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# Visualizing Motion Sensor Data from Senior Citizens for use in Physical Therapy

A User-centred Approach

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## Abstract

Recent studies have shown that only one in five Norwegian adults and elderly reach the national recommendation of 30 minutes of daily activity. Increasing the activity of the elderly is one of the main foci of Hagen Utvalget, a committee appointed by the Norwegian government to solve future challenges in care services. The report emphasizes on using technology to help solve such health problems. Using a sensor called the activPAL we are able to classify a patients activity into periods spent walking, standing and sedentary. Data gathered by the sensor is used to create visualizations illustrating the patients activity throughout a week. The question we aim to answer is: Which visualizations are most fitting to aid physiotherapists in interpreting and understanding accelerometer data from patients in communication with patients and other healthcare workers? A prototype was created and reviewed in two focus groups with physiotherapists. The process was iterative and feedback from the first focus group was used to modify and improve the prototype before the second focus group. In addition to the prototype, scenarios for the use of the system and a set of functional and user experience requirements were created. The requirements and prototype form recommendations on how to create visualizations that aid physiotherapists in specific tasks. All of the participants of the focus groups were positive to the prototype presented and could see themselves using such a system in their work. The participants were also convinced that using such technology would improve the quality and effectiveness of their work.

# Sammendrag

Studier har vist at bare én av fem voksne og eldre når den nasjonale anbefalingen om 30 minutters daglig aktivitet. Å øke aktiviteten hos de eldre var en av de viktigste utfordringene for Hagen Utvalget, et utvalg oppnevnt av regjeringen for å løse fremtidige utfordringer i omsorgstjenesten. Hagen Utvalgets rapport trekker frem viktigheten av å bruke ny teknologi for å løse disse utfordringene. Ved hjelp av en sensor kalt activPAL kan vi klassifisere pasienters aktivitet i tre ulike kategorier: gående, stående og stillesittende. Data samlet av sensoren brukes til å lage visualiseringer som illustrerer pasienters aktivitet gjennom en uke. Spørsmålet vi prøver å besvare er: Hvilke visualiseringer er best for å hjelpe fysioterapeuter med å tolke og forstå akselerometerdata fra pasienter, i kommunikasjon med pasienter og andre helsearbeidere? Det ble laget en prototype som ble vurdert i to fokusgrupper bestående av fysioterapeuter. Prosessen var iterativ og tilbakemeldinger fra den første fokusgruppen ble brukt til å modifisere og forbedre prototypen før den andre fokusgruppen. I tillegg til prototypen, ble scenarier for bruk av systemet og et sett av funksjonelle og brukeropplevelses krav opprettet. Kravene og prototypen danner anbefalinger for hvordan å lage visualiseringer som kan benyttes av fysioterapeuter til å løse spesifikke oppgaver. Alle deltakerne av fokusgruppene var positive til prototypen som ble presentert og kunne se for seg å bruke slik teknologi i sitt eget arbeid. Deltakerne var også overbevist om at bruk av slik teknologi vil øke kvaliteten og effektiviteten på deres arbeid.

# Preface

This master thesis is the final part required for us to attain a Master of Science degree at the Norwegian University of Science and Technology (NTNU). The work in this thesis was conducted from the start of February to the end of June 2013 at the Department of Computer and Information Science (IDI).

We would like to thank our supervisor Professor Dag Svanæs for the invaluable guidance we have received during our work. We also wish to extend gratitude to the domain expert at St. Olav's Hospital and the physiotherapists who participated in the two focus groups. Without their knowledge and insight this project would not have been possible.

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# List of Acronyms

**CHI** Computer-Human Interaction.
**CSV** Comma-Separated Values.

**D3** Data-Driven Documents.

**HCI** Human-Computer Interaction.
**HU** Hagen-utvalget.

**NDH** Norwegian Directorate of Health.
**NIPH** Norwegian Institute of Public Health.
**NTNU** Norwegian University of Science and Technology.

**PI** Personal Informatics.

**QS** Quantified Self.

**SVG** Scalable Vector Graphics.

**UX** User Experience.

# Chapter 1
# Introduction

As the name suggests the purpose of this chapter is to introduce our work. It begins by explaining the background for the thesis and introducing the context of study. It then presents the research questions and ends with the thesis outline.

## 1.1 Background

The elderly population is in a constant rise, currently 15% of the Norwegian population is above the age of 65. By the turn of the century, the elderly population in Norway is estimated to double [1]. After 2025, a great increase in the population above the age of 80 is expected. The Norwegian Institute of Public Health (NIPH) reports that two out of three above the age of 75 consider themselves having "good health", but only a third preserve this level of health until death [1]. The amount of time adults spend in a sedentary position has increased over the last 30 years. The reasons for this are many, but increased use of technology and ease of transport are one of the main factors [2].

With such predictions the Norwegian government formed a committee known as Hagen-utvalget (HU) to investigate the current situation and suggest solutions for accommodating the increase in the percentage of elderly [3]. One of the conclusions in the report was that too little of today's technology is incorporated as welfare technology for the elderly. A Danish report refereed to by HU states that around 20% of the tasks performed by healthcare personnel could be completely or partly replaced by technology [4].

Recent studies on the activity level of adults and elderly in Norway show that only one in five reach the national goal of 30 minutes of activity each day [5]. Increasing the overall activity level of elderly is one of the main foci in the HU report. To handle the rising percentage of elderly in the population, HU suggests a national three step program that focuses on using welfare technology to diminish falls, social isolation, and cognitive failure, thus improving the overall quality of life for the elder population as well as reducing the workload for health care personnel. Step three states:

> *Opt on technology that stimulates, activates and structures daily life* [3, page 120]

We wish to address step three in the national program through the use of Personal Informatics (PI) technology. Personal Informatics (PI) technology is a set of tools that individuals can use to gather quantitative data about themselves for the purpose of self-reflection and self-monitoring. By allowing physiotherapists to collect patient data from an activity monitor and visualizing user patterns, we hope to bring awareness to their activity levels, and identify periods of long sedentary time. The data can in addition be utilized in consultation with health care personnel and rehabilitation facilities, to improve treatment and motivation of patients.


**Figure 1.1:** A Nike+ Fuelband synced up to an iPhone. This is just one of many PI devices available.

## 1.2 Context of Study

A large EU project known as FARSEEING is currently in progress. FARSEEING is a collaboration between ten partners in five EU countries and is funded by the European Commission. The aim is to create a thematic network that promotes healthy and independent living for the elderly. FARSEEING wishes to improve fall prediction and prevention, support older adults through technology, and use unique proactive opportunities to keep adults in their own environment.

Our work is not a deliverable in the FARSEEING project, but our advisor and the people we have been in contact with are a part of the project. This leads to a certain influence by the agenda of the FARSEEING project, and we hope that some of our work will aid them in the future.

A practical approach is taken and the entire FARSEEING project is divided into work packages which combined expand the research, technological development and overall knowledge in this area [6]. The Norwegian University of Science and Technology (NTNU) is responsible for Work Package 5 and the overall objective for FARSEEING is to develop and validate feasible telemedicine service models for detection of accidental falls, fall risk assessment and exercise counselling [7]. The service models should not be dependent on a specific technological platforms or sensor systems used to collect and disseminate data. The overall objective has been divided into three different domains. The second domain is partly relevant to the work performed in this thesis.

> *To develop a service that can demonstarte an exhcange of information between the older person and caregivers about fall risk, e.g. health-care personell are given information to be used for clinical decision making about the older person's fall risk and related movements.*

An example of such information is sensor data from a patient. A typical situation could be the user wearing a sensor for a week. The data would then be extracted from the sensor and used to create diagrams and visualizations. These visual representations of the data can help health care personnel, in our case physiotherapists, create a treatment plan for the patient to improve their activity and overall health.

