detailed view.

#### 3-dimensional

In 3-dimensional data types large amounts of data will be used. These data will have complex relationships between each other. User tasks when dealing

with such data will be to distinguish the proximity of different objects, and to say something about the relationship of the objects. Important concepts when visualizing such data types are to give the user an overview, a perspective and color coding of different objects. An example of a 3-dimensional visualization is the 3D output from a MRI-scan showing an organ in the human body.

### **Temporal**

Temporal data is data that can be placed on a time line. Such data will have objects with start and end times, where objects may overlap each other. A typical task when using temporal data is to find the start and end times of different events, to find past events, to find events that occur during a specific time, or future events. An example of temporal data is a patient's body temperature measured over a period of time. Using a time line it will be possible to see previous measurements of temperatures, a measurement in the moment, and when future measurements are to be made.

### **Multi-dimensional**

Multi-dimensional, or n-dimensional, data will typically be extracted from databases where multiple attributes are laid out in an multi-dimensional space. In visualizations of such data it will be possible to move from one dimension to another dimension. From such data, user tasks involve finding patterns in data, clusters of data and relations between different parts of data. An example of a multi-dimensional visualization from health care is the use of cluster analysis to explore genomes, with the possibility to explore different dimensions, relations and level of details.

### **Network**

What Schneiderman refers to as a network is equivalent to the more known notion of graphs. With graphs it is possible to connect a node to an arbitrary number of other nodes via edges. In visualizations of graphs, tasks or descriptions can be added to the nodes and edges. Another typical feature of graphs is that cycles is allowed, where a cycle is defined as a closed loop of edges. The list of different types of graphs is extensive. The key user task when using graphs to find the relationship between nodes. The key design goal is therefore to give the user a representation that makes it easy to focus

on different parts of a graph, and to differentiate between different objects and their relations. An example of a graph visualization is the rooms on a floor in a hospital, where more than one room can lead to another room, which will form a cycle.

### **Tree**

Trees are a specialized type of a graphs. Trees have one parent node, and zero or more child nodes, and must be acyclic - that is, a parent node can have an edge to a child node, but a child node can not have an edge to parent nodes. Trees have the same user tasks and design goals as graphs in general. An example of a tree structure in hospitals is the flow of events in a hospital, for example that anesthesia must be given before an incision is made in an operation.

### **Categories Used in this Thesis**

In this thesis we have used the 2-dimensional category, the temporal category and the network category. Our use of these categories will be further described in Chapter 4.

#### **2.1.4 The Visual Information Seeking Mantra**

Through his work in projects related to visualizations Ben Schneiderman has introduced the Visual Information Seeking Mantra. The mantra is a set of general tasks that users should have the possibility to perform when interacting with the different visualization methods presented in Section 2.1.3, and reads:

Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand  
Overview first, zoom and filter, then details-on-demand

Schneiderman writes: “Each line represents one project in which I found myself rediscovering this principle and therefore wrote it down as a reminder”. The different tasks given in Schneidermans mantra is presented below:

1. **Overview**

As the name implies, the purpose is to give an overview of a collection of data. An example of an overview is a zoomed out view of a map.

2. **Zoom**

Based on the overview a user can zoom into portions that he is interested in. An example of zooming is the user clicking on a portion of the screen, where this portion is shown in higher detail.

3. **Filter**

When filtering the user is given the ability to filter out portions that are uninteresting for his task, where unwanted items or objects are left out. Filtering can be related to zooming, but might for example also be achieved by giving the user option on which attributes to include in a visualization.

4. **Details-on-demand**

Details-on-demand means that the user should have the possibility to select an item or a group of items and get details when needed.

## 2.2 Computer-Supported Cooperative Work

### 2.2.1 What is Computer-Supported Cooperative Work?

Introduction of computer systems in the field of health care is regarded as problematic, and studies have shown that half of the introduced systems fail to get acceptance because of resistance among users and staff. One of the main challenges is the highly dynamic nature in hospital work, where planned schedules are frequently altered.[17]

Modern work settings have made it necessary to come up with new methods when it comes to cooperative work. Among others, decision making, rule interpretation and cooperative work processes all impose an increased requirement when it comes to flexibility of work, fast production and to adjust the complexity of production. These needs were identified in research communities, and in 1984 Iren Greif and Paul Cashman organized a workshop where people interested in knowing how technology could be utilized in

work environments gathered. The workshop resulted in the introduction of the term Computer-Supported Cooperative Work (abbreviated CSCW)[8].

CSCW is a complex field, as it involves solving complex problems, work processes where several people are dependent on each other, and decision making. This means that support for flexibility must be supported. Before, cooperative work was largely done verbally by face-to-face communication, often in groups. The emergence of computer based systems has led to increased demands in terms of production and efficiency - that is; businesses and organizations need to produce results faster than before in order to keep up with both competition and work. It is also crucial that activities are done in a timely manner to make sure that problems do not propagate, and cause trouble for future activities.[2]

Schmidt and Bannon[19] state that “CSCW is an endeavor to understand the nature and requirements of cooperative work with the objective of designing computer-based technologies for cooperative work assignments”. They argue that CSCW should primarily be seen as design principle. Understanding the users should be in focus when understanding cooperative work, and this should serve as the foundation when designing computer systems to support it. Another argument for using such an approach is that cooperative systems developed for one organization is often not suitable for another organization, although the former system was reported as successful after its implementation. Because of this it is hard to come up with methods and frameworks that are applicable in general.

## 2.2.2 Concepts of CSCW

When designing CSCW systems different concepts have been introduced. These concepts are defined in literature as a foundation for designing successful CSCW systems. Pratt et al. [17] define three key concepts of CSCW, which should be in focus when designing CSCW systems: incentive structures, workflow and awareness. These are all presented below:

### **Incentive Structures**

As computer systems often fail to gain acceptance among its users, costly development projects often lead to software that never is used, or that the potential of introduced software is not utilized.



## 2.2. COMPUTER-SUPPORTED COOPERATIVE WORK

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This has been recognized in the field of CSCW, and it has become evident that it is important to get institutional acceptance in order for such systems to be accepted. CSCW systems are often seen as a supportive tool for the organization as a whole, for example by improving efficiency and thus also improving income. This is good news for managers of an organization, but for the users the introduction of CSCW systems will often lead to more work, and the advantages are often not clear. Because of this it is important to motivate the users to get them to use a new system by showing them the benefits they can get from using it. To expand the example above, increased income for an organization will lead to increased profit, which in the long term can be shared with the users as bonuses. Communicating this to the users will form an incentive, and will more likely lead to an acceptance of the introduced system.[9]

### **Workflow**

In short, workflow can be described as the processes that organizations adopt in order to do their work and to execute work tasks efficiently. In CSCW, one of the central concepts is to support users when change or exceptions to the original schedule occurs. The systems designed can either be an imitation of the work methods used before the introduction of a new system, an introduction of a completely new system, or a combination of these. Imitations of existing systems have the advantage that users will be familiar with the concepts used, but from the designers point of view it might not release the full potential of the system in terms of efficiency. Introducing a completely new system will likely lead to a more efficient and feature-rich system if it is used correctly. But for a system to succeed it is necessary to gain incentive from the users, which is, as mentioned above, not always easy. Because of this it is common to develop a system that imitates traditional features, and introduce new ones.

### **Awareness**

To support separate work activities it is necessary to provide actors with awareness. Dourish and Bellotti[5] define awareness as "...an understanding of the activities of others, which provides a context for your own activity". In this thesis we have looked at how positioning data can be visualized to best support coordination of activities. To do this actors will have to know about the progress of activities. As we can see from the definition by Dourish

and Belotti, and from the previously defined concepts of CSCW, this can be regarded as the most relevant CSCW concept for our work.

Bardram et al.[1] have developed a system named AwareMedia to support coordination of operations in a hospital. AwareMedia will be presented in detail in Section 2.2.3, but we will here present three types of awareness that they propose should be covered in CSCW systems. Although the article describes the use of a CSCW system in a specific work practice, they state that “the design principles and features of AwareMedia[1] may be useful in other settings”. The three awareness types proposed by Bardram et al. are:

1. **Social awareness**

From the definition of awareness we see that having an understanding of other people’s activity is central. When designing systems to support social awareness the idea is that the users of the system should get access to information about the activities of their colleagues in order to adapt their own work. This information should say something about the location of other persons, and what they are doing. Most people will probably not be comfortable with the fact that colleagues know about their exact position, and exactly what they are doing at all times. Because of this, it will, for most CSCW systems, be sufficient to provide users with clues about the activities of their colleagues.

2. **Temporal awareness**

One of the main ideas of CSCW systems is that they should be able to handle changes to planned schedules. Such changes includes cancellations, delays and rescheduling of activities. Merely knowing about the work of other actors in the moment will not be enough to know something about the context of their work. The idea of temporal awareness is to provide users with such information. By letting users get an overview of past, present and future activities it will be easier to adapt their own work accordingly, which leads to a more efficient use of time and resources.

3. **Spatial awareness**

To say something about the activities in one of the locations used in a CSCW system it is important to provide spatial awareness. Spatial awareness gives information about exactly what is happening in a location. Such information makes it possible for others to say something about the progress of an activity in a location. Spatial awareness information does not necessary need to be detailed, providing *just enough information* is often enough to the give users clues about the state of an activity. In addition, if implemented correctly, this assures that

## 2.2. COMPUTER-SUPPORTED COOPERATIVE WORK

sensitive information about the actors is hidden.

In the designed prototypes we have used these three types of awareness. We will describe how these have been used in Chapter 4.

### 2.2.3 Example of a CSCW System Utilizing Positioning Data

AwareMedia is a project carried out at the Centre for Pervasive Healthcare at the University of Aarhus in Denmark, and later deployed at a large Danish hospital. The system is defined as “A shared interactive display supporting social, temporal, and spatial awareness in surgery”, and is designed to support coordination related to operations at the hospital. In such environments the involved persons needs to know what other persons are doing so that they can adjust their own work. This is hard, as the personnel are walking around in the building and are busy finishing their work tasks. In addition operations often needs to be performed because of emergencies, which means that allocated time slots in the predefined schedule need to be changed. Figure 2.6 shows a screenshot of AwareMedia.

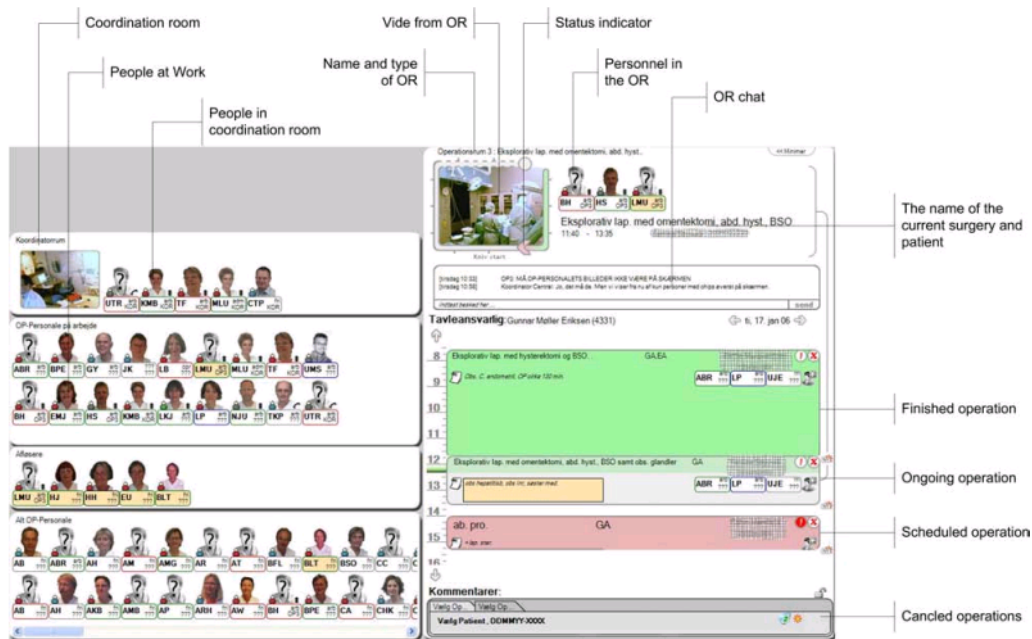


Figure 2.6: The AwareMedia system. Figure from Bardram et al.[1].

In relation to the implementation of the AwareMedia system, video cameras

were placed in the different operating theatres. This video is presented in low-resolution, so that patients cannot be identified, but the resolution is high enough to say something about the activity that is going on in the theatres. To the right of the video information about the persons located in the room and the status of the activities is shown. An obvious advantage here is that they do not need to go to the different operating theatres to see the state of an operation, or to contact health personnel that are in the middle of an operation. All of these features makes the AwareMedia system cover spatial awareness.

Temporal awareness is supported in two different parts of the AwareMedia system. Around the video image presented above there is a status bar, which is divided into portions. The portions indicate different states of an operation, and via a touch screen the persons in the operating theatre can set the state that the operation is in. This information will then be visible to health personnel that are not located in the room. Additionally, AwareMedia supports temporal awareness through a schedule showing different operations that are to be performed. In this schedule, color coding indicate the status of the different operations. According to the authors, this means that changes to the schedule no longer need to be communicated to actors that have interest in knowing about changes.

AwareMedia supports social awareness through icons showing a small image of the different health personnel. Under the icons the initials of the persons, their position and a status indicator is shown. The status indicator will tell others what persons are doing in the moment, and is self-reported. Also, the profession and working hours of the different persons is shown. Through this information health personnel will get a clue about what their colleagues are doing.[1]

## 2.3 Positioning Systems

As we in this thesis try to give answer to how positioning data best can be visualized we will here describe different positioning technologies. The reader should note that we for this thesis have used no real positioning data, and that we present the different technologies in order to give the reader a view of the possibilities underlying these.

GPS, Radio Frequency Identification (RFID), Wi-Fi, infrared light, ultrasound and other technologies make it possible to position objects with differ-

ent levels of accuracy. While GPS is mainly suitable for outdoor positioning of objects, the rest are most suitable for indoor use. For this thesis the interesting feature to investigate is the granularity, or accuracy, that the positioning system can provide.[7]

Sonitor Technologies have developed a positioning system that use ultrasound to position objects. Their product makes it possible to track objects with an accuracy down to one and a half meter, which is among the best in the market. Also, ultrasound does not penetrate solid walls, which is a disadvantage found in most of the other positioning technologies.[24] Since Sonitor is also a partner in the COSTT-project, it was natural to choose their product as the *imagined* underlying positioning technology for this thesis.

## 2.4 Summary

In this chapter we have presented background information and theory on visualizations, CSCW and positioning data. We have given an introduction to advantages of using visualizations to present data, along with a presentation of the three broad classifications of visualizations. These classifications have been narrowed by presenting a proposed taxonomy for how different data types should be visualized. In addition to this we have presented theory how the user should be able to interact with visualizations.

Modern work settings face complex cooperation processes, and the field of CSCW was introduced to see how computers could help improve these processes. We have presented three different concepts of CSCW, and have focused on the concept of awareness which is most related to our work. By presenting a Danish CSCW system named AwareMedia we have looked at how others have implemented support for awareness in their product.

In the end of the chapter we have introduced different positioning systems, and have given an introduction to the positioning system that is assumed to underlie the visualizations that we have designed in this thesis.

The theory that we have presented has served as a foundation for the paper prototypes that we have designed in our thesis, which is presented in Chapter 4. Also, we will relate the theory to our analysis of results in Chapter 6.



# Chapter 3

## Methodology

We start this chapter by giving a brief overview of the different research methodologies used in academic research. These methods can generally be classified as either quantitative or qualitative. In this thesis we have used a case study, which is a qualitative method, to conduct our research. This method will therefore be presented in detail. In addition, we will present a typical life cycle of usability engineering as we have used methods from these field in the design of visualizations in this thesis. Both of these methods will be used when we in Chapter 4 present the research that we have done in this thesis. In addition, we will reflect on the applicability of the methods that we have used when we in Chapter 6 discuss our work.

### 3.1 Overview Of Research Methods

In general, either quantitative or qualitative research methods are used in research. Quantitative and qualitative research methods address different kinds of questions and goals, and are not two different ways of doing the same thing.

Quantitative research focus on using quantities of data, and to come to conclusions based on these data. This means that the sample data need to be large to have any use.

Qualitative research seldom use quantities of data. In qualitative research the focus is on getting data from more abstract sources, to analyze the meaning of these data, and to come to conclusions based on the analysis of these

data.[16, p. 266] Action research, ethnography and case studies are three examples of qualitative research methods.

In this thesis we have studied a specific work practice at Aker. As we planned to conduct a limited number of interviews, observations and document analysis we chose to use a qualitative research method in our work, more specifically a case study.

## **3.2 Qualitative Research**

### **3.2.1 Performing Qualitative Research**

In qualitative research meaning from the gathered data must be interpreted by the researcher. Different researchers might therefore come to different conclusions using the same set of data. Qualitative research goes through a series of phases. The first phase is to collect relevant data, which in turn make ground for the second phase where the data that have been collected are to be analyzed. This phase involves categorizing the data by finding key phrases and themes, mainly focusing on the portions of data that are directly relevant for the research. The categories used can be said to be either deductive or inductive. Deductive categories are based on theories that already exist in literature, or theories that have been formed by the researcher himself. Inductive categories are found in the data that is being analyzed, for example from the material itself or from the author of a document that are being analyzed. The list of categories found will most likely be extensive, and it is often necessary to refine this list to make sure that only categories that answer the research question are included. The final task is to find patterns and meaning from the data, and to link these data to theories that the research is based on, or to other relevant theories from literature. Based on this linking, the researcher will see if his data are in accordance with personal or external theories, and will describe why or why not this is the cause.[16, pp. 266-279]

### **3.2.2 Data Gathering From Case Studies**

Case studies is an abstract definition of several more concrete data gathering methods, namely interviews, observations, document analysis and questionnaires. These methods can be used separately, or in combination.[16, pp.



## 3.2. QUALITATIVE RESEARCH

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186-188] Myers and Avison give the following definition of a case study: “A case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups or organizations)”[13, p. 81] This coincides with the work that was to be done for this thesis. From the definition, our phenomenon is the coordination of activities at the Cardiovascular Surgery Department at Aker. To gather information we have used document analysis, interviews and observations as our methods. The data were gathered from Aker, the coordinator at Aker, and from the test persons that were recruited for testing of the designed visualizations.

### **Document Analysis**

In document analysis, documents are used as the data source. Documents can be generated throughout the research process, or exist prior to the research. An example of the former is images that have been taken during the research process, which are later analyzed by the researcher. For this thesis we have used the latter method.

When looking at existing documents, they can be used to study a specific phenomenon to get an understanding of it. This understanding can further be built upon by using other data generation methods, for example interviews and observations. Documents also make it possible to verify data that have already been generated, for example from interviews. For the researcher, the key concern when doing document analysis should be to ensure that the document comes from a reliable source.[16, pp. 233-242]

In our work we used document analysis to gain knowledge about the specific work practice and the role of the coordinator on the examination days. Our document analysis is presented in Chapter 4.

### **Interviews**

Interviews are a special kind of conversation between persons. It differs from normal conversations in that the motive for conducting interviews is to gain information from the persons being interviewed. Interviews will typically be used in situations where the researcher needs to get detailed information on a specific topic. Interviews can be either structured, semi-structured or unstructured, and the choice of method depends on what data the researcher wants to gather.

When carrying out structured interviews, the researcher has a list of specific questions prepared for the interview. When interviewing more than one person, the questions asked will be the same, which makes it easy to compare the different answers. The researcher's task is to present the questions without indicating his own views, and let the interviewee respond. In a sense, one can say that a structured interview is a verbal questionnaire, where the researcher does the job of reading out the questions and writing down the answers from the interviewee.

For semi-structured interviews, the researcher has a general topic that he wants to know more about. From this topic questions have been formed. Unlike structure interviews, the flow of the interview and the response given, decides how the interview evolves. The researcher can add new questions, refine existing ones or leave questions out based on the response from the interviewee.

In unstructured interviews, the interviewer brings no prepared questions to the table. Instead, the interviewee is asked to tell everything they can come up with on a topic.

For structured interviews the goal will most often be to check assumptions that the researcher has made prior to the interview, and see if these can be confirmed or invalidated. For semi-structured and unstructured interviews, the goal is to discover new information. By letting the interviewees lead the flow of the interview, they will be able to present their impression or knowledge on a topic which later can be used in the researchers work.[16, pp. 186-99]

In our work we conducted a semi-structured interview with the coordinator at Aker to gain insight into her work. We also conducted unstructured interviews after the user testing of the prototypes we designed. The interviews will be presented in detail in Chapter 4 and Chapter 5, respectively.

### **Observations**

In research, observations are used to find out what people do by observing them. Although the researcher can ask people to tell what they do, there will often be differences in what is actually done.

Observations can be covert or overt. In covert observations people do not actually know that they are being observed. The advantage of using this method is that people will behave like they normally would, and are undis-

turbed. But, the obvious disadvantage is the invasion of the privacy of the people being observed. Also, the researcher will not be able to ask questions to the ones being observed, for example asking them to describe why they do things in a certain way. In overt observations people know that they are being observed. Because of this, the researcher can ask questions. While this at first might seem relieving, one will often experience the “Hawthorn effect” where people behave differently from what they normally would because they know that they are being observed.

Conducting observations can be done either systematic or as a participant. Systematic observations is a quantitative research method where the researcher notes the frequency of events or actions, for example by counting or timing. In participant research, the researcher places himself in the position of those being observed, either covertly or overtly. Although there are different types of participation, participant-observer is the only method relevant for this thesis. In this type of observation the researcher follow a person being observed, and notes how they go on about carrying out their tasks, how they feel about it, and so on. Observations will be most successful if the researcher is accepted by the ones being observed. This will often make the ones observed forget that the researcher is observing them, which in turn will give the research more valuable data.[16, pp. 202-216]

We supplemented the insight gained from the interview with the coordinator with an observation. The observation will be presented in Chapter 4.

## 3.3 Usability Engineering

Presentation of data in an understandable way should be one of the key goals when doing visualization design. Despite this most work in this field has focused on the aesthetics and usability of the *tools* used to present visualizations, and the evaluation of these (e.g. [22], [23]). The ISO9241-11 standard[10] specifies that the objective when designing for usability is to “enable user’s to achieve goals and meet needs in a particular context of use”. This fits in with the objective of this thesis, and because of this methods for designing for usability has been chosen.

Nielsen[14] has defined 11 stages for performing usability engineering. These stages serve as a general guideline to usability engineering, and depending on the project in question some of them can be let out or be emphasized more than others. Literature broadly covers guidelines for performing usability

engineering. We will here present Niensens 11 stages as a foundation, and will supply these with information from other sources when deemed necessary.

### 3.3.1 Know the User

In order for a product to be successful it is crucial to get an understanding of the users. Studying the users lets the designers be informed of how work is traditionally done, and how the users think this work can be improved by the use of a new product.

For the designers it is also important to define the characteristics of the prospective users. Two users are not the same, and a product that is seen as easy to use by one user can be seen as difficult to use by another. By obtaining information about the users' knowledge of computer products, their educational background, what work they are performing, and so on, the designers are given valuable information when designing a product. This is important when the usability goals for the product are to be formed.

In addition, it is common for designers, in collaboration with the other persons involved in a project, to define the functional goals for the product. This is done by performing a functional analysis. The purpose of doing a functional analysis is, as the name implies, to define the functions that the product should hold.

Information for defining both usability goals and for performing the functional analysis can be obtained by doing a market analysis to see how other designers have designed their products. Another alternative is to make use of the qualitative research methods described in section 3.2. The source of information to be used depends on the project in question. Pure innovations of existing products should at least be based on the products they find inspiration from and want to improve. They can also be accompanied by qualitative research methods. For projects where little related work has been done before it is hard to solely rely on other people's work. For such projects the main source of information should be gathered from qualitative research methods.

Products are designed with different audiences in mind. In general, one can distinguish between products that are developed to attract the masses, and products that are tailor-made for an organization or person. Products that are developed for a broad audience, for example websites for handling in tax reports, will often be used sporadically. Because of this, a good user experience has to be ensured at the first visit. Tailor-made products, however, will

### 3.3. USABILITY ENGINEERING

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often be used on a day-to-day basis and have more functionality, for example software for visualizing MRI scans in a hospital. In Sharp et al.[20, p. 173] one can read: “[...] introducing something new into people’s lives, especially a new “everyday” item such as a microwave oven, requires a cultural change in the target user population, and it takes a long time to effect a cultural change.” Introducing tailor-made products will introduce something new into people’s lives. This means that it takes time for users to get accustomed to the all the new functionality provided in the product, and it will because of this be acceptable to have a higher learning-curve.

#### 3.3.2 Competitive Analysis

Duplication of other people’s work is a copyright infringement, but getting inspiration from other peoples work is a legal and common approach when designing products. Usability tests can be done using already developed products. This will make shortcomings and advantages of the product obvious to the ones carrying out the usability tests. The advantage of this is that they can create a product that utilizes the positive aspects of a product, while the negative aspects are either left out or improved. If more than one product is available for testing, it is natural to do a comparative analysis of their different design and features. This will lead to both guideline for development of a new product, and it will identify features that are commonly used in competing products.

#### 3.3.3 Setting Usability Goals

When designing or redesigning a product it is common to form a set of usability goals. These goals can be placed in several different categories. The categories should be weighted in terms of their relevance and importance for the product. As an example the ability to learn how to use a product can be weighted lower for those who use the product every day, than for those who use the product occasionally.

Usability goals can be measured in a usability goal line, where the number of user errors are plotted on a line. The line is divided into ranges, where each range defines the number of errors observed. For example can a usability goal line can go from a range defined as unacceptable, where the number of errors is too high. The counter-example to this would be on the other side of the line, where the number of errors are lower than what is acceptable. What is

seen as acceptable for the product will probably be somewhere between these extremes, but obviously a low number of errors is preferred. An example of a usability goal line is shown in Figure 3.1

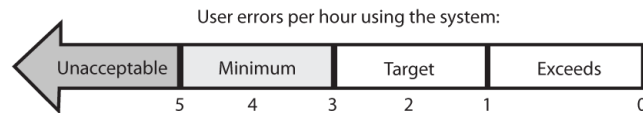


Figure 3.1: Example of a usability goal line. Figure from Nielsen [14].

The use of a usability goal line is not applicable for all projects. For example it can be hard to measure the number of errors in a project where no similar work has been done before. For such projects a number of user exercises can be defined, and the designers can observe the users while they perform these. Another alternative is to ask the users for comment about the product after the testing is done.

### 3.3.4 Parallel Design

When doing parallel design several designers make drafts for the product. These designers work independently, and will thus not be influenced by each others ideas. When the drafts are finished the designers meet. The meeting will often show that the designers have taken different approaches when making design proposals for the same product. The designers will then work out a design proposal using the advantages found in each of the independently designed prototypes.

Designing prototypes in parallel is especially suitable when a new and undiscovered product is to be designed. At first it might be seen expensive to let the designers design different proposals, but in general this approach means that further work with the design will be more effective as flaws and mistakes are identified early in the design process.

### 3.3.5 Participatory Design

Representative users have a deep understanding of their needs of a new product, based on their experiences with the product to be replaced, or how things have been done before a new product is introduced. Even though designers have studied how the users carry out their work, they will not know the ins

and outs of their work. Designers will also be influenced by their previous work on usability engineering. Because of this the designs that are presented to the users should be understandable without technical terms and complex design methods that are only understandable for the designers themselves. The goal of participatory design is to include the users in the design process.

#### 3.3.6 Coordinated Design of the Total Interface

Designers should strive for consistency in their products. In short, consistency in the field of usability engineering is the task of making each screen, language and graphical elements in a design resemble what the users are used to. As an example a web page can have a search in the top right of the start page. The visitor notices this, but clicks to other pages before he decides to perform a search. For the design to be consistent the search field should be visible in the same location in the all the other pages that the user visits in a web page.

For consistency to be assured it is important that the work of each designer in the project is transparent. Each designer should have access to other designers work, to make sure that inconsistencies are solved as they appear. A useful way of making sure that consistent interface components are used is to define project specific libraries, which is possible in most mock-up and illustration tools. Stress is often a factor in project work, and can possibly let the designers feel that keeping up with other people's work is a burden. In such cases it is common to let a project manager have the responsibility for the overall consistency of the product.

#### 3.3.7 Apply Guidelines and Heuristic Analysis

Guidelines are advice for how a product should be designed. They should not be confused with standards, as standards can be seen as requirements more than advice. In general, guidelines can be placed into three different categories:

- **General guidelines**

General guidelines are commonly used in a special field, such as the field of usability engineering. General guidelines are abstract advice on how something should be done. An example is "Words used in a product should always be understandable to the users".

- **Category specific guidelines**

Experience from similar projects, often commercial ones, are used to make category specific guidelines. An example of a category specific guideline for a web project is “For the website to be viewable to persons with a screen resolution with a width more than 1024 pixels, the width of the content should not exceed 900 pixels.”

- **Product specific guidelines**

Product specific guidelines are used internally in an organization, either for a specific product or for a line of products. An example of a product specific guideline is “Paragraph text in the product should use the Verdana-font with a height of 12 pixels and the color black”.

Several collection of guidelines are available on the market. When using guidelines, one of the main advantages is that it makes the development of a product more efficient. Also, guidelines will have advantages when testing a product, as one easily can see if all parts of a product complies to the used set of guidelines.

Heuristics are a set of “best practices” that should be supported when designing a new product. Heuristics can be compared to general guidelines, which we described above. In heuristic analysis an expert will evaluate the product against a list of heuristics, and the purpose is to identify usability problems early in the life cycle. The advantage of using heuristic analysis is that it can eliminate the need to use external test persons early in a project, which is both time and cost saving.

### 3.3.8 Prototyping

In early stages of the design process, prototypes are used to show the intended functionality and features of a product. To do this prototypes either emulate or have a limited set of functions compared to the final system. In usability engineering prototypes are commonly made using either as drawings or printouts on paper, or via partial implementations of the final system.

Paper prototypes, or minimalist prototypes, can either be drawn directly on paper, or printed from drawings made in specialized computer tools, such as Microsoft Office Visio<sup>1</sup>. When testing a product one of the persons in charge of the testing will act as the “computer”. The test person can click on the

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<sup>1</sup>Microsoft Office Visio is a tool for making technical drawings and diagrams. For more information see <http://office.microsoft.com/en-gb/visio/default.aspx>



“screen” (the paper prototype), and the “computer” will change it according to the test persons choice. Paper prototypes can be designed rapidly and at low-cost, which makes them both cost effective and easy to revise based on the input from customers or test persons. The disadvantage of using paper prototypes is that their simulation of a system can be somewhat distant to how a final system will function, because of the limited functionality and slow response time. When using minimalist prototypes a scenario based technique is often used for testing. A set of scenarios are defined before the testing takes place, and the designers design prototypes that match the different scenarios, where the ultimate goal is that the test person moves from the first to the last scenario without errors.

Partially implemented prototypes are either made by using specialized tools, for example Axure RP<sup>2</sup> or by the use of programming languages such as Java. The advantage of such prototypes over paper prototypes are that they closely resemble a finalized system. The disadvantage, especially when using programmed prototypes, is that they are expensive and time consuming both to develop and redesign.

#### 3.3.9 Empirical Testing

##### Overview

Improving the usability of a product is the motivation for conducting users tests. Empirical testing can be performed by prospective user’s, usability specialists, or by both.

When performing empirical testing with prospective users they are asked to evaluate the product. Users will most likely not be able to evaluate a product by reading descriptions of how a product will be designed, and because of this it is common to use one of the prototyping methods described above. Think-aloud technique is often used for performing such testing. Using this method the test persons are asked to communicate their interpretation of the prototypes by solving a scenario. The designers will clarify uncertainties, and write down comments from the test persons.

User testing does not necessarily need to be done with one person at a time. In co-discovery testing two persons collaborate on solving a task. The advan-

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<sup>2</sup>Azure RP is a prototyping tool for web and desktop applications. It has the possibility to emulate user interaction, for example by letting the user jumping from screen to screen. For more information see <http://www.axure.com>

tage of using this method is that the test persons can collaborate on solving the tasks used for the user testing. Another advantage is that this technique facilitates discussions with the test persons on how to solve the task, which often generates more data than the think-aloud technique presented above.

Another method that is often used, both for testing with one test person or in co-discovery testing, is active intervention. Here the test persons are asked probing questions as they are performing the test tasks. By asking questions throughout the testing it is possible to get more knowledge about the test persons evolving view of the product.[6, pp. 30-32]

It is common for designers of a product to consult usability specialists that are not related to the product being developed. For low-budget projects or projects with a strict time frame usability specialists can evaluate requirement specifications and documents describing the product. They will try to identify problems in the product, and give advice on improvements to the designers. Another way of doing usability engineering is to consult usability specialist who rate comments from test persons in terms of severity. Different test persons are likely to comment different on usability problems in a product. Because of this, a problem that is identified by one test person might not be mentioned by another. The task for the usability specialists is to rule out the important usability problems from these comments.

### **Testing Different Kinds of Prototypes**

In Section 3.3.1 we explained that there are differences when developing products that are meant for big audiences, and products that are tailor-made for a specific organization or person. When testing these there are also differences. When testing products that are meant for a wider audience the main focus should be on finding problems related to the user experience, and whether or not the test persons easily can perform their objective tasks using the product. Tailor-made products will have more functionality. When testing these the main focus should be to assure that the needed functionality is covered in the product, although the designers should also focus on the user experience.

### **Rating of Parts or Drafts of Products Using Card Sorting**

User testing will give the designers a view of what the test persons think about certain parts of a product, or the different drafts made in parallel

design sessions. But it will often be hard for the designers to know exactly what parts or drafts the test persons favor over others. Card sorting is a technique that resembles the sorting of playing cards, where the paper prototypes are the imagined cards. The cards are laid on a table in random order, and the test persons are asked to rate them from low to high. This method will give the designers insight into the test users' mental models of the parts or drafts, and make it easier to see if the test person's views are consistent or inconsistent.