## 1.3 Research Questions

The main question we are attempting to answer is: *Which visualizations are most fitting to aid physiotherapists in interpreting and understanding accelerometer data from patients in communication with patients and other healthcare workers?*

In order to understand the problem, we have divided it into three research questions, each dealing with a specific problem. First we need to understand typical scenarios in which a physiotherapist will use accelerometer data and how they are utilized. Afterwards a set of requirements should be created to form the basis for creating prototype visualizations. The prototype should then be evaluated to see what types of visualizations are preferred by physiotherapists.

Research questions:

**Research Question 1:** What are the relevant scenarios for visual presentation of accelerometer data in physical therapy, from the physiotherapist's perspective?

**Research Question 2:** What are the functional and user experience requirements for visualizations of accelerometer data in the scenarios (RQ1) identified by the physiotherapists?

**Research Question 3:** What are the preferred visualizations by the physiotherapists for the scenarios (RQ1) and the requirements (RQ2)?

## 1.4 Thesis Outline

The outline below provides a brief insight on what the various chapters in this thesis address.

**Chapter 1: Introduction** introduces the background, project context and research questions.

**Chapter 2: Human-Computer Interaction and User Centered Design** provides an insight into Human-Centered Interaction and research methods used to answer our research questions.

**Chapter 3: Body-worn Sensor Technology** looks at existing solutions, how they visualize their data and the communities that surround and support them.

**Chapter 4: Physical Therapy for Senior Citizens** presents the health situation today and how sensor technology can raise awareness and combat sedentary behaviour.

**Chapter 5: Research Design** provides an overview on how we plan to conduct our research in order to answer our research questions.

**Chapter 6: Initial Requirements** details how the initial requirements for the prototype were created through an interview with a domain expert.

**Chapter 7: Prototype 1** depicts the preliminary paper sketches and explains the technology used to create the running prototype. It finishes off by showing the first iteration of the prototype.

**Chapter 8: Focus Group 1** explains the planning, execution and results of the first focus group conducted.

**Chapter 9: Prototype 2** describes what changes were made to the initial prototype and why they were made, before presenting the second version.

**Chapter 10: Focus Group 2** explains the planning, execution and results of the second focus group.

**Chapter 11: Discussion** discusses the research questions based on our results and insight gained throughout the project.

**Chapter 12: Validity** reflects upon the execution of the chosen research methods and discusses their validity.

**Chapter 13: Conclusion** draws conclusions based on findings that have been made, and suggests further work and research.

Chapter 2

# Human-Computer Interaction and Human-Centered Design

This chapter contains guidelines, best practices and theoretical information on how HCI research and development should be conducted. ISO 9241-210 is explained, before various techniques for information visualizations are presented. The remainder of the chapter is dedicated to research methods used to answer the research questions posed in Section 1.3.

## 2.1 HCI and Human-Centred Design.

The science of Human-Computer Interaction (HCI) studies the interaction between humans and computers. The goal is to make this interaction as smooth and seamless as possible. Research done in the HCI-field has resulted in guidelines and design methods for the creation of efficient and usable software. An example of such guidelines is ISO 9241-210 [8].

ISO 9241-210 provides guidance and acts as a usability standard for HCI through the entire life cycle of an interactive system. The ISO takes a human-centred design approach to interactive system development. According to the ISO the aim of human-centred design is to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors and usability knowledge and techniques.

The standard describes six key principles, as listed below:

1. Users are involved throughout design and development.
2. The design team consists of members with varied backgrounds
3. The design is based upon an understanding of users, tasks, and environment.
4. The design is driven and refined by user centred evaluation.
5. The process iterative.
6. The design addresses the whole user experience.

These principals in combination with Figure 2.1 will ensure that the design is user centred. The figure is in no way a strict linear process to follow, it merely shows the required input and expected result of each activity.

The first principle emphasizes user involvement throughout the entire process, and not just at the start and the end of the system design, but through the entire cycle of activities. It is important to include a wide range of views and input from experts in various fields, this is where the second principle comes in. It ensures that everyone does not think and approach the problem in the same way. The third principle involves understanding the user, what they want to do with the system, and the environment the system will be used in.

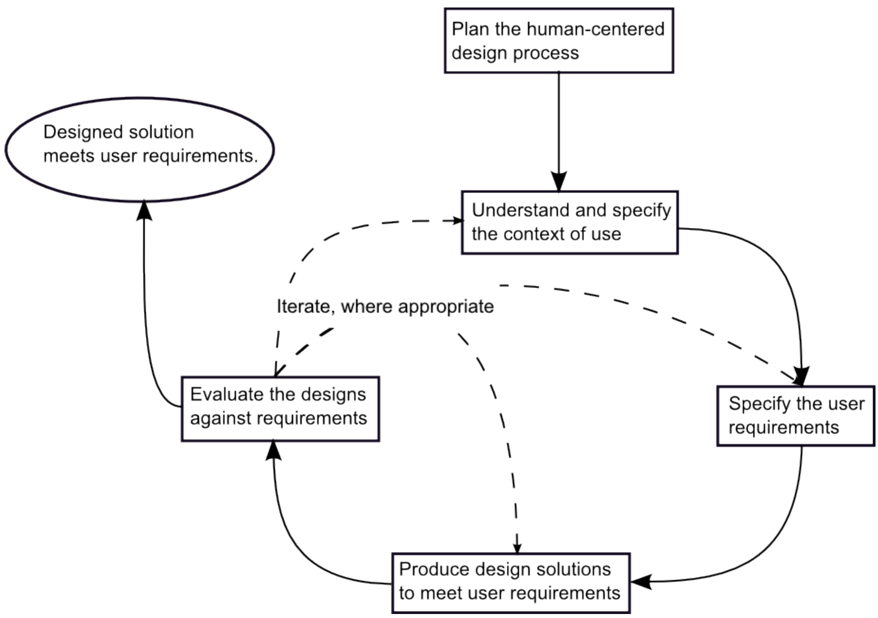



**Figure 2.1:** The human-centred design workflow

Principle four and five address the fact that several iterations might be required for a satisfactory design to be reached. Users might not know what they want, but they do know what they do not want once they have experienced it. Multiple iterations and examples may then be required to find something that is satisfactory to the user. The final principle states that the usability is not just about making things easy to use, but provide the user with an emotional and perceptive stimuli as well. They should wish to use the system and feel good about it.

## 2.2 Information Visualization

Information visualization is useful when displaying large amounts of data simultaneously. The human brain is ineffective at getting an overview of the information by looking at large tables of numbers or text. Visualizations utilize the strengths of human cognition. By using computer graphics to make visualizations, large amounts of information can be displayed in a way that humans can process and analyse quickly and intuitively.

Many guidelines have been suggested for creation of the optimal visualization. Shneiderman summarized many of these principles in his *visual-information-seeking mantra* [9]:

> *Overview first, zoom and filter, then details on demand.*

For the visualization to be effective, the user has to get an overview of how the information is presented. The system should also allow zooming in on interesting parts of the information, as well as giving the opportunity to filter out information that is not of interest. Most visualizations remove some level of detail for the data to be more accessible and easier to read. It is therefore important that the system allows the user to access more detailed data when needed.

Shneiderman also identifies the importance of showing the relationships between different items, allowing the user to extract subcollections of the displayed items and storing the user action history to allow for undo/redo functionality.

### 2.2.1 Visual Variables

One important factor to consider when creating visualizations are which visual variables to use. To create an intuitive visualization it is important use the different visual variables correctly. We will briefly go through some of the more common visual variables here and discuss how and how not to use them, based on Carpendales article about the subject [10]. The tables below explain the different types of visual variables and their characteristics, examples are shown in Figure 2.2 and 2.3.