The card sorting technique makes it possible to generate substantial amounts of data in short time and is cheap and easy to complete. But it also has its negative sides. For example, can the ratings given by different test persons be inconsistent, which in turn will make it difficult to analyze the data.[3]

#### **Number of Test Persons**

There are different views on how large the sample of test persons should be in order to get valid results from user testing. Nielsen[15] claims that it is enough to test with only five test persons to get valid results. In the article, Nielsen writes that testing with one user will identify about one third of all usability problems in a product. One more test person will most often identify the same problems as the first test person, but will also notice things that the first test person did not point out. The third test person will also generate some new data, in addition to the problems identified by the first and second test person, but will only give a marginal amount of new data. From the fourth and fifth test person only a marginal amount of new problems will be identified, and these will likely not provide many new problems. From the sixth user and onwards Nielsen argues that one will only find previously identified problems, or problems that have no real value for the product to be developed. Figure 3.2 shows a line graph depicting Nielsen's view. As we can see from the graph, user testing with five persons will identify approximately 80% of the usability problems in a product.

Nielsen has been criticized for proposing a theory that favors such a low sample. Wolrych and Cockton [27] argue that it is not possible to generalize the sample of test users that should be recruited. In their opinion the sample used should be based on the complexity of the product.

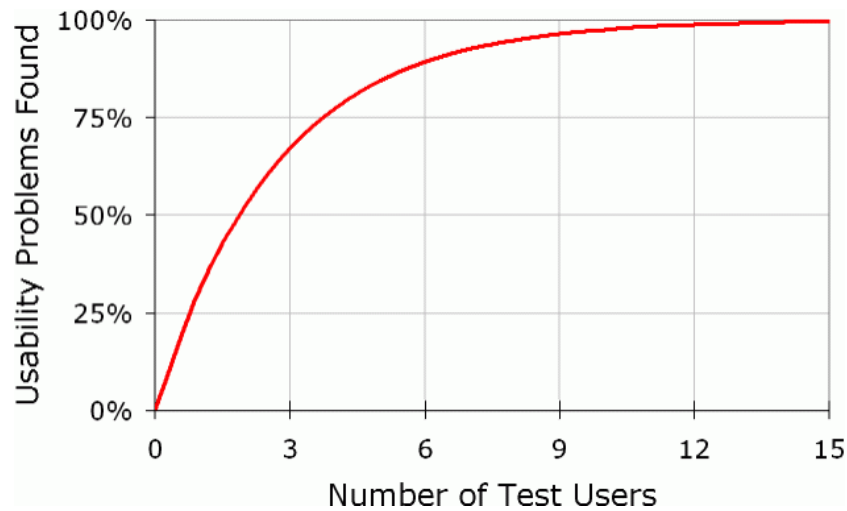


Figure 3.2: Nielsen's graph showing identified usability problems related to the number of test persons. Figure from Nielsen[15]

### 3.3.10 Iterative Design

Figure 3.3 shows the waterfall model. The waterfall methodology has been the traditional method for developing software. When using this method, software is designed in a sequential way, which means that each step should be completed before the next step can start. From the figure 3.3 we can for example see that the coding comes before the testing. The disadvantage of using this methodology is that it is not allowed to make refinements to certain parts of the product once one has jumped to the next step. As an example it will not be allowed to fix coding errors once the testing has started.[18]

In recent years a set of so called agile methodologies has been introduced in the field of software development as an alternative to the waterfall methodology. Agile methodologies consists of a group of different methods. In 2001 the Agile Manifesto[11] was formed, stating:

- **Individuals and interactions** over processes and tools
- **Working software** over comprehensive documentation
- **Customer collaboration** over contract negotiation
- **Responding to change** over following a plan

As a comment to the manifesto, the authors add: “..while there is value in the items on the right, we value the items on the left [bold text] more.” With

### 3.3. USABILITY ENGINEERING

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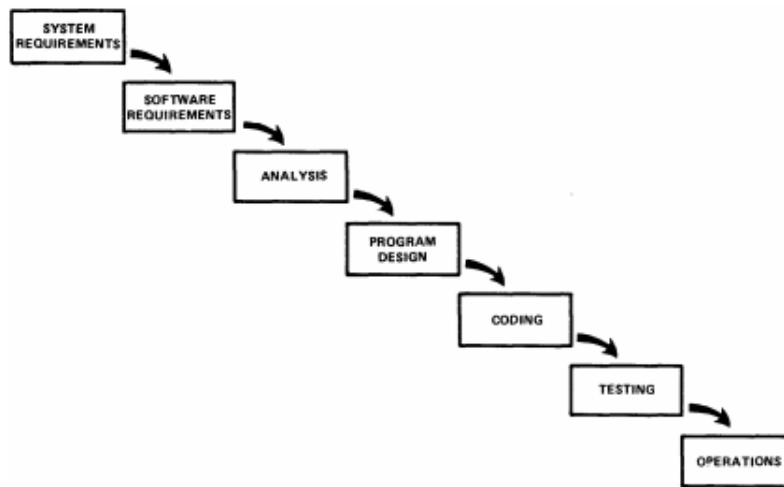


Figure 3.3: The waterfall model. Figure from Royce[18].

the introduction of agile methods user satisfaction has gone up, development has been made more efficient and introducing change late in a development project has been made possible.

Usability engineering is ideally one of the tasks in software development, which also uses its own iterative cycle throughout the development of the software. Feedback gained from user testing or from usability specialists will lead to new iterations of the design. The new design can be presented to the test persons, or get reviewed by usability specialists. If needed (and possible), new iterations will be started until the product satisfies the quality requirements.

#### 3.3.11 Collect Feedback from Field Use

Through experiences, work and education humans gather knowledge, which often comes handy later in life. This is also the case when doing usability engineering. When developing a product designers will notice new ways of doing things, getting aware of pitfalls and gain experience that can be used in new versions of a product, or in a completely new product.

This can be done in many different ways. For example the use of marketing studies can tell whether or not a product has been successfully recognized in the market. Field studies, like the one used for doing analysis of requirements for a product, can also be used. Field studies will typically be conducted using questionnaires, observations and interviews. As noted above, it can

be hard to recruit test persons for such studies. Because of this it might be easier to get indirect feedback from users, for example via help lines, usage statistics and request for refinements of the product.

### 3.3.12 The Complete Iterative Design Process

The complete iterative design process is shown in Figure 3.4. The figure is a compressed outline of the 11 stages presented above with focus on the progress of moving from a beginning concept to a finalized system. Gaining knowledge about the user, performing competitive analysis, defining guidelines and setting usability goals will likely be done in the first phase of the design process, and will lead to the original design concept. This will be followed by parallel design, where several versions are designed. By extracting the advantages from the parallel designs a concrete prototype will be formed, which will be tested and/or evaluated, and refined through iterations before the product is released.

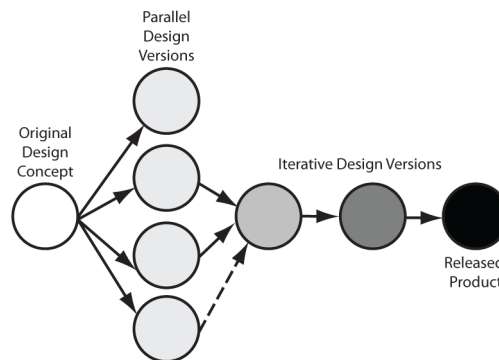


Figure 3.4: The complete iterative design process. Figure from Nielsen[14, p. 86].

### 3.3.13 Stages Used in Our Work

Because we did not implement a full system, and because only some of the stages were found relevant to our work, we chose to only use some of the stages presented by Nielsen. The stages used are presented below:

1. Know the user
2. Parallel design

### 3.4. SUMMARY

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3. Participatory design
4. Coordinated design of the total interface
5. Guidelines
6. Prototyping
7. Empirical testing

Some of the stages were emphasized more than others, and some of them were adapted to fit in with our work. A detailed description of how we have used these specific stages and why we have left out some of the stages will be given in Chapter 6.

## 3.4 Summary

In this chapter we have given a thorough presentation of qualitative research through the use of case studies, which was the research method that we chose to use for this thesis. We have also presented theory on usability engineering. A typical usability engineering life cycle has been described, from the initial forming of requirements to the release of a final product. Both case studies and the usability engineering life cycle will be revisited when we in Chapter 4 present the work we have done for designing the paper prototypes for this thesis, and when we in Chapter 6 discuss the methods we have used in our work.





# Chapter 4

## Design of Prototypes

As explained in Chapter 3, we chose to use a case study as our research approach. We will in this chapter give background information on the examination days, and describe how we used the case study to identify the challenges that the coordinator at Aker face during these days. From the identified challenges we have designed five different paper prototypes of visualizations. Each of these paper prototypes will be presented in detail. In the end of the chapter we will account for the types of awareness (presented in Chapter 2) that are covered in each of the paper prototypes.

### 4.1 Prestudy

For this thesis we have used the Vascular Surgery Department at Aker as our case. This department is a part of Oslo Vascular Centre. Traditionally, vascular surgery has been the main treatment for disorders related to blood circulation. In recent years, new examination techniques and treatments have been developed. This has made it necessary to make use of competence from other medical disciplines when treating these disorders and in preparing patients for operations. The motivation for establishing Oslo Vascular Centre was to unify this competence into one unit.

Up until the late 1990s, patients who were scheduled to undergo vascular operations at Aker had to make multiple visits to the hospital to undergo pre-operative examinations. Aiming to increase satisfaction among the patients and personnel, and to raise the productivity at the hospital, the Vascular Surgery Department at Aker carried out a project called “Pasienten Først”

(“The Patient First”). One of the main outcomes of the project was that all preoperative tests and work-up that patients needed to undergo between the decision for an operation and the operation itself were organized into a dedicated “examination day”. Following the “Patient First” project, the Vascular Surgery Department at Aker has dedicated every Wednesday to these examination days. Every examination day is preceded by a so called decision day. During the decision day radiologists and cardiovascular physicians meet and discuss the further treatment of patients that have come to a polyclinic examination.

Figure 4.1 shows the traditional way of conducting the preoperative examinations. Each of the boxes depict one day. As we can see from the figure the patients had to come in to the hospital on five different days for preoperative examinations.

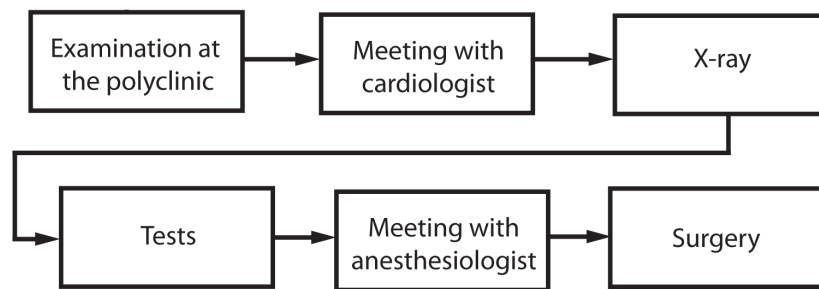


Figure 4.1: The flow of examinations before the introduction of the examination day.

Figure 4.2 shows how the preoperative examinations are carried out after the introduction of the examination days. As we can see the number of days used before an operation is now reduced to one instead of five.

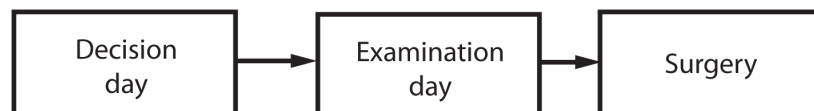


Figure 4.2: The flow of examinations after the introduction of the examination day

### 4.1.1 Detailed Description of the Examination Days

On the examination days patients are examined by physicians and other health personnel with different medical competency. This is time-saving both for the patients and the hospital. But this also means that several different actors located in several different departments are involved. On the examinations days a coordinator is responsible for making sure that all the examinations are carried out as planned. In addition to the coordination of activities, the coordinator is also responsible for several other tasks on the examination days. The assumption of our work is that positioning systems can help the coordinator during the examination days. More specifically, we have looked at how data from such systems should be visualized in order to support this.

In addition to the coordination of activities the coordinator also has several other work tasks on the examination days. For example she is the one that types what physicians involved in the examinations have dictated. This task has been somewhat simplified by the recent introduction of speech recognition. Speech recognition makes it possible for physicians to dictate the information that should go into the journal using speech, and a computer then automatically inputs the corresponding text into the electronic patient journal. Unfortunately this technology is, at the time of writing, not very mature and the coordinator has to manually go through the text and correct spelling errors. The coordinator then needs to make these journals available to the health personnel that need them later during the examination day, which involves walking from department to department.

The patients undergo the same examinations and tests during the examination days day, but at different times. An exception to this is patients with abdominal aorta aneurysms (AAA)<sup>1</sup> which are also examined by a physiotherapist. The different activities that the patients are to undergo during the examination days are listed in a paper-based schedule. This schedule gives the coordinator an overview of where the patients and health personnel should be located at specific times. The schedule is shown in Figure 4.3. It consists of three rows, one for each patient. Each row lists the planned starting time for all the different examination activities each of the three patients will undergo during an examination day. A translation of the different activities is given in Table 4.1.

If a patient or physician does not show up the coordinator has to start investigating where he or she might be. The coordinator contacts the physicians

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<sup>1</sup>Abdominal aorta aneurysms are dilations of the aorta in the abdomen

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	Blod-Prøver	Angiologisk pol journalskriving.	Røntgen	Spirometri	Kardiolog	Fysioterap v/AAA	Anestesiolog	Samtale karkirurg	Samtale sykepleier
Pas. nr. 1	kl. 07.50	kl. 08.30	kl. 09.15	kl. 09.30	kl. 10.00	kl. 11.45	kl. 12.00	kl. 13.45	kl. 14.00
Pas. nr. 2	kl. 08.15	kl. 09.00	kl. 09.45	kl. 10.15	kl. 11.00	kl. 14.00	kl. 13.00	kl. 14.15	kl. 14.30
Pas. nr. 3	kl. 08.45	kl. 09.30	kl. 10.15	kl. 10.45	kl. 13.00	kl. 14.30	kl. 14.45	kl. 15.00	kl. 14.15

Figure 4.3: The figure shows the paper-based schedule that is used by the coordinator on the examination days

Norwegian	English
Blodprøver	Blood sampling
Angiologisk Pol. Journalskriving	Writing of journals at the Angiologic Polyclinic
Røntgen	X-ray
Kardiolog	Cardiologist
Fysioterapeut (v/AAA)	Physiotherapist, only for AAA patients
Samtale karkirurg	Interview with cardiovascular surgeon
Samtale sykepleier	Interview with nurse (this activity has been phased out)

Table 4.1: Translation of the activities in the schedule from Norwegian to English

using calling, which according to the coordinator works well. The patients, however, are harder to keep track of. The patients and the coordinator exchange phone numbers during the briefing in the morning, and they can call the coordinator if they have any questions. The other way around is more problematic. Often the patients will not be able to describe their location. According to the coordinator she has found patients in the cafeteria at the time they are expected to be seeing one of the physicians. Because she has other work tasks to perform and a tight time schedule, it is frustrating for

the coordinator to spend a lot of time on this.

## 4.2 Requirements Analysis

Through a document analysis, an observation and an interview we have done a in-depth study of the challenges that the coordinator face on the examination days. This helped us find the requirements for the prototypes we have designed in this thesis. In the following, we will present the challenges that we have identified.

### 4.2.1 Document Study and Talks with Domain Experts

We put an emphasis on gaining a thorough understanding of the work practice at Aker before the interview and observation was carried out. To do this we first studied a document provided by Aker. The document gives a broad introduction to the examination day. In addition, talks with two domain experts were carried out.

The document provided by Aker is both an explanation of the purpose of the examination day, and a comparative study between the traditional sequential patient inquiry and the use of examination days. The comparative study is mainly focusing on the reduced waiting times for the patients, and the increased satisfaction among patients and staff as a result of the introduction of the examination days.

The domain experts are one researcher and one physician that both work in the COSTT-project. The researcher has done both observations and interviews at the Vascular Surgery Department at Aker. The document provided by Aker gave us an introduction to the examination day, and his knowledge about the work done at Aker served to clarify uncertainties, and also gave more thorough explanations of the challenges faced by the coordinator on the examination days. The physician's expertise gave us a broadened insight into the medical terms used in the document, and specific terminology used in medicine in general.

### 4.2.2 Interview at Aker

The document review and talks with the domain experts gave us a good knowledge about the challenges that the coordinator has. By using this knowledge we conducted a semi-structured interview with the coordinator at Aker. In Appendix A we have included the questions that we brought to the interview. As this was a semi-structured interview the questions were broad, and follow-up questions to the coordinators responses were asked as the interview progressed.

The interview can be said to have gone through three phases. In the first phase the coordinator was given information about the project that was to be carried out. A detailed description about uncertainties found in the documentation and information from third parties (the researcher and the physician) were presented to the the coordinator. In the second phase the coordinator was asked to give a detailed description of the examination day, with a focus on the activities that take place these days. She gave a clear understanding about her role as a coordinator on the examination days, and the challenges faced both for her, the patients and other health personnel involved. Follow-up questions were asked, and several differences from our understanding of the examination day were identified. In the third phase information about the purpose of this project was presented to the coordinator. The coordinator was asked about her thoughts on introducing such a system. The coordinator replied:

“[...] I think it works quite good as it is today. But I haven’t experienced any other way of doing it, so I guess I’m a little biased.”

We replied: “Do you think you could have use for such a system?”, to which she answered:

“In certain cases, yes. Sometimes I have to search for... like last Friday there was a patient who we could not find an anesthesiologist for. Then I had to get hold of him. In such cases it would be very useful to see where he was [...]”

### 4.2.3 Observation at Aker

The observation was carried out on a regular examination day at Aker. The purpose of the observation was to see what challenges the coordinator is

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facing on the examination days. Also notes about the floor and room layout were taken, for use in the prototypes that were to be designed.

The main observation that we did was that the coordinator has to walk between three floors to get to all the examination rooms used during the examination days. In addition, if a patient is missing he may be located outside of the building, for example in the canteen, which is located several hundred meters from the building where the examinations take place. The coordinator is already under time pressure to fulfill her other work tasks during these days, and walking these long distances is seen both as disturbing and time consuming. She uses a step counter, and told that it was not unusual that 10,000 steps had been registered at the end of an examination day.

During the observation no specific coordination problems were observed, but a researcher that had previously done observations at the polyclinic noted:

“I remember when I was there, there was a patient that did not turn up on time for the interview with the anesthesiologist. The coordinator and the anesthesiologist looked for the patient, even going to the cafeteria to search, but without success. I suspect that the anesthesiologist finally left to go do other work. Shortly after, the physiotherapist walked around the corner to give a message about the patient she was having a consultation with. This turned out to be the missing patient. As the patient was not scheduled for an AAA procedure, the patient was not supposed to have seen the physiotherapist. Nevertheless, while the anesthesiologist and coordinator had been running around trying to locate the patient, the patient had been happily engaged in the consultation with the physiotherapist in the room next to the anesthesiologist. ”

## 4.3 Design of Prototypes

### 4.3.1 Design Method

Visualizations can be designed in an endless number of ways. Paper prototypes were chosen as the prototyping method for this thesis. Based on the understanding from the document provided, the talks with the domain experts, and the interview and observation at Aker, we identified requirements for the prototypes. As one can see from our research questions our focus has

been to see if we have used a valid approach in our work, and to investigate the amount of information richness needed in visualizations to support coordination work.

Based on this, five prototypes were designed. All of the prototypes provide different amount of information richness and granularity. The prototypes we have designed can broadly be classified as information visualizations. For the design of the prototypes we have used three of the categories in the taxonomy proposed by Schneiderman, which were presented in Chapter 2. Prototypes 1, 2 and 3 are all based on a map analogy, and for these prototypes we used the 2-dimensional category as inspiration. Prototype 4 is inspired by the temporal category, where data is placed on a time line. Prototype 5 is designed as a graph, and is based on Schneidermans network category.

### 4.3.2 Presentation of the Designed Prototypes

The design of each prototype went through three stages. In the first stage, we made a quick mock-up of the concept that the prototypes should represent. These prototypes were presented to the domain experts, which gave their comments, helped to sort out mistakes and made suggestions for how the prototypes could be improved. Based on this the prototypes were redesigned and again presented to the domain experts, before the final prototypes were designed. Figure 4.4 shows the three design stages for one of the prototypes.



### 4.3. DESIGN OF PROTOTYPES

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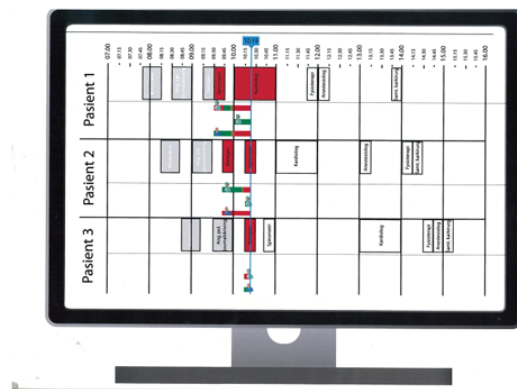
	BP	ANG POL	RTG	SPIRO	KARDO	FYSIO	ANEST	SMAT KARIE	SMAT SINTELEK
PAS 1	F	F	F	F	F	F	F	F	F
PAS 2	F	F	F	F	F	IKKE AAA-BI	F	F	STATUS IKKE PÅBEGYNT
PAS 3	F	F	F	F	F	F	STATUS IKKE PÅBEGYNT	IPB	IPB

Initial sketch

	ANESTESI	ANESTESI POLY	RONTGEN	SPIRO- METRI	KARDE- LOGI	FYSIO- TERAPI	ANESTESI- LOK	SANITARI KONTROL	SMATTE SINTELEK
Pas 1	F	F	F	F	F	F	F	F	F
Pas 2	F	F	F	F	F	IKKE PÅBEGYNT	F	F	STATUS IKKE PÅBEGYNT
Pas 3	F	F	F	F	F	F	STATUS IKKE PÅBEGYNT	IPB	IPB

F = FERDIG  
IPB = IKKE PÅBEGYNT

Refined sketch



Final prototype

Figure 4.4: From initial sketch to final design of one of the prototypes

## Prototype 1

Prototype 1 shows the room layouts for all the floors and rooms used during the examination day. Along with this there is a status indicator in the top right corner of each room. This indicator is either green, red or white, which denotes the state of the different rooms. A green indicator means that everything in a room is going according to the plan, a red indicator means that something is not going according to the plan, while a white indicator means that no activity is scheduled in the room at the time, or that none of the persons that should be present at other locations are in this room.

As an example one can imagine that the time is 10:12 in the morning. At this time patient 1 is scheduled to meet the cardiologist. If they are both present in the room at this time the indicator will be green. If one of the persons is not present in the room the indicator will be red. Figure 4.5 shows the final design of prototype 1.

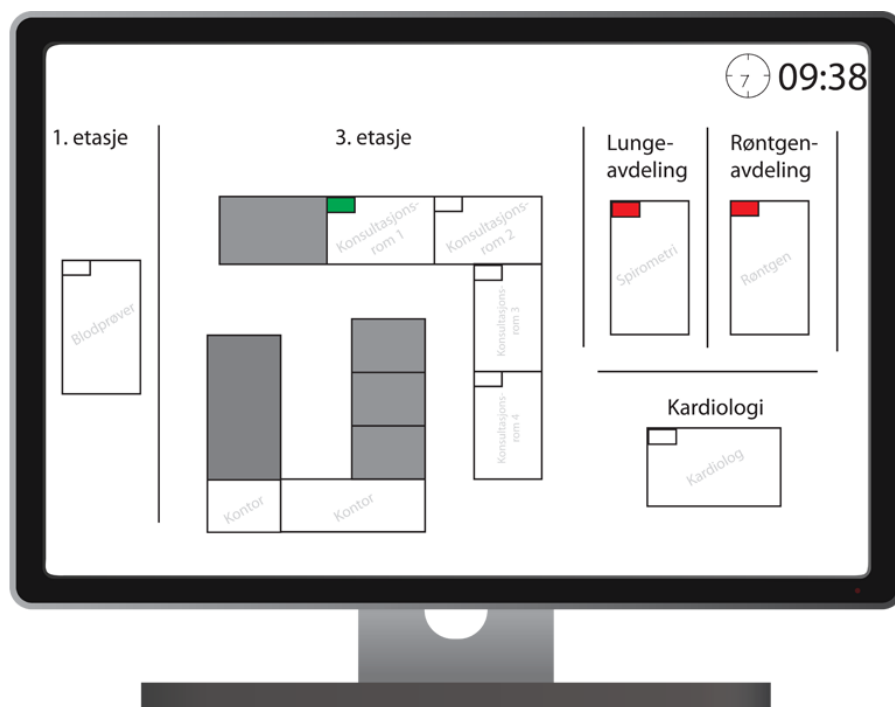


Figure 4.5: The final design of prototype 1

### Prototype 2

Prototype 2 is a reformation of prototype 1, where more information is provided to the coordinator. In addition to the status indicator presented in prototype 1, the location of health personnel and patients is shown in this prototype. The patients are marked with blue icons, while the health personnel are marked with green icons.

Like prototype 1, the status marker will tell the coordinator something about the situation in the different rooms. But unlike prototype 1, if a person is missing the coordinator will also be able to make assumptions about where he is based on the icons. Prototype 2 is shown in Figure 4.6.

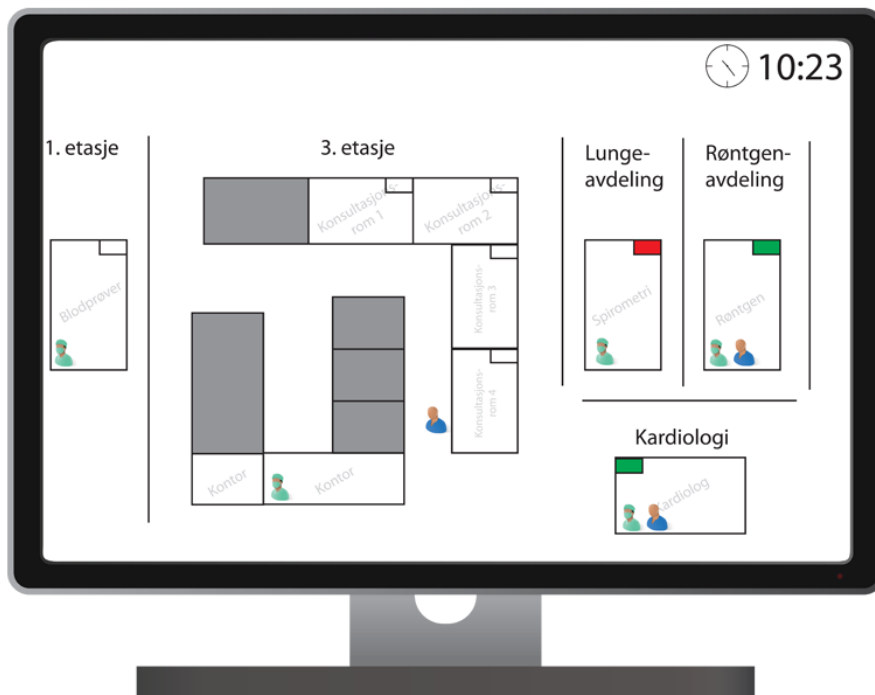


Figure 4.6: The final design of prototype 2

### Prototype 3

Prototype 3 is based on three different screens. In this prototype the status indicator has been removed. Like prototype 2 the different persons are shown in the prototype, but in this prototype their role has also been added to the icon. A green icon will be shown for health personnel, for example along with

the role “Cardiologist”, while the blue icons will be shown with the number of the patients. The first screen shows a three-dimensional view of the floors in the building where the examination days take place. Along with this the persons located on each floor are shown. From the prototype it is possible to click on a specific floor. This will give a more detailed visualization that shows in which room the patient is located. This information can be further detailed by clicking on a room, which will show the proximity between the different persons and equipment in the room. The idea is that, by looking at their proximity, the coordinator should be able to tell how far in the process an examination has come. All three screens of prototype 3 is shown in Figure 4.7.

### 4.3. DESIGN OF PROTOTYPES

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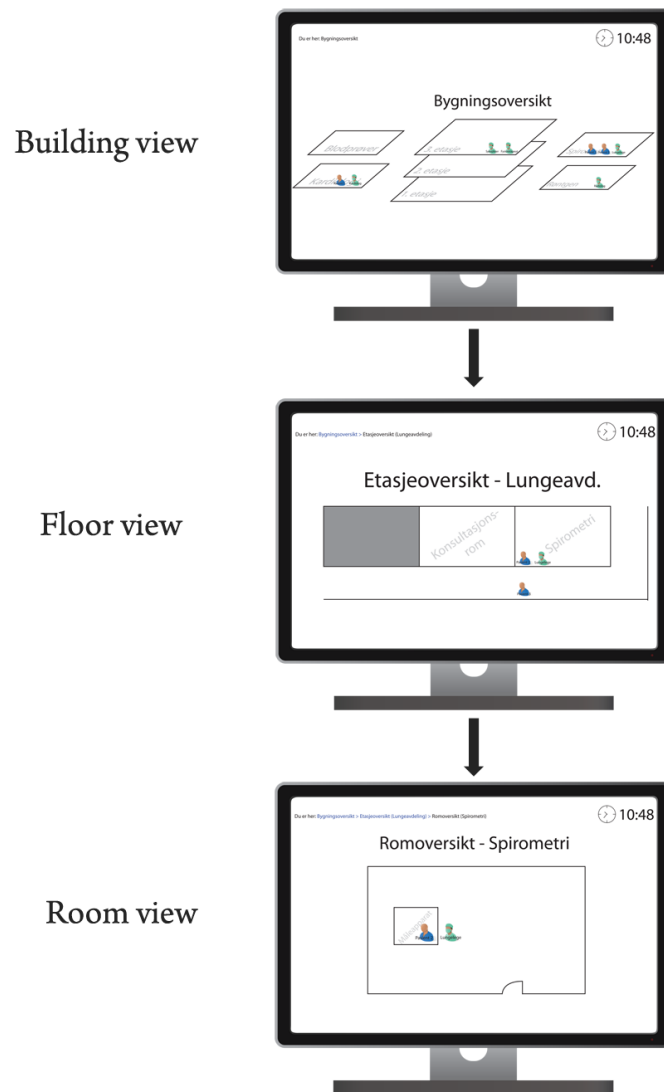


Figure 4.7: The final design of prototype 3

### Prototype 4

Prototype 4 is designed as a time line. The prototype resembles the coordinators time schedule for the examination day. In the time schedule used by the coordinator the different activities on the examination days is not laid out sequentially. We saw this as inconvenient, and therefore designed our time line with a sequential representation of the activities. In Chapter 2 we presented the Workflow concept from theory on CSCW. This concept says that for a CSCW system to gain acceptance it is often best to make it resemble the traditional system, and to introduce new features. This has been the main thought behind the design of this prototype. Prototype 4 is presented in Figure 4.8.

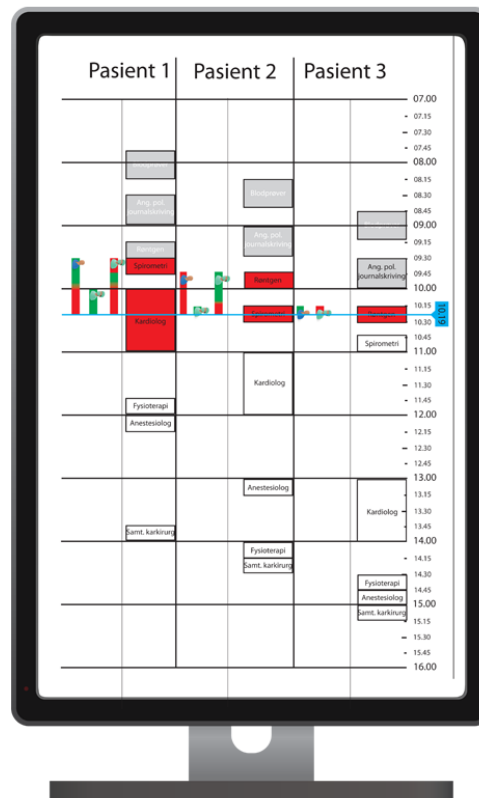


Figure 4.8: The final design of prototype 4

The prototype has three columns, one for each patient. For each column the examinations that the patients are to undergo are listed as boxes. The blue line shows the current time. As in prototype 1 and 2, the boxes show the status of the different examinations, the green icons depict health personnel,

### 4.3. DESIGN OF PROTOTYPES

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while blue boxes depict patients. Patients and health personnel also have their own assigned status lines, behind their icons. Green boxes depict examinations where everything is going according to the plan, and red boxes depict examinations where something is not going according to the plan. In addition, gray boxes depict examinations that are finished and white boxes depict examinations that have not yet been started. The gradient between the green and red status line behind the actors icons marks that the status is not severe at the moment. However, when this gradient is showing, the coordinator should be aware that problems could occur in near future, and that the status soon will change to a red state.

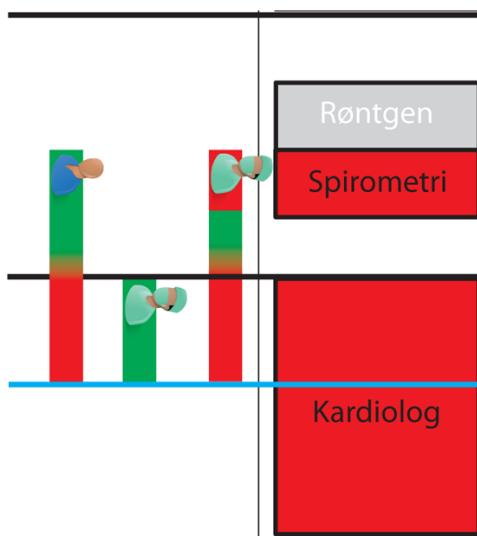


Figure 4.9: Detailed excerpt of prototype 4

Figure 4.9 shows a close-up view of two examinations that are not going according to the schedule. From the blue line in the figure one can see that patient 1 at this time should be seeing the cardiologist. One can see that the boxes underneath the blue lines are marked with red. Also, the two previous examinations for the patient are marked with red. From the figure we can see that patient 1 showed up at the spirometry examination at the time it was supposed to begin. We can also see that the physician that was supposed to be performing the spirometry is marked with red for the first part of the examination. What this visualization shows is that the physician did not

show up for the spirometry at time, which caused the delay to propagate into the patients meeting with the cardiologist.