**Visual variables:**

| | |
|---|---|
| Position | Position of object, for example x- and y-coordinates in a two dimensional system. |
| Size | Size of object. |
| Value | Change in colour scale from light to dark. |
| Colour | Change hue for given value, for example blue, red and yellow. |

**Table 2.1:** Overview of visual variables.

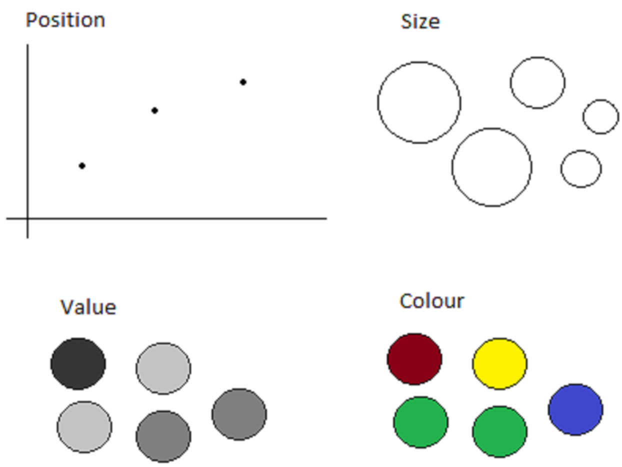



**Figure 2.2:** Examples of the visual variables.

**Characteristics of visual variables:**

| | |
|---|---|
| Selective | Will a change in this variable make it easier to select it from a group of variables? |
| Associative | Will changes in variables make it easy to distinguish different groups of variables? |
| Qualitative | Can the visual variable be used to illustrate the numerical value and relationship between variables? |
| Order | Will changes in the visual variables allow us to order them? |
| Length | How many changes is it possible to distinguish between for this type of variable? |

**Table 2.2:** Description of the characteristics of visual variables.

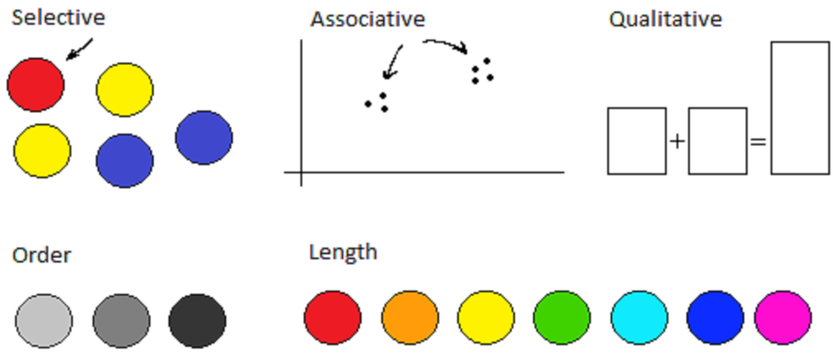



**Figure 2.3:** Examples of characteristics of visual variables.

Position fulfils all the characteristics of visual variables. When thinking of a scatter plot it is easy to see that positioning the points will make them selective and associative. By using scales, position can be used to show the value of the variable in a numerical sense, so it is also quantitative. Order is also fulfilled, a ruler is a simple example of how position can be used to order. The length is theoretically infinite, and only restricted by the screen resolution.

Size fulfils all of the characteristics. It is both selective and associative, humans can easily identify for example the smallest circle in a group of circles. Though size can be used to visualize a numerical value, it is often hard for humans to accurately see how much larger one object is compared to another. Different sizes can easily be ordered. As for the length of this variable Carpendale suggest about five different sizes for selection and about 20 different sizes for distinction. It is important to note that humans can identify small changes in size when objects are close, however when the distance between objects increases, it is hard to distinguish between these differences.

Value can be used both for selection and association. Humans can identify darker parts and group them with ease. It is not quantitative as it is difficult to identify that one tone of grey is twice as dark as another. One can however say that one grey tone is darker than another, and therefore they can be ordered. Carpendale suggest that the length of this variable should be less than seven for selection, and about ten for distinction.

Colours are selective and associative. Unless the user is colour blind, the user he can easily identify and group different colours. Colours are not quantitative, as it is hard for humans to say that one colours is twice that of another. Though we have colour scales, humans do not intuitively order colours, this can easily be illustrated by a question: Which colour is greater, blue or yellow? Most people will not have an answer. Carpendale suggests that one uses less than seven different colours for selection, and about ten for distinction.

### 2.2.2 Interactivity

One of the benefits of creating visualizations for computers is the ability to add interactivity. Shneidermann mentions six tasks that should be implemented when creating information visualizations:

**Overview** Show an overview of the entire data set.

**Zoom** Let the user look closer at elements of interest.

**Filter** The user should be able to filter out tasks that are not interesting.

**Details-on-demand** Show details when elements are selected.

**History** Let the user undo or redo actions.

**Extract** Allow the user to extract a subset of the entire data set.

The first thing the users should see when interacting with an information visualization is an overview of the data set. This can be done by zooming out and then letting the user zoom in on areas of interest. Another approach is to aggregate the data into separate sections that can then be investigated further.

It is rare that the user is equally interested in every part of the data set, therefore it is useful to be able to zoom in on elements for a more detailed look. It is important to make sure that the user does not loose their sense of position and gets lost in the visualization.

Often some of the data in the set is not relevant and only distorts the visualization. In such cases one should be able to filter out those elements. The user should be able to filter out unwanted data using sliders, buttons etc. The update should happen in real-time, allowing the user to see how the filter affects the visualization.

Typically information visualizations hide the numerical data (or other detailed data) behind the element. It is therefore paramount to give the user the ability to access this data when it is needed. The user should be able to select an element or a small group of elements and browse the details in a list or other textual representation.

When working with visualizations where the user can make changes to filter, zoom, etc. It is useful for the user to be able to undo and redo tasks. Undo will give the user the ability to go back from an undesired zoom level or filter setting quickly. Users will often do more actions than they can keep track of, so giving them the ability to trace their steps improves usability.

Once the user has used the visualization and found what he was looking for,he should be able to extract those elements. The extracted elements should be saved in a format that can be sent to and seen by others.

## 2.3 Research Methods

This section covers the research methods used in our project. They are presented without being related to our work, but merely serve as an introduction to the basic theory behind each research method. How we plan to use these methods in order to answer our research questions can be found in Chapter 5

## 2.4 Interview

Interviews are used to acquire knowledge from a subject (interviewee) by asking him a set of questions. Interviews can be unstructured, semi-structured or structured [11]:

**Unstructured interviews** are exploratory conversations around a certain topic or area of concern. These can be completely informally.

**Semi-structured interviews** follow a general guideline or script that serve as a checklist and provide consistency between interviews. The order and wording can be freely modified to follow the conversation flow, and unplanned follow up questions are often asked.

**Structured interviews** have set of predefined questions with fixed wording and are in a pre-set order. It is much like a questionnaire but allows for slightly more open-response questions.

The ideal choice of structure for an interview depends on the purpose, what questions need to be addressed and how far has the development come? If the goal is to gather first impressions, initial design ideas, or information about a particular topic, then unstructured interviews are often the best approach. A more structured approach is useful when the goal is to get feedback on particular design features such as the layout of a website. In such cases structured interviews or semi-structured interviews are useful.

The advantage with interviews is that they are flexible and easy to alter prior or during an interview session. The interviewer gets an immediate response from the subject, and can change accordingly if the interview is not going as planned. Interviews do have drawbacks, often the interview has to be transcribed, which is a time consuming process. Bias might also be present, the subject being interviewed says things he believes the interviewer wants to be hear or neglects to provide information. This might particularly be the case when the interview has gone on for too long and the participant wants it to end [12].

## 2.5 Brainstorming

Brainstorming is a generic technique used to generate, develop and refine ideas. It is widely used in interactive design to generate alternative designs and provide better ideas for certain problems [11]. In addition to the list below, Sharp et al. [11] mention two key success factors: Participants should know the user goals that the system is intended to support, and that no ideas should be criticized or debated, everything is initially accepted.

1. Participants should ideally be from a wide range of disciplines and have a broad range of experience.
2. Do not exclude unconventional ideas, these can often be turned into useful requirements.
3. Build one idea on top of another. Suggest jumping back to an earlier idea if the vigour diminishes. Use a random word from the dictionary and related it to the product if stuck.
4. Keep records without censoring, and number them so jumping back to previous ideas is easy. Participants should be encouraged to sketch, create diagrams, and keep notes.
5. Staying focused is important. Having a well articulated and honed problem helps focus people and direct the session back on topic if it wanders.
6. If the participants are unfamiliar with each other it is important to have warm-up exercises such as word games or exploring physical objects available to them.