### Prototype 5

Prototype 5 is designed like a graph. The graph consists of boxes and icons, where rooms and equipment are shown as boxes and actors are shown as icons. The boxes for rooms will be either green, red, or light gray with black text. A green box means that everything in a room is going according to the plan, a red box means that something in a room is not going according to the plan, while a light gray box means that no activity is scheduled in the room at the moment. Between the boxes for rooms and boxes for equipment (shown in dark gray with white text) and icons for actors there are status lines. There is also status lines between boxes for equipment and icons for actors. These lines are either green or red. If all of these lines are green the box showing the room will also be green. But if one of these lines are red the box for the room will be red. Figure 4.10 shows the complete prototype.

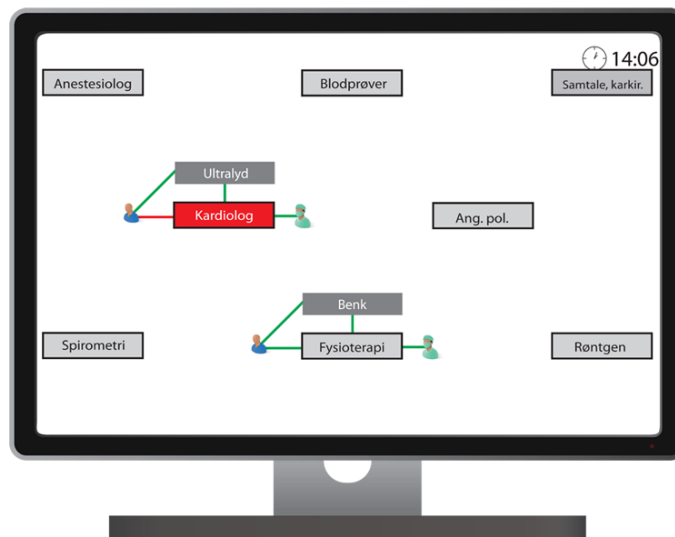


Figure 4.10: The final design of prototype 5

Figure 4.11 shows part of prototype 5. From this figure we can see that the overall status for this room is marked as red. We can see that there is a green line between the patient and the ultrasound machine, the ultrasound machine and the room, and from the physician and the room. But, between the patient and the room there is a red line. From this the coordinator can



assume that the patient should not be at a cardiology examination at this moment, and that this is the cause for the box to be shown in red.

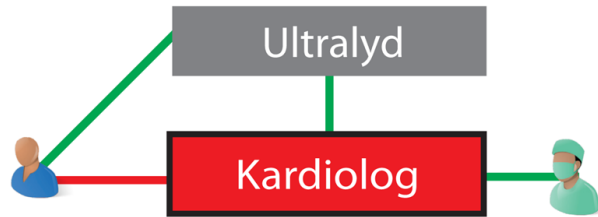


Figure 4.11: Detailed excerpt of prototype 5

## 4.4 Coverage of Awareness in the Prototypes

For this thesis awareness was especially interesting, as we have designed prototypes that link visualizations to positioning data. In Chapter 2 we presented the types of awareness that Bardram et al. have proposed should be covered in a CSCW system. We will here describe how these types of awareness are covered in the prototypes that we have designed.

### Social Awareness

We have previously defined social awareness as “[...] users of the system should get access to information about the activities of their colleagues in order to adapt their own work”. All the prototypes designed cover spatial awareness, but because of their different level of abstractions some of them provide a higher level than others.

Prototype 1, which can be said to be the most abstract prototype, requires a high cognitive load for the coordinator to say something about the activities of others. As only the status for the different rooms are shown, she will have to use this information and relate it to the time on the screen and the time

schedule to say something about the activities of the actors. It can therefore be said to provide partial social awareness.

Prototype 2 lets the coordinator see the location of the different actors that take part in the examination day, where green icons depict health personnel and blue icons depict patients. But, health personnel will not be marked with their role (e.g. “Anesthesiologist”), so she will still have to rely heavily on her time schedule to say something about the specific activity that is going on.

Prototype 3 allows the coordinator to zoom between building, floor and room level views. In addition it marks health personnel with their role. This means that the coordinator will not have to rely as heavily on the time schedule to say something about what is going on in a room. This prototype will not show the status of the different rooms, and the coordinator will have to zoom down to at least floor level to see who is present in a room. Though it requires more interaction from the coordinator, it will not be critical for her to use the time schedule to say something about the status of a room. As an example: if she sees that the cardiologist is present in a room and that the patient is missing she can assume that she will have to locate the patient in the map and guide him to the cardiologists office. To sum up we can say that this prototype covers a high degree of social awareness.

Prototype 4 shows a status line for each actor in a time line. From this information the coordinator will be able to see the activities the different actors that are performing in the moment. But on the contrary, if they are not in their expected location at their expected time this prototype will not say anything about their location.

Prototype 5 is designed as a graph, and shows the relations of different actors, equipment and rooms through status lines. As with prototype 4 this prototype does not give any information on the location of other people than those who are associated with a room in the moment.

### **Temporal Awareness**

Temporal awareness is the ability to see activities that have performed in the past, activities that are going on in the moment, and activities that are to be performed in the future. Temporal awareness is fully supported in prototype 4. By looking at the time line the coordinator can see previous examinations (grey boxes), examinations going on in the moment (boxes placed under the blue time line), and future examinations (white boxes). Prototype 1, 2, 3

## 4.5. SUMMARY

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and 5 all shows examinations that are going on in the moment, but will not show past and future activities. These prototypes will require different amounts of cognitive activity for the coordinator to say something about the examinations going on in the moment.

### **Spatial Awareness**

Spatial awareness is the ability to say something about what activity is going on in a location at the moment. This information makes it possible for the coordinator to say something about the progress of an activity. All of the designed prototypes support spatial awareness. But as the coordinator would have to rely heavily on the time schedule in prototype 1 and 2 their degree of spatial awareness is marginal. The other prototypes can be said to have a higher degree of native support for this type of awareness.

Prototype 3 lets the coordinator zoom into room level view. By looking at the proximity between the patient and the physician, or the proximity between patient and examination equipment it is possible to say something about how far an examination has come.

In prototype 4 the blue time marker will say something about how far an examination has come, based on its position above the boxes. The status line will also tell the coordinator when an examination started. For example, if an examination has taken longer time than expected the coordinator can look at the status line, and get an explanation of why the examination is delayed.

Prototype 5 links the different rooms, persons and equipment with status lines and status boxes. The lines say something about the connection between the different objects. As an example one can say that a patient is linked to an x-ray machine via a green status line. The coordinator will from this information be able to interpret that the x-ray examination is still taking place.

## **4.5 Summary**

The Vascular Surgery Department at Aker has been looking into how pre-operative examinations could be made more efficient in a project named “Pasienten Først”. This led to the introduction of the “examination day”, where all preoperative examinations are finalized in one day. On these days

the activities are coordinated by a coordinator. As the examination day involves many actors located in different departments it is often a challenge to solve coordination problems when activities are not going according to the planned schedule. Our assumption is that positioning data can help the coordinator in such situations.

To get an understanding of the challenges that the coordinator faces we conducted a case study. The case study served as the basis for designing five paper prototypes of visualizations, which we have presented in detail. The five prototypes have been designed with different amounts of information richness, which will help us get answers to the research questions which we defined in Chapter 1.

In Chapter 5 we will present the results from the user testing of the designed paper prototypes.

# Chapter 5

## Results from User Testing of Prototypes

In Chapter 4 we described the process of how we in this thesis have designed the paper prototypes, along with a presentation of the different prototypes. In this chapter we will present the results of the user testing of the paper prototypes.

Three test persons from two hospitals were recruited for the user testing. These had both direct and indirect knowledge about the coordination of activities in hospitals. We will first present an overview of how the user testing was carried out. The user testing will be presented in two separate parts, one for each hospital. In each part we will give a brief description of the different test persons, and a report from the user testing, along with a summary from an unstructured interview that was conducted after the testing. To get a clearer picture of what the test persons thought about the different prototypes we asked them to card sort the prototypes. The results from this card sorting will be presented in the last part of the chapter.

### 5.1 Overview of the User Testing

For the testing three persons with medical background were recruited. All of the test persons are directly or indirectly related to coordination of activities in hospitals. The purpose of the user testing was to see how the test persons interpreted the prototypes that we have designed. For each prototype they were asked to identify a problem. If they managed to do this they were

asked how they would go on about solving it. The problems to be solved differed from prototype to prototype, to prevent that the test persons got accustomed to how to solve the problems. At last, they were asked about their thoughts on the different prototypes. The questions asked to the test persons are presented in Appendix B.

For all interviews we gave an introduction describing the prototypes and the purpose of the testing. They were told about the use of paper prototypes, and they were also informed about the shortcomings that such prototypes have. One of the prototypes were shown to them, and they were told that they should act as if what they were seeing was a computer monitor. Further, they were told that they could interact with one of the prototypes (prototype 3), by “clicking” on the screen shown in the prototype.

The test persons were told that they for prototype 1, 2, 3 and 5 could use the time schedule traditionally used by the coordinator to solve the problems. In addition they were told that there is a time marker in the top right corner of these prototypes, which shows the time in the imagined moment.

The prototypes used were the same as those presented in Chapter 4. The prototypes can also be seen in high resolution in Appendix C.

## 5.2 User Testing at Aker University Hospital, Oslo

### 5.2.1 Overview of the Testing at Aker

For the testing at Aker in Oslo the coordinator and the chief vascular surgeon at the Vascular Surgery Department were recruited. The coordinator is the main interested party for this thesis, and because of this it was natural to recruit her for the testing. The chief vascular surgeon has been working with the introduction of the examination day, and also patients on the examination days.

Due to time restrictions the tests had to be carried out as a collaboration between the two, and they were asked to give separate input whenever possible. As discussed in Chapter 3 this technique is named co-discovery testing.

### 5.2.2 Testing of Prototype 1

When they were asked to identify the problem in the first prototype, the coordinator replied that “someone is not in place or they are delayed”, as the status marker for two of the rooms were red. It became clear that additional information about how the prototypes functioned had to be given to the test persons. From this information it became easier for the test persons to grasp the intention of the testing, but still they had to be given a lot of clues about what was wrong in order to solve the problems.

When asked about what the coordinators thoughts of this prototype she replied:

“I need to look at it a little more than what I have done in order to identify the problem. And the question is, what do I do if they [the patients or health personnel] are not in their expected location? I would have to call and investigate why the patient had not carried on to the next examination. And if they [persons in the examination room] are busy, my phone call would not get answered, and I would have to go down and ask.”

The coordinator was asked if she understood what our thoughts were when designing the prototype:

“Yes, I understand what you mean, but I do not think it is very easy to understand at once. I guess it requires a little more time to get accustomed to the way of doing things [using the prototype]”

The chief vascular surgeon followed up:

“I understand the logic behind it, but I did need an explanation about how to do it. I think one should have more color nuances. For example, where there is no patient but one should be present... that one could have another color. And one could say that when red the patient is present, but there is a delay. I think one gets a little confused by the fact that the colors are too similar. For instance, if this one is red [points at one of the rooms marked with a red status], there is a physician waiting for a patient.”

### 5.2.3 Testing of Prototype 2

The test persons were informed about the similarities and changes in relation to prototype 1. It was explained that the green icons depicted health personnel, and that the blue ones depicted patients.

When asked if they could solve the problem the coordinator replied “I don’t think this is easy”, to which the surgeon replied “Maybe we should solve it together?”. The surgeon started to think aloud about what the problem was, and eventually identified the problem, but had trouble identifying the cause for why the problem had occurred. He said: “This is like an IQ test”, but with additional help they were also able to identify why the problem had occurred.

The coordinator was asked if this prototype could be of help to her. “If I learn to use it, yes. But I need more knowledge into the way of thinking about it”. They were asked if they liked prototype 1 or 2 the best. The coordinator replied:

“I think this one [prototype 2] is better, maybe because I have gotten a little used to how I should think about solving the problems. In addition the patients are marked, and I can see which persons are in the rooms. I think this one [prototype 2] is easier.”

She was asked, “do you think this is something that you could have and make use of during the examination days?”

“I can’t say yes or no. I would not oppose the use of it. I cannot say that this does not give me anything before I have tried it a little more. I do not think that is right.”

The surgeon followed up: “It is clear that this is a way of thinking that one would get used to.”, and they both agreed that this prototype was better than prototype 1. The coordinator added: “...it would be far easier if the patients were distinguished by their number, because then I could say: OK, the time is this or that, and at that time the patient should be here [points at a room].”

### 5.2.4 Testing of Prototype 3

In prototype 3 interaction is supported, as the users can jump back and forth between building, floor and room level views. Also, patient icons are marked



with their assigned number, and physician icons are marked with their role. The test persons were informed about this.

The test persons were asked to identify how far one of the patients had come in his examination. This patient is shown in an examination room together with a pulmonologist. They are both shown close to the spirometry machine. The idea was that, based on the proximity between the different objects, the test persons should perceive this as a sign that the examination was still going on. They were both able to identify this. When asked how they would solve this problem, the surgeon replied “This tells me that the patient standing here [by the spirometry machine] is not finished with his examination. I think this [prototype] is a rational one, as it gives an explanation of the delay one is facing. ” The coordinator followed up:

“Yes, this sounds relevant. And at all times one can say... say, if they call from the cardiology polyclinic and say that the patient has not arrived. Then one can click its way through and say: “No, he is not yet finished with his spirometry.” This [prototype 3] one is the best I have seen so far.”

### 5.2.5 Testing of Prototype 4

Prototype 4 only says something about the progress of the examinations, and does not say anything about the location of patients, health personnel or equipment. We started the testing by giving a brief explanation of the layout of the prototype to the test persons. Immediately after the coordinator said:

“The fact that I can see whether or not a patient is finished [with his examination]... that is a big advantage. If they are a little late for the writing of journals, and I wonder if they have been taking their blood samples [...]. Then I can go in and see if the blood samples are collected. This [prototype 4] is the best I have seen so far.”

The prototype shows a lot of information, and the test persons had problems solving the questions that we presented to them. As the coordinator said: “It is hard to understand what it communicates and how to use it at first sight”. When asked about what they liked and disliked about the prototype, the coordinator replied:

“I like the fact that I can see where the patients have been. But

I did not like the confusion of using it - I think there is too much information crammed into it. What is nice with this is that... say... If a patient should be with the cardiologist I could look at this and know where the error is. Then I could call the cardiology lab and say that there is a delay because of this or that. That is very helpful. I think this one is well arranged once I understood it.”

The surgeon followed up:

It is good in the sense that it gives an overview of the situation in the moment. If everything is green or everything is gray, you [the coordinator] can grab a cup of coffee. I wonder, cannot this [prototype 4] be substituted with this one [prototype 3]? I think this one is much more rational to work with.

The coordinator came with a suggestion about getting more details if necessary:

“Let us say that it is possible to click further, so that you can go to room view if something is wrong. I see this as very useful, although I think it can be improved a little. I like that it is laid out sequentially.”

The surgeon agreed:

“This could be work tool number one. And if everything is OK there is no need to think. And, since you have got a snapshot here... then one should be able to click on [a red box or red status line] this, and get the answers that is needed.”

The colors of the status indicators confused the test persons, and they suggested that a wider range of colors should be used in order to make it to easier differentiate between the different states:

I think that red should indicate that something is wrong. And I suggest that a yellow color is also introduced that indicates that a physician is available to do an examination.”

The prototype was originally laid out horizontally. When looking at the horizontal prototype the text was laid out vertically, which made it hard to read. One of the first things the test persons did when they saw the prototype was to place it vertically, as they thought this gave them a better view. The coordinator said: “I think it is easier to follow when it is laid out like this [vertically].” Because of this I decided to lay it out vertically for the meeting

with the test person from St. Olavs Hospital.

### 5.2.6 Testing of Prototype 5

The examination room with an anomaly (red status) were correctly identified by the test persons at first sight. However, it was hard for them to identify *the cause* for why the room was marked as red.

For the examination room that was marked as green the coordinator thought that the examination had finished, while the visualization meant to show that an examination was taking place and that everything was going according to the plan.

When asked about her thoughts on the visualization, the coordinator replied:

“It is easy when I see it like this [after some explanations had been given]. But I like this one [prototype 4] better.”

The surgeon noted that it was hard to get an overview of the actual status in the room, because of bad color shading:

“If we think about color shades, it is possible to get a little dazed, because it immediately looks like everything is OK [because there are green lines (depicting relations) where the boxes are red (depicting rooms)].”

### 5.2.7 Final Thoughts from the Test Persons at Aker

After the interview we had an unstructured interview with the test persons from Aker. The coordinator was asked if she thought an implemented version of it would support her on the examination days, and both were asked to give their view on the designed prototypes.