## 2.6 Prototyping

A prototype is a realization of a design that stakeholders can interact with and explore. The limitation of a prototype is that it often only focuses on one product characteristic and neglects the others. A prototype can be anything from a complex piece of software to a simple storyboard or sketch. Prototypes serve as an aid by clarifying communication between team members, and efficiently exploring design ideas with stakeholders and designers. Building the prototype itself encourages reflection of the design and is recognized by designers from many disciplines as an important aspect of the design process [11].

### 2.6.1 Low-fidelity vs. High fidelity

Low-fidelity prototypes do not resemble the finished product, but only some aspect with it. It often uses completely different and much cheaper materials then the final product, making them cheap, simple and easily modifiable. Examples of such prototypes are storyboards, sketches, and paper prototypes. Low-fidelity prototypes are important in early development stages because the simplicity encourages exploration and modification. The disadvantage is that these prototypes are never kept or integrated into the final product.

High-fidelity prototypes are much closer to the final product, and therefore give a much stronger impression of the final product. The high-fidelity prototype is useful for identifying technical issues and selling ideas to people. These prototypes are often reused or developed into a final product, but require more time and resources to create.

Two common compromises that are often traded against each other are breadth of functionality vs depth of functionality. *Horizontal prototyping* focuses on a wide range of functions but little details and *vertical prototyping* focuses on providing a lot of detail for a few functions. The very nature of a prototype involves making compromises. Therefore the choice of prototype lies in what kind of of questions we want to answer.

### 2.6.2 What do Prototypes Prototype?

In the article *What do Prototypes Prototype* [13], Houde and Hill discuss how prototypes need to be designed to test or rather prototype a certain design aspect of the final product. The model shown in Figure 2.4 represents a space which corresponds to important design aspects of an interactive system. Each corner of the triangle represents a set of questions which are essential to the design of a system. *Look and feel* covers questions that are concerned with what the user feels, sees and hears when using the system, in other words the sensory experience. *Role*, as the name states, refers to questions about what role the system has in the users life, what function does it serve and how is it useful to the user. *Implementation* addresses the technical aspects of the system, what techniques and components should be used for it to perform the intended function. The triangle is intentionally skewed to emphasize that no set of questions is more important than the other.

The purpose of the model is to help designers separate design issues into the three aforementioned set of questions, which often require very different approaches to prototyping. Look and feel requires the user experience to be created or simulated, implementation requires a running system to be built, and role involves researching the use context for the system. Categorizing the important design questions will help decide what kind of prototype should be built, and help focus the exploration.

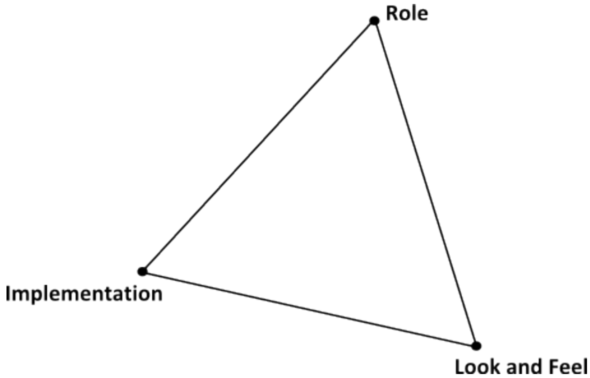



**Figure 2.4:** The prototype triangle described by Houde and Hill [13]

## 2.7 Focus Groups

A focus group, or group interview is an informal technique that can help software developers identify the users needs and feelings about a system. The technique can be used both before interface design and long after the system has been implemented.

According to Nielsen [14], the focus group should have at least six participant to maintain a flowing discussion and provide different perspectives. The participants should be representative of the intended users, or be the final users themselves. Sessions normally last two hours and are run by a moderator. The moderators job is to keep the discussion flowing and let everyone get their point across. Moderators can also guide the discussion in the direction relevant to the goals of the focus group.

A single session may not be representative enough or can get sidetracked, it is therefore important to run more than one focus group. If improvements suggested by participants have been implemented it is important to run another iteration of the focus group with the same participants to attain feedback on the changes that have been made. Enough focus groups have been conducted when new information is no longer being received, i.e. a point of saturation has been reached [15].

Nielsen discusses two pitfalls with focus groups. The first states that because sessions are in groups the users do not test the system themselves, instead they are presented with a demo. The problem with such a demo is that the participants never have to question what to do next or consider the meaning of the screen options. Another problem is that what participants say they want, is not necessarily what they need. The second pitfall is that ideas described by the moderator might be perceived differently by the participants. By providing concrete examples through prototypes of the technology, one can minimize this problem.

## 2.8 Questionnaire

Questionnaires are a research tool that consist of a series of questions with the goal to attain information from the respondent. It is a well established technique for collecting demographic data and user opinion. Questionnaires are similar to interviews in the fact that they can contain both closed and open ended questions. Clear unambiguous questions and allowing efficient data collection is important, especially if a large quantity of questionnaires have been issued. Questionnaires can be used on their own or as an addition to other methods in order to gain background information, or deepen understanding of a particular topic. Below is a short and general guideline provided by Sharp et al. [11] on things to watch out for when creating questionnaires:

- The order in which questions appear is important, it can influence the impact of a question.
- Consider having alternate versions of the questionnaire to suit different populations.
- Clear instructions on how the questionnaire should be answered is essential. Clear wording and good typography is important.
- Balance must be attained between whitespace and needing to keep the questionnaire as short as possible. Long questionnaires cost more, and might deter people from participating.

The advantage with questionnaires is that they provide a relatively simple and straight forward study, and may be adapted to collect generalized information from almost any human population which means high amounts of data standardization. If the survey is anonymous it can encourage more honesty than another research method would have if sensitive topics are involved. Questionnaires are also relatively cheap to perform compared to the amount of data that is gathered. There are downsides to this method of data collection, people might respond in a way that puts them in a good light, and data is affected by the respondents characteristics. Their memory, knowledge, experience and motivation also influences how they answer the survey. If the questionnaire is performed without any kind of monitoring, participants will not be able to ask the researchers about ambiguous questions, which might lead to misunderstandings and biased results.

## 2.9 Validity of Research Methods

Validity addresses how trustworthy a study or parts of a study are, and to what extent the results are valid. Wohlin et al. [16] provide a well structured overview of various types of validity:

**Construct validity** is concerned with whether the method measures what it is suppose to measure. For example if an interview is conducted and the interviewee interprets the questions differently from the interviewer, there is a threat to validity.

**Internal validity** is of concern when casual relationships are examined. If a researcher is investigating if a factor A affects a factor B, there is a risk that a factor C is also affecting B. If the researchers are not aware of factor C and/or how it affects B, there is a threat to internal validity.

**External validity** focuses on finding out to what extent it is possible to generalize the findings, and if they are of interesting to other people outside the investigative case. Generalizing qualitative methods is hard, and requires finding common characteristics and having findings that can be generalized for situations that meet a certain criteria, i.e. defining a theory.

**Reliability** looks at to what extent the data and analysis are depended on the specific research. Good reliability means that if the same study is conducted by a different researcher at a later time, the results should be the same. A questionnaire or interview with unclear questions, or a research report that lacks important information on how the research was conducted are examples of threats to reliability.

Another important concept in validity, especially in qualitative research methods, is bias. Bias is when the results are distorted by the researchers and evaluators. Evaluators might fail to note certain behaviour because they deem it irrelevant, or an interviewers tone of voice may influence the answers of the interviewee. It is therefore important to be open to the possibility of bias.

Validity in HCI is a complex topic and we have only mentioned some of the basic issues. Thimbleby reviews some of the more complex issues and suggests some practical recommendations for solving them in his *Validity and Cross-Validity in HCI Publications* paper [17]. One of the simpler suggestion he makes is to use *triangulation*. Triangulation involves using multiple methods or sources to achieve the same result. A more elaborate method to assure good validity involves creating a universal star rating system, where papers should be rated based on how easily a researcher can reproduce or build upon the original work.

# Chapter 3
# Physical Therapy for Senior Citizens

This chapter presents the physical activity and health situation in Norway and internationally, and presents the Norwegian recommendation for physical activity. It then covers physical therapy in Norway and looks at how sensor technology can help improve their work.

## 3.1 Physical Activity and Health

In 2010 one of the largest ever systematic efforts to describe the global health situation was conducted. The article was later published in The Lancet [18]. One of their many findings was that since 1970 men and women have gained an additional ten years to their life expectancy, but spend more time living with injuries and illness.

The amount of time adults spend in a sedentary position has increased over the last 30 years. The reasons for this are many, but increased use of technology and ease of transport are one of the main factors [2]. An American study shows that one of four US adults spend 70% of their waking hours in a sedentary position, 30% in light activity, and little to no time is spent exercising. During the last decade research has started to emerge that links extended periods of sedentary time to metabolic risks [19], obesity, and abnormal glucose metabolism [20]. It is suggested that prolonged periods of sedentary time should be avoided by increasing the number of breaks taken during sedentary activities.

Based on these findings health recommendations regarding breaks in sedentary time should be added to the already existing ones [20]. Another study goes as far as stating that prolonged sedentary time is strongly related to metabolic risks independent of physical activity [21], and that elderly benefit more from reducing time spent sedentary than younger people. Though researchers agree that long periods of sedentary time is unhealthy, research still has to be done on how long a subject can stay sedentary before it has negative impact on the individuals health. How long one needs to stay active between periods of sedentary time, is also debated.

The Norwegian Directorate of Health (NDH) has issued recommendations and guidelines pertaining to the minimum amount of physical activity for an elderly person. The recommendation is set to a minimum of 30 minutes a day with moderate activity [22]. In addition to this an elderly person should be standing in a skeleton bearing position for total of five hours per day to preserve the skeletons strength and form. Skeleton bearing position means that the subject is standing upright without any aid, such as a walking stick.

## 3.2 Physical Therapy in Norway

Physical therapy consists of two main steps: diagnosis and treatment. In the diagnosis phase the physiotherapist tries to determine what is wrong with the patient in order to apply the appropriate treatment. In case of elderly patients their problems might often be caused by lack of activity. When the therapist is finished with the diagnosis, a treatment plan is created. The plan often includes a set of exercises the patient should perform throughout the week, these are designed to let the patient reach his goal regarding incerased activity.

The treatment phase consists of the patients following the agreed upon plan to improve their activity level, or regain normal movement after operations or fractures. Some time after the patient has been presented with the treatment plan, the physiotherapist will return to the patient to monitor his progress. Often the patient may lack the dedication or motivation needed to follow the plan strictly. In such cases the plan might need to be revised or the physiotherapist needs to perform checkups more often to ensure that patient stays motivated.

## 3.3 Sensor Technology in Physical Therapy

There is no use of sensor technology to track activity in Norway today. Some of the physiotherapists we have been in contact with worked on research projects where such technology was utilized, but they had never used it outside of academic work.

Even though there is little use of this type of technology in physical therapy today, the Norwegian government has an increasing focus on the use of welfare technology. A committee formed by the Norwegian government called Hagen Utvalget (HU) [3] also concluded that there is a need for more welfare technology to tackle the ever increasing number of elderly. A system that could increase the effectiveness and quality of physiotherapist's work toward increasing the activity of the elder population, fits well with the technological goals presented in the HU-report.

## 3.4 Accelerometer Data in Physical Therapy

Using accelerometer data to classify activity can help physiotherapist's both in the diagnosis and treatment phase. Having quantitative data of the users activity over one or more weeks, will give physiotherapists a much better overview of the patients current activity level. This can be helpful when creating a treatment plan.

Letting the patient see their improvement using information visualization can be a powerful tool for motivating the patient. Sometimes the improvement might be subtle and it can be hard for the patient to be motivated to continue the exercise plan without seeing some kind of indicator that they are in fact improving. Visualizing quantitative data can show these subtle improvements in the patients activity level, and display them in a way that motivates the patient to continue with the plan.

## 3.5 Certification of Medical Equipment

In 2006 a regulation concerning medical equipment in Norway came into effect [23]. The purpose of the regulation is to ensure that medical equipment used in Norway does not present a danger to either patient or users. To insure this, the regulation instils a set of requirements to both the use and the production of the equipment. In the regulations definition of medical equipment, standalone software is also to be perceived as medical equipment.

# Chapter 4
# Body-worn Sensor Technology

The purpose of this chapter is to give an insight into relevant commercial products that exist today. It starts off by looking at the communities that surround these products before presenting the technology itself. Finally we discuss and display how these products present their activity data.

## 4.1 Personal Informatics and Quantified Self

Currently there are two names that stand out within the self-monitoring field: Quantified Self (QS) [24], and Personal Informatics (PI) [25]. QS is a community of end-users who share data and exchange experiences with tools that help them collect information. PI is a label used to classify a set of tools used for self monitoring. PI also refers to a community that hosts conferences concerning research in the field of PI.

### 4.1.1 Personal Informatics

Personal informatics is the label used to classify tools that help people collect personal information for the purpose of self-monitoring and self reflection. These tools are used to help individuals gain self-knowledge about their behaviour, habits, and thoughts.

The Computer-Human Interaction (CHI) conference has since 2010 [26] held workshops and accepted papers on Personal Informatics. The aim is to increase the understanding of how the tools affect the users as well as explore new possibilities, and overall improvement of the user experience.

### 4.1.2 Quantified Self

In 2011 QS had their first conference [27]. Here people shared data that they had collected about themselves using different types of devices. Members of the community collect information about everything from sleep patterns and diets to mood and stress levels. The goal is to use quantitative data to improve ones own life, either through a more healthy lifestyle or by achieving a better understanding of oneself.

To promote further development in tools that gather these types of information, the participants of Quantified Self have worked closely with companies and individuals that create personal informatics tools. Devices such as Nike's FuelBand and Fitbit are results of this cooperation, and both products have been well received by the community.

## 4.2 Sensor Technology

This section covers some popular commercial activity monitoring sensors currently on the market. The products that will be discussed are Nike Fuelband, Fitbit Flex and activPAL. Both Nike FuelBand and Fitbit Flex are designed for personal use, while activPAL is mainly used in research projects.

### 4.2.1 Wrist-worn Body Sensors

Since the release of the Nike+ FuelBand [28] in early 2012 several new wrist-worn activity monitors have emerged. Nike FuelBand, Fitbit Flex [29] and Jawbone Up [30] are the only ones, so far, who are either available to the public or soon to be released. The devices are designed to be inconspicuous, durable and quietly monitor the users activity by counting steps taken, kilometres walked, time spent sleeping or sedentary etc. All of the bracelets use a built in 3-axis accelerometer to record movement. The classification of activity level is done by individual proprietary algorithms for each of the products.

**(a)** Fitbit Flex **(b)** Jawbone Up

**Figure 4.1:** Two commercial wrist worn body sensors.

Being worn on the wrist these devices come with certain drawbacks, all the information gathering is based on movement from a single point (i.e. the users wrist). This leads to certain physical activities not being registered properly, one such example is riding a bike. The Fitbit developers have attempted to compensate for this by allowing the user to track such activity manually. The manually entered data is then added to the daily statistics.

### 4.2.2 activPAL

The activPAL sensor has the shape of a small rectangle and is worn on the thigh. When the device is active it continuously records accelerometer data using an internal accelerometer. This data can be interpreted using algorithms provided by PAL Technologies.


**Figure 4.2:** An activPAL tri-axis sensor.

When the activity data has been gathered the *Intelligent Activity Classification*-algorithm is used to classify the data into three states: sitting/lying, standing and walking. Because activPAL is worn on the thigh, the accelerometer is unable to detect the difference between sitting and lying. Number of steps is also counted when walking.

activPAL differs from the other sensor presented in this chapter as it is designed for use in research and not commercial use. The sensor has a longer battery life than Fitbit Flex and Nike+ Fuelband, but does not include a practical way to be carried and has to be taped to the thigh. It is also much bigger than Fitbit Flex and Nike FuelBand.