In Chapter 4 we saw that the coordinator said that she would have use for the system designed for this thesis in “certain cases”. After the testing was over she was asked the same question, and replied: “I can see the use. In cases where the patient is missing it would be useful to see where they are. What I think, not many patients get lost, but in such cases it would be useful”.

She was reminded about the case where she found a patient in the canteen, and answered: “In such cases it would be very very useful. It would have saved me a lot of time.”.

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When asked about their general view of the prototypes they stressed that it is important to provide details when necessary, and that these details should not overlap. As the surgeon formulated it:

“I think that the rationale... or let us say, the possibility to click through various levels should not provide information that we have already been given. It has to give more information than what was given in the previous level.”

The surgeon also gave his ideas on how such a system could appeal to other people than the coordinator:

“I think that part of the idea here should be that, apart from the coordinator... that she has an overview... should be that the next level [other health personnel] gets information about the progress of the different activities.”



Figure 5.1: Discussing the prototypes with two of the test persons after the testing.

## 5.3 User Testing at St. Olavs Hospital, Trondheim

### 5.3.1 Overview of the Testing at St. Olavs Hospital

The test person recruited from St. Olavs Hospital works as a nurse, and has a specialization as a theatre sister. In her daily work she has the responsibility for the coordination of emergency patients that come to the hospital for operations.

The test person from St. Olavs Hospital was seen as a good candidate for the user testing as she works with coordination on a daily basis. One of the main reasons for recruiting her was to see the outcome of the user testing from a test person that does not work at Aker. The coordinator at St. Olavs Hospital faces different challenges from the coordinator at Aker. As she has the responsibility for coordinating emergency patients for operations the flow of events is much faster, which means that she has to act faster than the coordinator at Aker. In addition she does not rely on a time schedule during the day, as she has to coordinate patient's as they come in to the hospital.

### 5.3.2 Testing of Prototype 1

The test person was asked to identify the problem, and described what she thought was the reason:

“The patient is delayed. Or delayed... he should be at spirometry at this time. Something has taken longer time than what it should.”

From her response the test person was given a more thorough introduction to the prototype, and the purpose of the testing, as she had not completely grasped what we were looking for. It became clear that she had not realized that there was a time aspect, and that she also should rely on the time schedule in order to solve the problem. In addition she had a problem with relating the work method at Aker to her own work at St. Olavs Hospital: “I look at this from my fixed place... for instance that I need to relocate patients to other rooms.”

After she had been informed about this she was able to identify the problem, but still she expressed that there were some differences to her own work practice:

“What I would have done... if there is a delay I would... then this one [one of the rooms] is available. I would check if... how far the next patient had come and maybe rescheduled him. Because the main goal is that patients are treated. The order of doing things has nothing to do with the examinations, the purpose is that the examination should be carried out.”

When asked about her view on the prototype she replied:

“I think it would be useful. But, it takes time to get used to things. Recently a patient from the emergency was sent to me, and he had to undergo operation quite fast. And I had another patient that was waiting, then I thought “should we place that patient at ward or should he continue to stay where he was?” With this system I could then get an overview of the situation there, and see how busy they were.”

### 5.3.3 Testing of Prototype 2

The test person was presented with the problem, and was able to identify it at her first try.

When she was asked how to solve it she responded:

“I would see that there was a missing patient. And then I would think: “Where is he?”. Then I would contact other health personnel, and ask them “where is he?”. I would then go and check, or send someone to check. And because I know where he is based on what is shown on the screen I would immediately know where to look.”

She was asked about her thoughts on this prototype, and to compare it with prototype 1:

“I think this one is really useful. Because here... say that the patient had a malaise, then I could see where he was. The first one [prototype 1], I think that one was more related to the status of the health personnel, whereas with this one I am also able to easier follow the patients.”

### 5.3.4 Testing of Prototype 3

When trying to solve the presented problem the coordinator was able to identify where the problem had occurred, but she was not able to interpret what the specific problem was:

“[Clicking into floor level view] The problem here must be that the radiologist is seeing two patients at once, which is a quite efficient way of doing things. I guess he has got two patients in two separate booths. To see how far they have come in the progress I would see if one of the patients has started the spirometry examination...”

At this point the test person was interrupted by us. We explained to her that at Aker only one patient at a time is going through a spirometry examination. She was also reminded that she could click into room level view in the prototype.

“Aha, I see. From the other picture [floor level view] it looked like they both were in the room. I would click here [clicking into room level view] and see how far they had come in their examination, based on the proximity of the patient, the physician and the equipment. From here I see that the physician is busy with the patient, and I would ask the patient standing outside the room to sit down and say ”it is soon your turn.” But of course, it depends on the time. If there is another patient scheduled after the one sitting outside I would maybe have to do it another way. I would check with the cardiologist, maybe they could rearrange a little... I would have to think how long it takes for the patient to walk to the cardiologist... If there is no time to be saved it would of course be useless, and I would say that he should wait.”

When asked about how she liked the prototype and to compare it with the other prototypes she responded:

“I did not understand why floors and boxes were shown in the first screen you showed me... To me it looked like both rooms and floors were shown. Why are they not part of the floors? ... But I like that it is very patient focused, and that I can see that physicians are available. Then I could make the phone calls and check, and try to make it work. I think there is quite a difference between this one [prototype 3] and the other ones [prototype 1 and 2]. This one and the last one [prototype 2] gives a good

overview of the patients. I do not think one should compare them against each other, but the first mainly shows information about the status. There is a lot of information that has to be rendered at the same time on the first [prototype 1].”

### 5.3.5 Testing of Prototype 4

First the test person was informed that the next two prototypes to be presented are visualized in other ways than the first three. Prototype 4 is information heavy, and at first the test person had problems understanding the prototype. Because of this, a thorough introduction about the thoughts behind the design had to be explained.

After the introduction the test person managed to identify the problem and the idea behind the visualization. When asked about her view on the prototype she answered:

“It would be easier to use this if I could relate it to a real situation that I am facing in my work. When I understood how it works I think it was easier to see how the different actors [patients and health personnel] relate to each other, because of the axis... it is easier to relate this to the time aspect. And I think... one has to get accustomed to using it.“

### 5.3.6 Testing of Prototype 5

As before, the test person was asked to identify what was wrong with the prototype:

“Everything looks OK with the physiotherapist. I guess the green lines going from each of them to the box, and the fact that the box is green, means that at all is well. For the other one... well I can see that something is not going... the box is red. That means that something is not going as it should. But what? The red line between the patient and the box... what does that mean?”

She was asked to see if she could get help from the time schedule to identify the problem, and continued:



[Looking at the time schedule] At this time the patient should not be present in the room. So I guess that that is why there is a red line... yes, that makes sense!"

When asked how she would solve it she replied:

"I would have called the next person at the next examination. No...wait... he does not have an examination straight after. Then I guess I could just let them go on without doing anything."

#### 5.3.7 Final Thoughts from the Test Person at St. Olavs Hospital

Like with the test persons from Aker we conducted an unstructured interview after the testing was over. In the interview the test person said that she found it hard to get accustomed to the way of thinking, but that she was convinced that a similar system would help her when coordinating operations at the hospital. The test persons at Aker said that it would be possible to first get an overview of the situation, and then request more details if necessary. The test person at St. Olavs Hospital also brought this up:

"I would like to have a combination of the different prototypes. I think it is good to see their exact position, but sometimes that is not necessary, and then it would be good to just get an overview of the situation. For example, combining prototype 2, 5 and 4 would give me this information. That would be good..."

She was asked if she saw advantages of using a system visualized like the prototypes:

"I think it would be very useful, but of course - it would have to be customized for my work in order to give any use at this department."

In the end the test person gave a final remark:

"The central part... since we are not computer specialists... I think... it is important that the system should be user friendly. Some of the systems we use today... users often get angry by using them. The computer folks have to understand that they should focus on creating user friendly products if they want people to use them. As it is now, some just think it is a waste of time to use them, and only use them if they have to."

## 5.4 Results from Card Sorting of the Prototypes

After the testing was over each of the test persons were asked to rate the different prototypes using the card sort technique described in Chapter 3. As Table 5.1 shows, the rating from the users has a high degree of consistency, where the most interpretative and concrete prototypes have a high rating, while the more non-interpretative and abstract prototypes have a low rating. As we can see from the table an interesting exception is that test person 3 rated prototype 3 in the bottom, whereas the other test persons rated this among the top three.

Rating	Coordinator, Aker	Chief Vascular Surgeon, Aker	Coordinator, St. Olavs Hospital
1st	Prototype 4	Prototype 4	Prototype 5
2nd	Prototype 3	Prototype 5	Prototype 4
3rd	Prototype 5	Prototype 3	Prototype 2
4th	Prototype 2	Prototype 2	Prototype 1
5th	Prototype 1	Prototype 1	Prototype 3

Table 5.1: Results from the Card Sorting of Prototypes

## 5.5 Summary

We have in this chapter presented the results from the user testing of the paper prototypes that we have designed. The presentation of the results has been divided into two parts, one for the user testing at Aker and one for the user testing at St. Olavs Hospital. In general the test persons favored the prototypes that had a higher degree of information richness. In the next chapter, Chapter 6, we will give a thorough analysis of our results in relation to the research questions we defined in Chapter 1.

# Chapter 6

## Analysis and Discussion

In this chapter we will first analyze our results from Chapter 5 in relation to the research questions we defined in Chapter 1. The coverage of our work in relation to the Iterative Design Process will be presented, and in the end of the chapter we will discuss the validity of the work that we have carried out.

### 6.1 Analysis of Results in Relation to the Research Questions

In Chapter 1 we presented the research questions that we defined for this thesis. By analyzing our results we will now answer these research questions along with a thorough argumentation for our answers.

#### 6.1.1 RQ1: Is the approach that we have used in this thesis valid?

**RQ1.1: Can people use this visualization in performing everyday tasks?**

In Chapter 3 we explained that most work on how visualizations should be designed have focused on the tools used to represent the visualizations. We also wrote that the objective when designing for usability, given in the ISO9241-11 standard, should be to enable user's to achieve goals and meet needs in a particular context of use. We therefore chose to use methods from

this field in our work. More precisely we chose to use Niensens 11 Stages of Usability Engineering, which were also presented in Chapter 3. For RQ1.1 we were interested in seeing if the use of these methods made it possible to use the visualizations for performing everyday tasks. To analyze our results in relation to this we will below describe how we have used Niensens 11 stages, and will after this discuss if we found these methods to be appropriate when designing visualizations.

In this thesis we have not used all of Niensens stages, since some of the them were found not to be relevant or applicable. Also, some stages that was seen as relevant have been slightly modified in order to fit in with our work. We will therefore present both the stages that we have used and the stages that we have left out in our work.

1. **Know the user**

For a product to succeed one should have a good understanding of the prospective users. By the use of a case study with a document analysis, an interview, and an observation we got a deep understanding of the challenges faced by the coordinator on the examination days. This gave us an overview of the requirements that needed to be covered in our prototypes.

2. **Competitive analysis**

The purpose of competitive analysis is to get inspiration from other people or organizations by identifying strengths and weaknesses in their work. This in turn means that existing work on the topic or product that is studied needs to exist. As we have found no theory that focus on the visualization of positioning data no competitive analysis was conducted.

3. **Setting usability goals**

Usability goals are goals that the designers of a product want the users to achieve. Since no related work had been done on the specific topic we are interested in, it was not possible to define usability goals for our product. Instead we chose to give the users exercises and ask them to comment on the designed prototypes. This is further presented below when we present empirical testing.

4. **Parallel design**

In parallel design, the designers independently make drafts for the product. The idea is that many different designers can identify different parts that should be included in a product. When designing prototypes for this thesis one person has done the work, and we have therefore not

## 6.1. ANALYSIS OF RESULTS IN RELATION TO THE RESEARCH QUESTIONS

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carried out a parallel design session with different designers. We did however design five different prototypes, which can be said to be design proposals. From these prototypes we identified the strengths and weaknesses in each of them through user testing, and made proposals for what features the next design iteration should include.

### 5. **Participatory design**

To some extent, one can say that participatory design has been used in our work. Through the identification of the needs of the coordinator she influenced the design of the prototypes. In the unstructured interview after the user tests, the test persons were asked to give their views on the designed prototypes. If a new design iteration is to be performed in the future this information can be utilized.

### 6. **Coordinated design of the total interface**

Providing consistency in a product helps user make sense of the information that is presented. In the designed prototypes we have focused on keeping the elements that are common in the different prototypes consistent. As an example, the red color in the status boxes will communicate the same information in all of the designed prototypes.

### 7. **Apply guidelines and heuristic analysis**

Guidelines provides advice for how a product should be designed. For the design of our prototypes we made use of the Schneidermans proposed taxonomies for visualization of data, and concepts concepts from CSCW work (both presented in Chapter 2). These can both be said to be category specific guidelines. As we have not found relevant general guidelines, product specific guidelines or heuristics these have not been used in our work.

### 8. **Prototyping**

Prototypes are used to show the intended functionality and features of a product. The main objective of our work was to see what degree of context information and information richness visualizations of positioning data should have in order to support the user. To do this we designed paper prototypes and presented these to the test persons.

### 9. **Empirical testing**

Through empirical testing prospective users or usability specialists evaluate a product. As our focus has been on looking at the users' understanding of visualizations, prospective users were recruited to test the designed prototypes. The test persons were given exercises and asked to try to solve these. By using the think-aloud technique the users

commented on their views of the prototypes as the testing progressed.

#### 10. **Iterative design**

In iterative design new iterations of the usability engineering cycle are carried out until the product satisfies quality requirements or provides the users with needed functionality. For this thesis only one iteration has been carried out. Yet our work has been done with the iterative design method in mind, and the analysis of our findings from the user testing provides valuable information which can be used in new iterations.

#### 11. **Collect feedback from field use**

Feedback from field use can be collected after a product have been implemented, for example through qualitative research methods or market analysis. As we have only designed prototypes in our work it has not been possible to collect this type of feedback.

Development and introduction of computer systems is expensive. This is especially true for the complex system which would need to be developed to utilize the visualizations that we have designed. An alternative approach to our work could be to develop a system without giving the prospective users the possibility to assess the visualizations before they were designed. In our work we have simulated scenarios and coordination problems, and presented these to the test persons which were asked if they could solve them. The advantage of developing a working computer system is that it would be possible to use these in real world situations where the test persons are faced with real coordination problems. From this the test persons would be able to assess if the system suited their needs in a more natural environment, but on the contrary it would also mean that failing to get acceptance for the system would lead to a costly redevelopment of the final system. It is widely known that computer systems introduced in the field of health care often have not gained acceptance due to their low usability, and in our user testing the coordinator from St. Olavs Hospital stressed the need for a good user experience when new computer systems are to be introduced. In the user testing that we conducted, all of the test persons expressed a wish to see an implemented version of our visualizations. In Chapter 2 we wrote that it is important to have an incentive from the users of CSCW systems in order for them to be successful, and we see this as a clear incentive from the test persons. Based on this, we regard methods from the field of usability engineering as applicable and well-suited when designing visualizations, but as described above some of the methods can be ruled out, and some of the methods needs to be slightly modified to be suitable in this field.

## 6.1. ANALYSIS OF RESULTS IN RELATION TO THE RESEARCH QUESTIONS

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### **RQ1.2: Are people able to give informative assessments of the different visualizations?**

The designed prototypes were all tailor-made for the coordinator at Aker. In Chapter 3 we wrote that there is a need for the users to get accustomed to all the new information that is provided in tailor-made products. This was also recognized in our work. In the user testing the test persons all expressed that they found it hard to get accustomed to the new way of thinking when they were presented with the prototypes, and we had to give them a great deal of help in the testing, especially when it came to identifying how problems could be solved.

The prototypes were presented to the test persons sequentially from prototype 1 to prototype 5. When the test persons from Aker were presented with the first four prototypes we noted that they for each new prototype said that they thought the one in question was better than the previous. An exception is prototype 5, where the test persons said that they liked prototype 4 better. We see this as a sign that the test persons got more and more accustomed to how the user testing worked. But it should be stressed that the learning period for tailor-made products is high, and that it will take time for the users to get used to how they work.

Prototype 3 was in the card sorting ranked high by the test persons from Aker, but was ranked at the bottom by the test person from St. Olavs Hospital. We asked her if she could clarify why, to which she replied:

“I think it has to do with the layout of the building. When I looked at it... OK, there are three floors, but there are also separate parts... that confused me. I think the parts which are not shown in a floor should be moved there. That would make it easier to understand. As it is, it looks like there are both rooms and floors used.”

The test person from St. Olavs Hospital has no knowledge about the layout of the buildings at Aker. Since the test persons at Aker made no remark about this, this can be the reason for her low rating. In addition this test person in general had few problems when it came to identify why a problem occurred, but had problem saying how they could be solved. This can also be seen as a sign that her lack of knowledge about the specific work practice made it harder for her to give answers on how to solve the presented coordination problems. This coincides with the view that CSCW should be seen as a design principle, and that a system designed for one organization seldom will

be directly suitable for another organization.

### 6.1.2 RQ2: What kind of information richness, in terms of context information and granularity, should a visualization have in order to support coordination work?

In RQ2 we by context information meant the semantical information that needs to be added to the visualizations for it to give meaning to the viewer. Examples of such information is time information, and the relation between different actors in a room. Granularity was defined as the level of detail that needs to be provided from the positioning data to make it possible for the viewer to say something about the activity that is going on.

RQ2 can be illustrated through the chart shown in Figure 6.1. From the chart we can see that the x-axis goes from low granularity to high granularity, and that the y-axis goes from low degree of context information to high degree of context information. By using the specific work practice at Aker as our case we were interested in seeing where a system should be placed to have use for the coordinator at Aker. We were also interested in seeing if other related work practices could make use of such information.

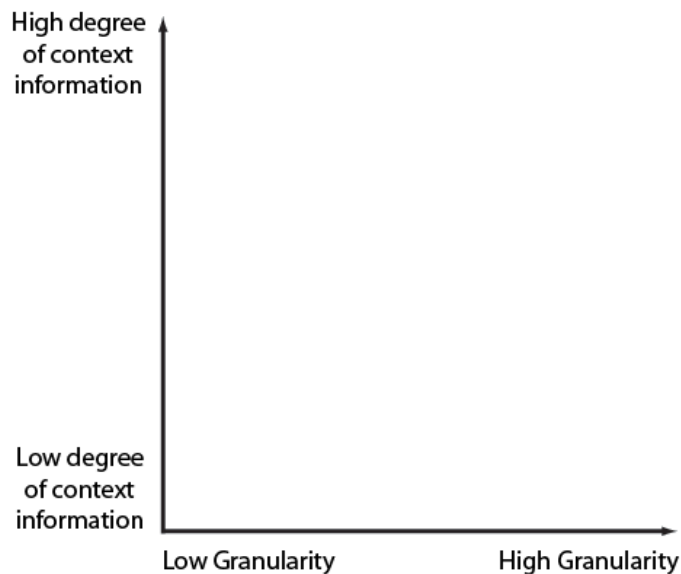


Figure 6.1: Chart illustrating what we wanted to investigate in this thesis.



## 6.1. ANALYSIS OF RESULTS IN RELATION TO THE RESEARCH QUESTIONS

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Dourish and Bellotti[5] define awareness as “...an understanding of the activities of others, which provides a context for your own activity”. Above we defined context information as the semantical or contextual information that needs to be added to visualizations for them to give meaning to the viewer. From this we can say that the contextual information is what provides the viewer with awareness in our work.

In Chapter 4 we described the different types of awareness that are covered in the designed prototypes. In our work prototype 1 is the only prototype that has a low level of both social, temporal and spatial awareness. This prototype was ranked in the bottom position by all test persons in the card sorting. The other prototypes provide both social, temporal and spatial awareness, although in different degrees and ways. Prototype 4 covers all types of awareness, and was ranked as the best by the both test persons from Aker, and as second by the coordinator from St. Olavs Hospital. In Chapter 2 we wrote that Pratt et al. suggest that both social, temporal and spatial awareness should be supported for designing a successful CSCW system. Both the comments and ranking from the test persons supports this suggestion.

The test persons at Aker said that they wished to have a visualization where they could get more details if needed. As an example they said that prototype 4 gave them a good overview of the situation in the moment. This prototype made it possible to say if previous examinations had finished, and if the current examinations were going as planned. If they were not, they wished to go to a prototype which gave them more detailed information about what was wrong. If they were still not able to solve the problem they would like to be shown even more detailed information.

The test person from St. Olavs Hospital did not mention a wish for this way of doing things during the testing. But when asked about her view on such a method, she said that she thought it would be a good way of doing things. While the test persons from Aker would like to see prototype 3, 4 and 5 in combination, the test person from St. Olavs Hospital said that she saw a combination of 2, 4 and 5 as the most useful.

The proposed Visual Information Seeking Mantra by Schneiderman was presented in Chapter 6. The mantra reads: “Overview first, zoom and filter, then details-on-demand.” The opinion from the test persons is in accordance with Schneidermans mantra. While we did not explicitly ask them in what sequence they would like the prototypes to be presented if they were to be used in combination, one possible way would be to first present prototype 4, then prototype 3 and at last prototype 5. From prototype 4 the coordi-

nator would get an overview of the situation in the moment. If one of the examinations were marked with a red status she could then go to prototype 3. This prototype would make it possible to say where the problem had occurred by the use of zooming which would provide the needed details. If additional information was needed she could then go to prototype 5 to get detailed information about what was wrong.

## 6.2 Coverage of the Iterative Design Process in this Thesis

In Figure 3.4 we presented the iterative design process, which is a proposed method for conducting usability engineering. In this thesis we have only covered parts of this method. To be more specific we first conducted a case study of the specific work practice. This gave us an understanding of the challenges faced by the coordinator during the examination days. We then designed five prototypes with different levels of information richness. These were in turn tested by three test persons who had direct or indirect knowledge about the examination days. Based on the analysis of the results from the testing, we have analyzed the results in relation the research questions we defined in Chapter 1. In Chapter 6 we will explicitly give our recommendations based on our answers to the research questions. Figure 6.2 illustrates the part of the Iterative Design Process that we have covered in this thesis.

## 6.3 Validity of Our Work

While coordination in general is common in everyday work at hospitals, it is not common to dedicate a whole day where patients are examined by several physicians with different specializations. Our prototypes were designed to facilitate the coordinator at Aker in her work on the examination days. The fact that we have studied a special work practice made it hard to recruit test persons that had insight into the specific problems that are faced in relation to coordination, and that had knowledge about coordination of activities in hospitals.

A total of three persons were recruited for the user testing. These were the coordinator at Aker, the chief vascular surgeon at Aker and a coordinator from St. Olavs Hospital. The coordinator at Aker is the only one that has di-

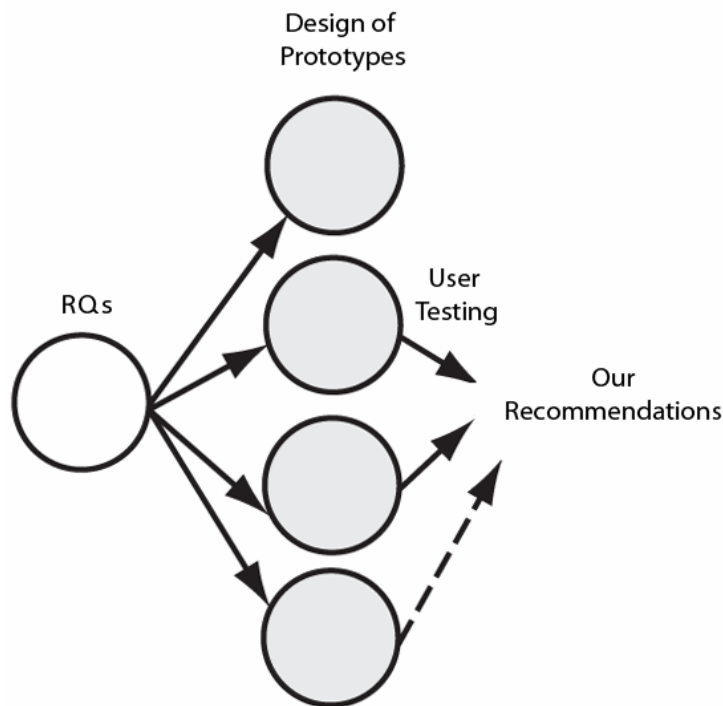


Figure 6.2: The part of the Iterative Design Process that we have covered in this thesis.

rect knowledge about the coordination of activities on the examination days. The chief vascular surgeon has indirect knowledge as he is one of the physicians carrying out examinations on this day. The coordinator from St. Olavs Hospital also has indirect knowledge, as she is responsible for coordination of patients that come in for emergency operations. As we saw in Figure 3.2 testing with five users will, according to Nielsen, identify approximately 80% of the usability problems in a product. Furthermore, the figure shows that performing user testing with three test persons will identify about 70% of the problems. It is hard to know if our user testing has provided us with valid results. The only way to ensure this would be to recruit more test persons, but as mentioned this were not possible for this thesis. But based on the consistency of the results from the user testing, it seems that our results give us a good hint to what the results would have been if the prototypes were tested with a larger sample of users. As mentioned the coordinator is the only person who has direct knowledge about the coordination of activities on the examination days. It can be discussed if her ranking in the card sorting should be valued higher than the rating from the other test persons, but because of the degree of consistency in the card sorting of the prototypes we

chose not to do this.

## 6.4 Summary

In Chapter 5 we presented the results from the user testing of the paper prototypes. In this chapter we have analyzed these results in relation to the research questions that we defined in Chapter 1. For RQ1 we were interested in investigating have used a valid approach when designing the visualizations, and we regard our work as a confirmation that methods from the field of usability engineering are appropriate when designing visualizations. For RQ2 we were interested in seeing what degree of information richness the visualizations should have to support coordination work. Our recommendation is that the information richness should be high, although it is hard to exactly say how high it should be. A summary of our answers to the research questions will be given when we in the next chapter, Chapter 7, present the conclusion of our work.

We have also in this chapter accounted for our coverage of the Iterative Design Process, and seen that we have performed one iteration of this process. At the end of the chapter we discussed the validity of our work. We have only used three test persons, which is low, and we are uncertain if this has provided us with valid results. Nevertheless, the consistency of answers from the user testing seems to give us a clue what the results would have been with more test persons.

# Chapter 7

## Conclusion

### 7.1 Conclusion

We have in this thesis looked at how data from positioning systems best can be visualized to support the coordination of activities in hospitals. We conducted a case study with a specific work practice at Aker University Hospital as our case, and used methods from the field of usability engineering to design paper prototypes of visualizations. The paper prototypes all differed in terms of complexity and information richness. The paper prototypes were tested by test persons who both had direct and indirect knowledge about coordination of activities in hospitals, and that both had and did not have knowledge about the layout of the building used in the specific work practice.

In Chapter 1 we presented our research questions for this thesis, and we will here summarize our answers to these:

**RQ1:** Is the approach that we have used in this thesis valid?

**RQ1.1:** Can one assess whether people can use the visualizations in performing everyday tasks?

In our work we have used methods from the field of usability engineering to design paper prototypes and to conduct user testing. An alternative to this would be to fully implement a system in the first place, and to introduce this system in the hospital. But, implementing full systems are expensive, and if the system would fail to gain acceptance it would lead to an expensive redevelopment process.

From our user testing we have seen that the test persons were positive when

it came to introducing our visualizations in an implemented system. In the field of CSCW it has been recognized that there needs to be an incentive from the user for a system to succeed. This was also recognized in our work, both because the test persons showed a positive attitude towards the visualizations, but also because it was stressed by the test persons that usability should be put in focus when introducing computer systems in health care.

From our work we conclude that methods from the field of usability engineering are suitable when designing visualizations, both because they include the prospective users in the design process, but also because it will reduce the risk of introducing expensive computer systems that are not accepted by its users.

**RQ1.2:** Are people able to give informative assessments of the different visualizations?

One of the test persons found it easier to identify the coordination problems than to solve them. This can be related to the fact that the visualizations were tailor-made for the specific work practice and that she had no knowledge about the layout of the buildings used in this work practice. Researchers in the field of Computer Supported Cooperative Work (CSCW) have stated that CSCW should be mainly seen as a design principle, and that CSCW systems must be individually developed to be successful. The results from the user testing with this test person supports this view.

The two other test persons showed an increasing understanding of the paper prototypes as they were presented to them. In the field of usability engineering it is recognized that there is a high learning curve for tailor-made products. Although these test persons had fewer problems when it came to make informative assessments of the visualizations, it is clear that the visualizations presented to them were for them an unfamiliar way of solving coordination problems, and that it takes time to get accustomed to this way new way of doing things.

Our view is that people in general are able to make informative assessments of the visualizations that we have designed, but we see it as important to both have direct knowledge about the work practice the visualizations are designed for and to accept that there is a high learning curve for tailor-made visualizations.

**RQ2:** What amount of information richness, in terms of context information and granularity, should a visualization have in order to support coordination work?

## 7.2. SUGGESTIONS FOR FURTHER WORK

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In the user testing the test persons favored the prototypes that had a high degree of context information and granularity. Despite this it is hard to say the exact amount of information richness that visualizations should have, as the viewers will interpret them differently and have different preferences. In addition the test persons expressed that they would like to have the possibility to move between the different visualizations depending on their information needs in the moment. Even so, we suggest that the visualizations should be information rich. If we revisit the goal chart presented in Chapter 6 we suggest that visualizations should be placed towards the top right corner of the chart. This is illustrated in Figure 7.1. In the figure the gray area shows our recommendation.

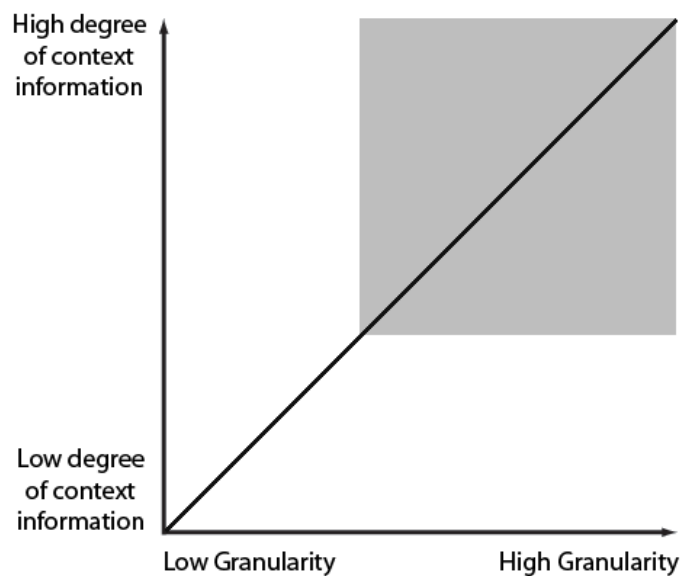


Figure 7.1: Chart showing our suggestion for information richness when visualizing positioning data.

## 7.2 Suggestions for Further Work

- In the field of usability engineering it is normal to do several design iterations before a final product is released. In our work we have carried out only one iteration. Based on this we suggest that more iterations should be carried out to ensure that the best possible visualization are designed before a possible introduction of a finalized system.

- Due to the fact that we have designed tailor-made visualizations it has been hard to recruit representative test persons. To ensure that our results are valid we suggest that one should carry out a similar project with a broader approach and a higher number of test persons, for example from a work practice where more people work with coordination.
- We have not included the privacy aspect in our work, but we still regard this as important when systems that link positioning data to visualizations are to be developed. We therefore suggest that one should investigate what level of details it is possible to present in such visualizations without impacting the privacy of the positioned actors.



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# Appendices



# Appendix A

## Questions for Interview with Coordinator

## APPENDIX A. QUESTIONS FOR INTERVIEW WITH COORDINATOR

### **Plan for intervju med koordinator ved Aker Universitetssykehus**

**Hans Petter Eide – 23.november 2008**

- Kan du fortelle meg litt om hvordan onsdagene fungerer på avdelingen?
- Kan du fortelle meg litt om hvordan en typisk onsdag for deg som koordinator fortøner seg?
  - Hva er arbeidsoppgavene?
- Kan du fortelle meg hva som er viktig for at utredningsdagen skal forløpe bra?
  - Hva kan skape forsinkelser? Hvordan unngår man det?
  - Hva er viktig for at utredningsdagen skal fungere greit for pasientene?
  - Hva er viktig for at utredningsdagen skal fungere greit for de ansatte?
  - Hvilken informasjon trenger du om pasientforløpene på utredningsdagen for å koordinere disse? (Start og sluttider for de forskjellige aktivitetene, hvor pasienten befinner seg, hvor personalet befinner seg, ufortsette hendelser...)
  - Er det annen informasjon som også ville gjøre det lettere for deg å koordinere?
- Kan du fortelle litt om hjelpemidlene du bruker i dag (gi evt. eksempler – telefon, notatblokk, planer osv.)?
  - Hva synes du om disse?
  - Opplever de du som utfyllende eller begrensende for dine behov?
- Diskuter grovt hvordan utviklingsiterasjonene for brukergrensesnitt fungerer, og undersøk om hun har mulighet/tid/lyst til å delta i dette arbeidet ved evalueringer og brukertesting?



## Appendix B

### Questions/Storylines Used in User Testing

## Storylines – Brukertest

### Generelt:

På arket du ser foran deg har jeg tegnet et tenkt skjermbilde, som i sin endelige form vil vises på en PC- eller TV-skjerm. Det du ser på arket er altså det samme bildet som du vil se på skjermen når det endelige produktet er utviklet. Hensikten med denne testen er å se hvor mye informasjon du kan lese ut fra disse skjermbildene.

Legg merke til at du øverst til høyre i enkelte av skjermbildene kan se det aktuelle tidspunktet. Dette tidspunktet vil variere på de ulike skjermbildene.

For å tolke informasjonen i skjermbildene kan du bruke timeplanen som du benytter deg av til vanlig under utredningsdagene.

---

## Skjermbilde #1:

I skjermbildet indikerer grønt at noen befinner seg i rommet og at alt går etter planen, og rødt at en person mangler i rommet eller at konsultasjonen har pågått lengre enn planlagt.