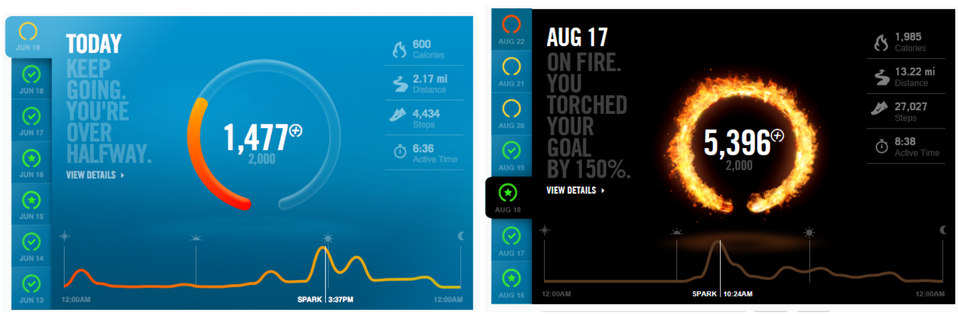
activPAL is frequently used in research, several studies have been conducted which conclude that the sensor is viable for recording and classifying activity [31, 32, 33, 34]. The sensor has also been used in multiple studies for obtaining and analysing activity patterns [35, 36, 37].

## 4.3 Presentation of Sensor Data

In this section we look at how the commercial activity monitoring devices presented in the previous section visualize their data. We will show that the Nike Fuelband and Fitbit Flex, designed for the general public, have a much broader range of visualizations with greater emphasis of being visually appealing than activPal.

### 4.3.1 Nike+

NikeFuel [38] is a unit of measurement used by all Nike's activity trackers. The FuelBand does calculate steps and calories burned, but the NikeFuel is the prime focus of their product line. NikeFuel does not take into account gender, height, weight, but looks purely at activity. Meaning that a kilometer of walking will award the same amount of points to users with very different physiology. The daily progress (Figure 4.3) is represented through a ring that fills up when the FuelBand detects activity. A full ring means that the daily goal has been reached. Progress beyond the daily goal will be displayed with numbers and visual enchantments on the ring.




**(a)** User having one third of his daily NikeFuel goal [39].

**(b)** User beating his daily limit by 150%, rewarding him with special effects on the ring [40].

**Figure 4.3:** Two examples of Nike+ visualizations.

An online profile provides detailed information about the users activity, showing steps, calories burned, active time, distance travelled and average fuel, as seen in Figure 4.4. Charts can be displayed for weeks, months or years. This allows the user to track their progress and look at how often they achieve or exceed their goals [40].

Virtual trophies are awarded for various achievements such as gathering an x amount of NikeFuel or beating the set goal by a 100%. These trophies can then be shared with friends or displayed on the public profile to show off achievements. A review has reported that the NikeFuel concept can almost become an addiction and lead to doing some last minute workouts in order to reach the goal [39].

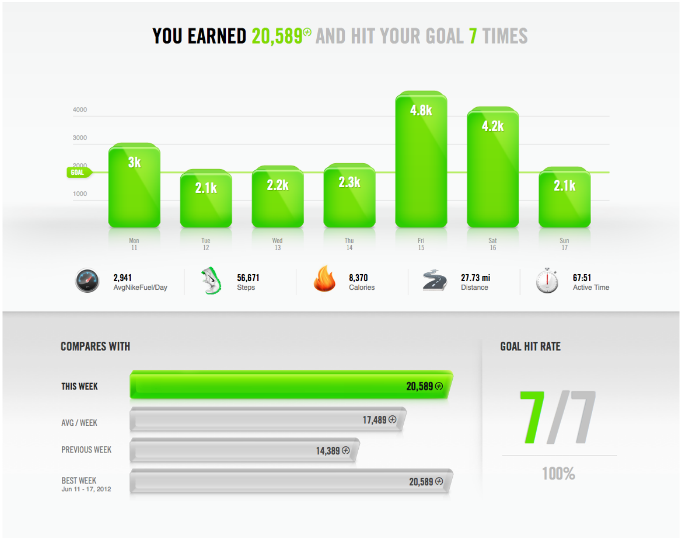



**Figure 4.4:** The weekly breakdown presented by Nike+. [40]

### 4.3.2 Fitbit

Similar to the Nike+, Fitbit [41] allows the user to set daily goals, but the Fitbit does not use the NikeFuel system. Instead it allows the user to set 3 separate goals: steps taken, floors climbed, and calories burned, as seen in Figure 4.5. Fitbit provides an active score, but there is no emphasis on it. On the Fitbit-webpage a daily activity breakdown is provided. Activity levels are separated into four categories: sedentary, lightly active, fairly active, and very active. All the goal histories can be viewed on the online profile and can be categorized into day, week, months and years.

Fitbit also offers the Fitbit Premium service, which adds more functionality to the online webapp. The premium service allows the user to get more detailed and aggregated information than the basic logs do. It gives advice on sleep, activity and food based on activity level and the recommended values for people in the users height, weight, age group.

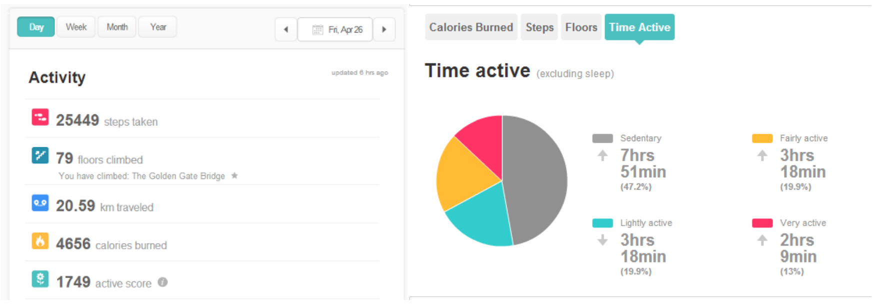



**Figure 4.5:** The breakdown provided by FitBit. It can be broken into day, week, month, or year.

### 4.3.3 activPAL

The activPAL only provides one diagram, which can be seen in Figure 4.6. Yellow represents a sedentary position, green indicates an upright position and red means that the user was walking. If there is activity during an hour, the bar will rise and the activity will be colour coded to either red or green depending on their activity type. Looking at Figure 4.6 we can see that at 10 AM the person spent a long time standing, a little while walking and almost no time was spent in a sedentary position. The pie chart and numbers to the right use the same colour coding and summarizes the activity distribution throughout the day.

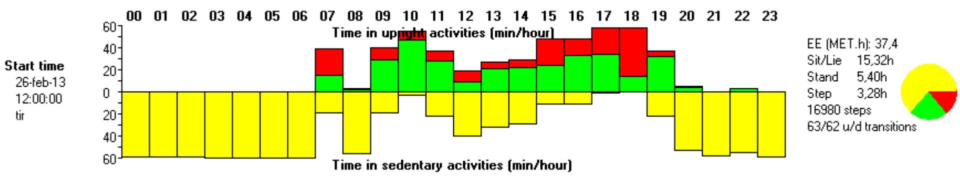



**Figure 4.6:** Visualization of sensor data from activPAL sensor.

Chapter 5

# Research Design

All of our research methods are of a qualitative nature meaning no empirical data is collected. This Chapter provides an overview of our chosen research methods, how they attempt to answer the research questions and discusses why these methods were chosen.

## 5.1 Overall Plan

This section provides an overview of how our chosen research methods relate to each other and how they assist in answering the research questions we have posed. Table 5.1 gives a quick overview of our methods and which specific research question the method contributes to. The table order corresponds to when in our project the research method was used.

The first research question is concerned with finding relevant scenarios for the use of systems such as the one we are creating. To answer this question we performed interviews and focus groups. A large part of the second focus group was dedicated to discussing different scenarios with the physiotherapists.

The second research question asks what functional and user experience requirements the visualizations should have. The initial requirements were gathered through an interview with a domain expert. Two additional revisions of the requirements were planned, one after each focus group. Feedback on the prototype was the basis for the modifications to the requirements. A portion of the second focus group was used to discuss the requirements with the physiotherapists.

Research question three asks which visualizations the physiotherapists prefer, given the requirements and scenarios created. Feedback on the visualizations was given in the focus groups. The larger part of both focus groups was dedicated to discussing and reviewing the visualizations with the physiotherapists.

| RQ | Method | Description |
|---|---|---|
| 1,2 | Interview | An interview was performed with a domain expert to establish initial requirements and scenarios. |
| 2 | Brainstorming | Based on the initial requirements, the authors performed brainstorming sessions among themselves and sketches were created. |
| 2, 3 | Prototype | The paper sketches were used as a starting point to create a high fidelity prototype that would be presented to the first focus group. |
| 1,2,3 | Focus group | The first running prototype was presented to the focus group and would enable us to refine it further. |
| 2, 3 | Prototype | Based on the feedback received from the first focus group the prototype was modified and improved. |
| None | Questionnaire | Before the final focus group, a quick questionnaire was answered by the users. |
| 1,2,3 | Focus Group | The new version of the prototype was presented and the requirements were refined. |
| 1,2 | Interview | The interview was carried out to help us understand how the physiotherapists work. |

**Table 5.1:** The overall design plan.

More detailed information about how the methods were executed and their result can be found in the subsequent chapters of this report, namely in Chapters 6 to 10. The following sections of this chapter explain the rationale and choice of method in further detail.

## 5.2 Overall Plan in Accordance to ISO 9241-210

This section aims to show how our chosen research methods relate to human-centred design activities describes in ISO 9241-210. Figure 5.1 show how our research methods correspond to the ISO activities. The gray text is the purpose of the step described in ISO 9241-210, inside of the squares are our research methods with a numbering showing the order in which they were executed. The brainstorming and questionnaire activities have been omitted from the figure, as they were primarily used as support methods for prototype 1 and focus group 2.

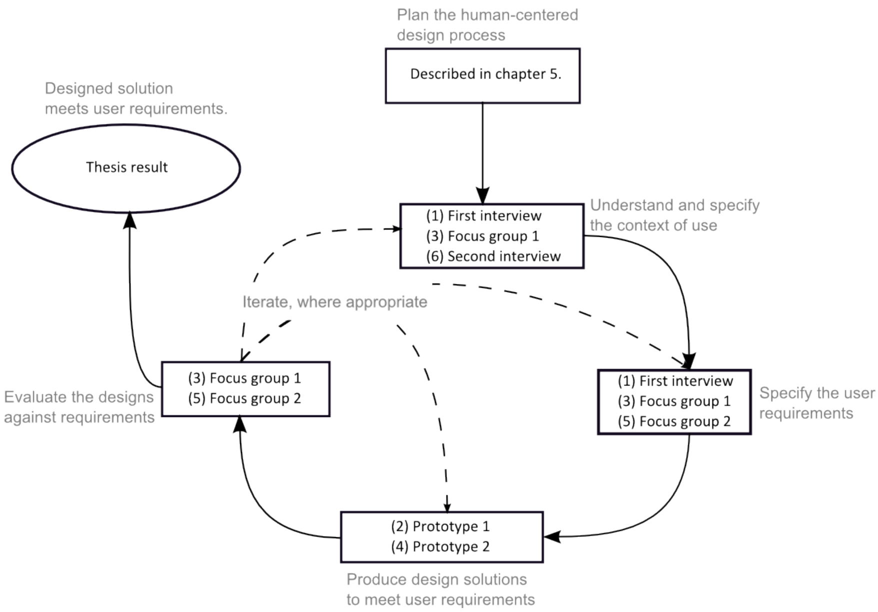



**Figure 5.1:** How our chosen research methods fit into the activities suggested by the ISO.

## 5.3 Interview

Initially we possessed little domain knowledge on how to create a system for showing visualizations of sensor data to physiotherapists. To increase our knowledge in the field we considered conducting a field study or a focus group, but settled on doing an interview with a domain expert at St. Olav's Hospital. We believed that a field study or focus group would not be fruitful enough to justify the amount of time it would take. We lacked some basic knowledge and terminology in the field, which could be covered by a simple interview. The procedure and results of this interview can be found in Chapter 6.

Originally we had intended to conduct a minor literature study to understand how physiotherapy is conducted in Norway. Sadly this was not a well documented process, and the little information we did find was not consistent. The routines varied from office to office, and what type of patients they focused on. Therefore we decided to conduct an interview with some of the participants from the planned focus group. The results of this interview can be found in Section 10.3.5.

## 5.4 Brainstorming

Jumping straight to a high fidelity prototype would be unwise, therefore we decided to conduct brainstorming sessions. The purpose was to create rough designs of possible visualizations that would fulfil the initial requirements, in addition to discussing any technical difficulties that might occur during implementation. The result of the brainstorming can be found in Section 7.2.

## 5.5 Prototype

Implementation of the first prototype was planned to start after the creation of paper sketches. We did not want to spend more time on low fidelity prototypes that would be thrown away at the end, and would most likely never be shown to a broader set of users. A running prototype showing real data and more polished visualizations would have a much bigger impact on the focus group than rough paper sketches. Another important factor was to show the participants of the focus groups visualizations created real-time from actual data. This way they could get an impression of how quick the parsing and rendering was, and how easy it was to switch between patients data. The first version of the prototype can be seen in Section 7.4 and the second version can be found in Section 9.1.

Figure 5.2 shows what type of design questions the paper sketches and running prototypes attempt to answer (see Section 2.6.2). The Paper sketches (PS) are a result of the brainstorming session conducted. They focus heavily on *look and feel*, as they were designed with the scenarios and requirements in mind, but some *role* questions are answered as well. Our first running prototype resolved any implementation uncertainties we had, and in addition helped us solidify our look and feel. Creating the second prototype after a focus group allowed us to refine the look and feel, as well as focusing more on the roles by using the feedback and comments from the focus group session.

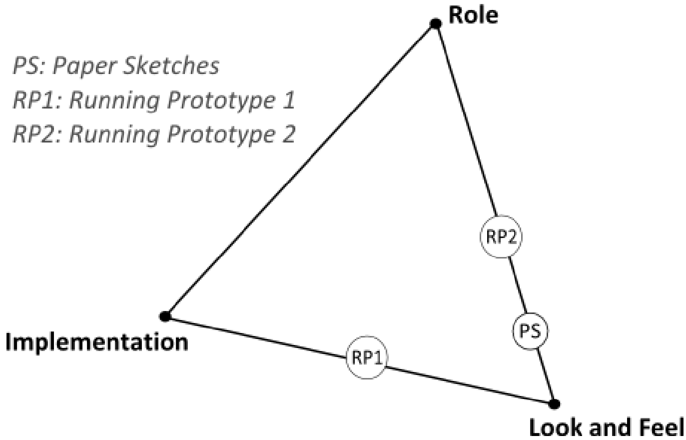



**Figure 5.2:** Showing where the focus of our prototypes lie.

## 5.6 Focus Group

We considered performing usability tests instead of focus groups to get feedback on the system. In the end we decided to conduct focus groups because the main priority was to evaluate the visualizations and not the application as a whole. Usability test focus more on navigating and completing tasks in a system, which is not the focus of this study. Focus groups are also less time consuming and gives the participants the ability to discuss different parts of the system and suggest new features and improvements. We can also use the focus groups to discuss other topics such as scenarios and requirements. Detailed information on how the first focus group was conducted and its results can be found in Chapter 8 while the second focus group is covered in Chapter 10.