Spørsmål:

- Hva tror du er galt ut fra den informasjonen du kan lese ut fra skjermbildet?
- Hvordan vil du gå frem for å løse dette problemet?
- Hva tenker du om denne visualiseringen? Vil den være til støtte for deg under utredningsdagene?

## Skjermbilde #2:

**Statusindikatoren indikerer det samme som i skjermbilde #1.**

**Ikonene i skjermbildet viser hvor helsepersonell og pasienter befinner seg. De grønne ikonene viser helsepersonell, mens de blå ikonene viser pasienter.**

- Hva tror du er galt ut fra informasjonen du kan lese ut fra skjermbildet?
- Hvordan vil du gå frem for å løse dette problemet?
- Hva tenker du om denne visualiseringen? Vil den være til støtte for deg under utredningsdagene?

---

## Skjerm bilde #3:

Skjerm bildet viser en oversikt over bygningen du befinner deg i. I likhet med skjerm bilde #2 er de grønne personene i skjerm bildet helsepersonell, og de blå pasienter. Helsepersonellet har en tekst under ikonene som viser hva de jobber med eller hvem de er. Du kan klikke på hver etasje og deretter rom for å få opp mer detaljert informasjon.

- Pasient 3 ringer og sier at det står opptatt på døren for spirometri. Hva tror du er galt ut fra informasjonen du kan lese ut fra skjerm bildet?
- Hvordan vil du gå frem for å løse dette problemet?
- Hva tenker du om denne visualiseringen? Vil den være til støtte for deg under utredningsdagene?

## Skjerm bilde #4:

I skjermbildet indikerer vises en tidsakse som går fra venstre mot høyre. Den blå linjen i skjermbildet viser hva klokken er i øyeblikket. Som tidligere indikerer rødt at noe er galt, og grønt at alt er som det skal. Dette skjermbildet viser også sluttidspunkt for undersøkelsene/aktivitetene på utredningsdagen. Dette er bare antatte tidspunkter, og stemmer ikke nødvendigvis med virkeligheten, men jeg vil likevel at du tar utgangspunkt i disse når du besvarer spørsmålene.

Spørsmål:

- Hva tror du er galt ut fra informasjonen du kan lese ut fra skjermbildet?
- Hvordan vil du gå frem for å løse problemene som har oppstått?
- Hva tenker du om denne visualiseringen? Vil den være til støtte for deg under utredningsdagene?

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## Skjerm bilde #5:

I skjerm bildet vises en graf. Grafene har linjer mellom personer, undersøkelsesutstyr og rom. Linjene er grønne eller røde, noe som markerer statusen på relasjonen mellom de ulike objektene.

De grå boksene indikerer utstyr som er i rommet. Dersom en person har en grønn linje mellom seg og utstyr vises dette med en grønn linje.

Spørsmål:

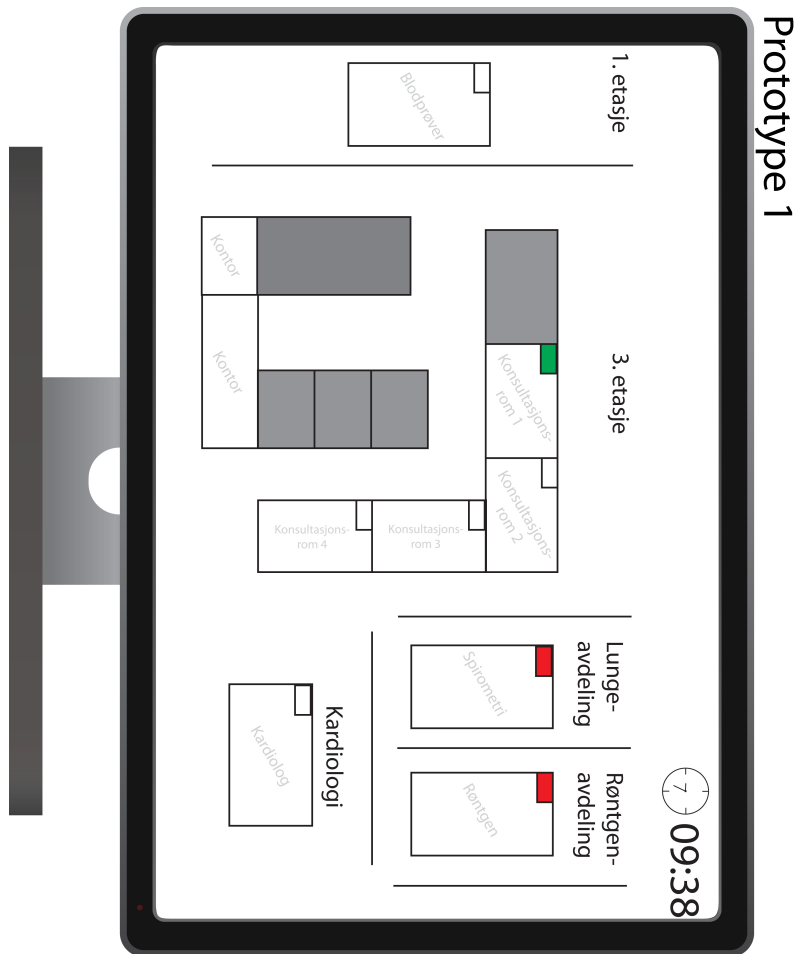
- Hva tror du er galt ut fra informasjonen du kan lese ut fra skjerm bildet?
- Hvordan vil du gå frem for å løse dette problemet?
- Hva tenker du om denne visualiseringen? Vil den være til støtte for deg under utredningsdagene?



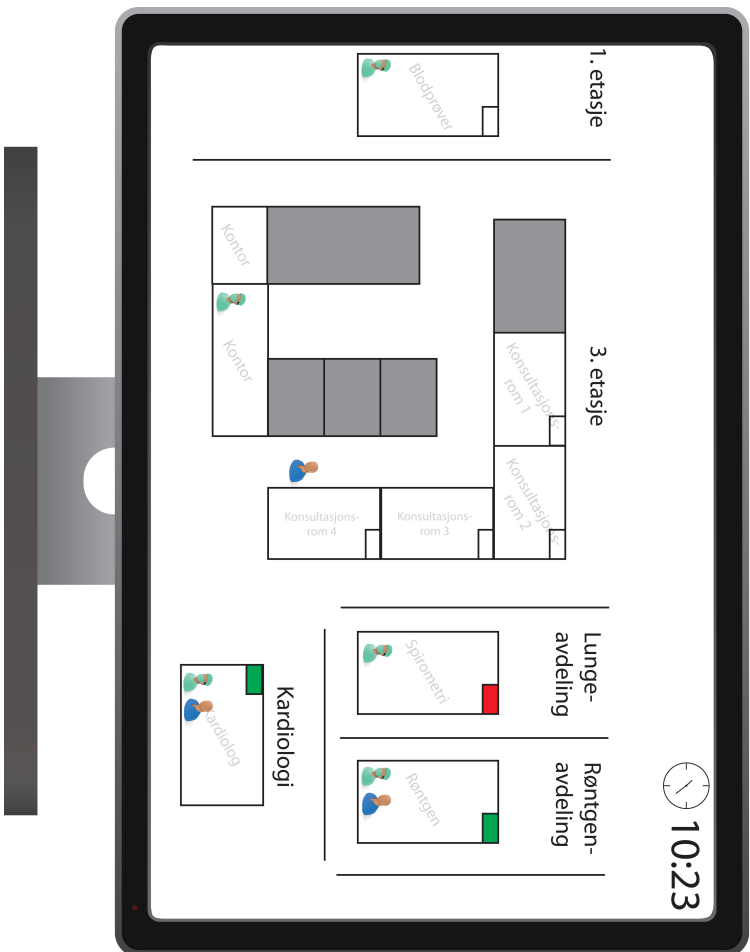


## Appendix C

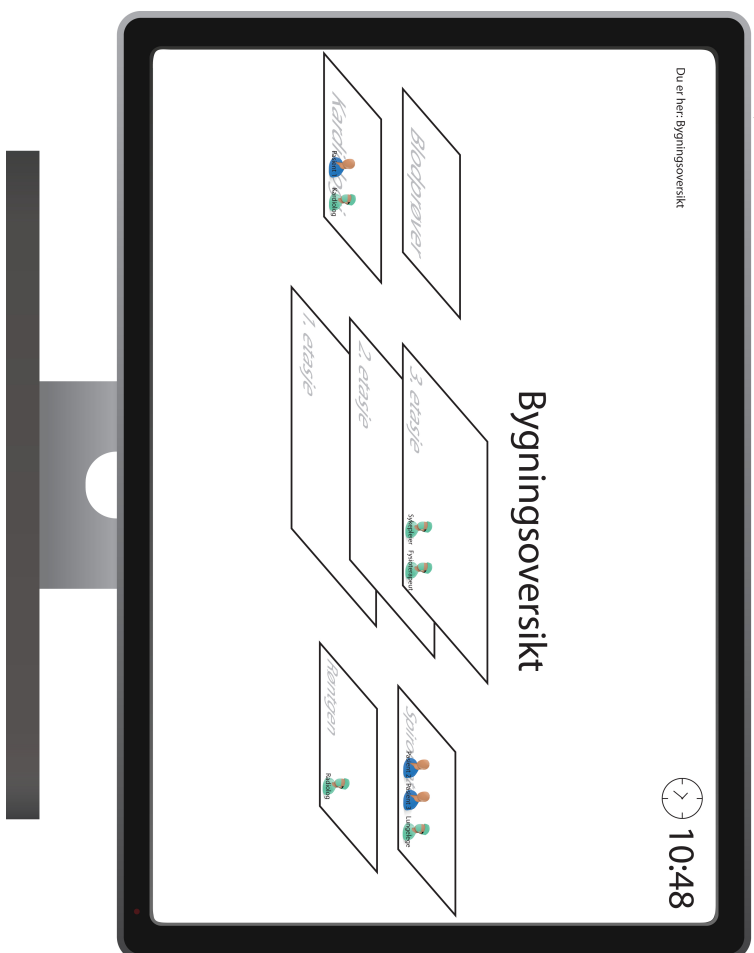
# High Resolution Versions of Prototypes



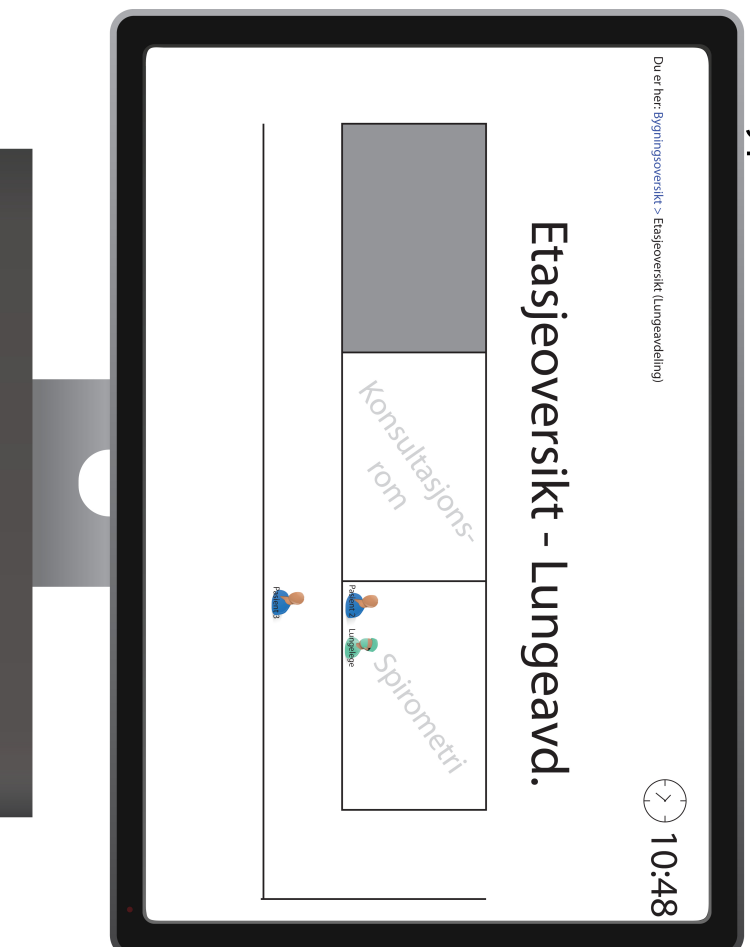
## Prototype 2



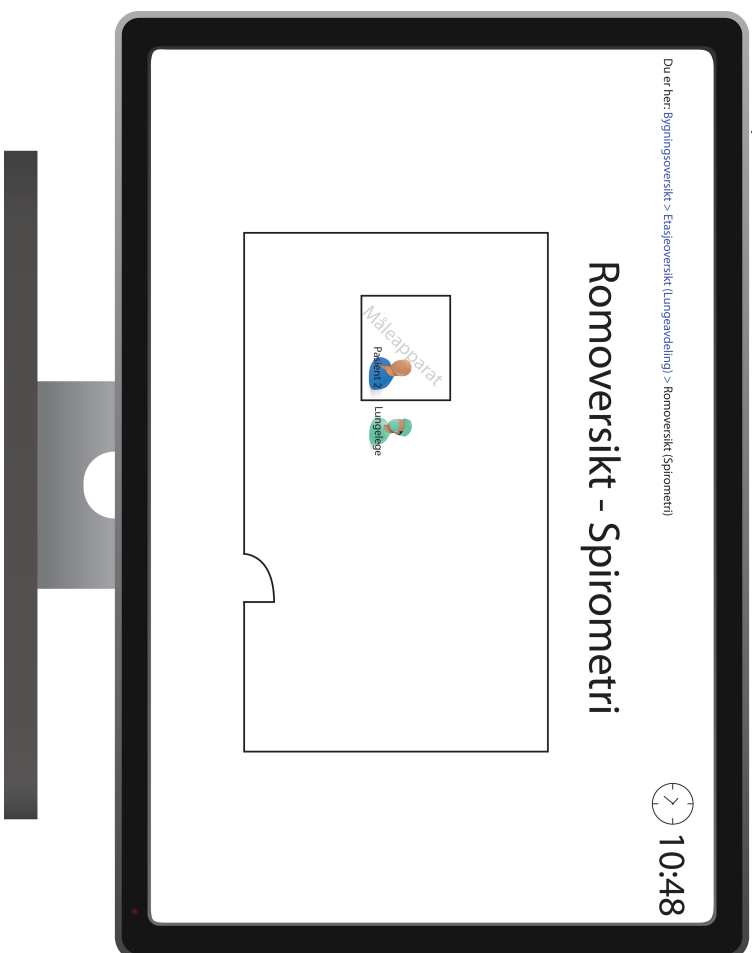
Prototype 3, screen 1



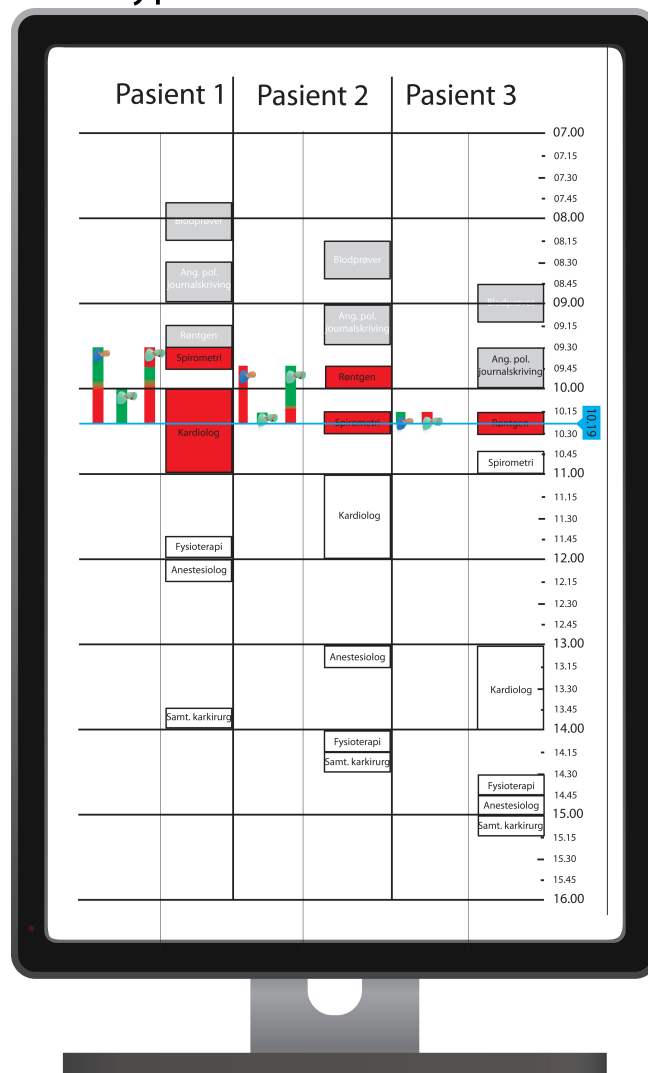
## Prototype 3, screen 2



### Prototype 3, screen 3



## Prototype 4



Prototype 5