## 5.7 Questionnaire

A questionnaire was prepared for the second focus group. The purpose was to gain background information about the participants, and to gain an understanding of their attitude towards technology. The questionnaire also asked the participants if they thought using technology such as the one presented in the focus group would improve the quality and effectiveness of their work. The questionnaire was answered at the start of the second focus group. The information received from it is summarized in Section 10.1

# Chapter 6
# Initial Requirements

The interview we conducted to create our initial scenarios and requirements for the research questions is covered in this chapter. The first section introduces the participants and the topics that were discussed. The subsequent sections present the interview results, scenarios, and initial requirements.

## 6.1 Participant and Process

The initial requirements were gathered with the help of a domain expert with a Master of Science in Human Movement Science. She is working on a research project at St. Olavs Hospital for her PhD, where the activPAL sensor is used to track the activity of patients being rehabilitated after hip-fractures.

Because of the lack of information we had on the current usage of sensor technology in physiotherapy and how this technology works, we conducted an unstructured interview with the domain expert. In the interview we discussed four topics:

1. How sensor technology like the activePAL is used in physiotherapy and research today.
2. What types of visualizations are used.
3. Technical aspects of using the activPAL.
4. Initial requirements for the visualization

## 6.2 Results

Based on the response provided by the domain expert the first three topics have been summarized below, while the initial requirements are presented in the next section.

– Currently there is little or no use of sensor technology in physiotherapy. There are some physiotherapists involved in the research projects using these types of sensors, but they do not use them in their normal practice.

- The only visualization utilized by the domain expert and physiotherapists using the activPAL sensor are the visualizations that are offered by the software that comes with the sensor, as presented in Section 4.3.3.
- From a technical aspect it is not hard to use the data gathered by activPAL. The data can easily be exported in the common CSV format. CSV is a machine-readable format, which means that it can easily be read and parsed by other software. activPAL offers options for exporting both event data (see Appendix C), or raw acceleration data.

### 6.2.1 Initial Requirements and User Scenario

After talking to the domain experts at St. Olavs Hospital, two main user scenarios emerged:

| Id | Scenario |
|---|---|
| IS-1 | Mapping the activity level of patients |
| IS-2 | In consultation with patients |

**Table 6.1:** The initial scenarios.

The current practice of physiotherapists working with the elderly is to first get an overview of the patient's activity level. This information is then used to create a program to improve the activity level of the patient. The activPAL sensor can be used to collect data so that an even better mapping of the patients activity level can be achieved. IS-1 is concerned with how to visualize this data so that the physiotherapists can get an idea of how to proceed with the treatment.

After the physiotherapists has an idea of the patients current level of activity the data is presented to the patient. This is usually a discussion about the results of the test and what the patient wants to achieve in relation to physical activity. IS-2 addresses that visualizations can be helpful in making the patient understand and become more aware of their current level of activity.

Using the two user scenarios above we created some simple requirements for the visualizations as a basis before starting development, as seen in Table 6.2.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| IR-1 | give an overview of the week |
| IR-2 | give a summary of the daily activity |
| IR-3 | show the activity level for each hour of every day |
| IR-4 | let the user compare hours from multiple days |
| IR-5 | show the activity level for each minute of every day |
| IR-6 | let the user compare minutes from multiple days |
| IR-7 | let the user identify patients that are active during the night |

**Table 6.2:** The initial requirements.

# Chapter 7
# Prototype 1

In this chapter we explain the role activPal plays in our prototype and we discuss the paper sketches that were a result of a brainstorming session conducted by the authors. In addition, the running prototype and the technology and frameworks used to create it are presented. Large screen shots of the visualizations can be found in Appendix A.

## 7.1 activPAL

As mentioned in Section 4.2.2 the activPAL classifies the accelerometer data into three different types of behaviour, this data can then be viewed through activPALs proprietary software. There is an alternative to export the data in the Comma-Separated Values (CSV) format, and several options for how the data should be presented or aggregated.

It is possible to export raw accelerometer data or event based data. For event based data a new line will be written with the time, duration and state type every time the activity state changes. A more detailed overview of the CSV file can be found in Appendix C.

For the purpose of our thesis the event based CSV data was the most suited format for the type of information we would need to create visualizations. Before feeding the data to our visualizations, the system parses the data into more suitable data structures. activPAL is not a key part of our prototype, we chose this sensor because it had been proven trustworthy in other research, and was easy to acquire. Other sensor can be used as long as the data has the correct data format.

## 7.2 Paper Sketches

Before starting the implementation of the system we created a set of paper sketches of the visualizations that we planned to implement. These were our first ideas on the visualizations that would fulfil the initial requirements efficiently, while providing several alternatives to choose from.

### 7.2.1 Overview Charts

Getting an overview of the week as a whole can be useful as an introduction. By looking at an overview the user can quickly identify bad days that can then be investigated further. In other words these visualizations address the weekly overview requirement IR-1. They can also be used as the top level of an interactive application. Each day could then be clicked to show either a timeline or pie chart.

The overview charts mainly focus on two type of visual variables (as described in Section 2.2.1): position and size. If one looks at Figure 7.1, one can see that the vertical position of elements illustrates how each day is classified. The close proximity of elements on each horizontal level, makes the viewer intuitively associate days that are on the same level as being part of a group. The size of each group makes it easy to see which classification has the most amount of days. Since size has a quantitative characteristic one can easily see that the top classification has twice as many days as the middle one, and four times as many as the bottom one.

#### Day classification

By calculating the overall activity level and classifying the days into three categories the physiotherapist can easily see which days a patient needs to be more active and which days the activity level is satisfactory. In our sketch, see Figure 7.1, the three different classifications are illustrated by smilies (smiling face for active days, and sad face for inactive days).

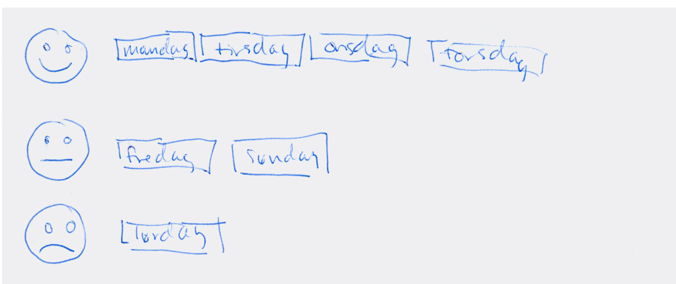



**Figure 7.1:** A more detailed overview chart, also showing activity for each hour of the day.

A more complex version of the above chart, see Figure 7.2, shows a square for each hour, while still using the same classification into sad and happy smilies. Each day square contains 24 smaller squares that represent each hour of the day. The small hour squares are coloured with a gradient to show the activity level for that hour. With this chart the user can get an overview of the week as a whole, and identify what hours of the inactive days had the most sedentary behaviour. It also lets the user compare hours from multiple days as stated in requirement IR-4.

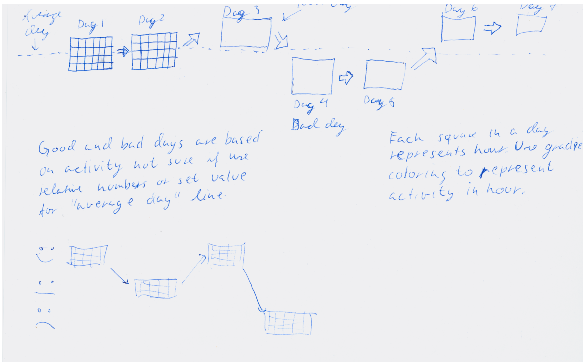



**Figure 7.2:** A more detailed overview chart that classifies the days.

### 7.2.2 Aggregated Charts

These type of charts show the sum of time spent sedentary, standing, and walking. Summing over the three classifications makes it easy to get an overview of the day as a whole. The drawback is that details are lost and it is not possible to pinpoint when each activity occurred during the day. Aggregated charts were created to cover the summary of daily activity requirement, IR-2. Aggregated charts can be used to get a general overview of the daily activity before spending time looking at more detailed visualizations. Additionally it can serve as an alert for patients with low activity levels, where the majority of the chart would be filled with inactivity.

Aggregated charts make use of two visual variables: Size and colour. The quantitative characteristic of size is used to determine the amount of each type of activity. For example for a pie chart, by looking at the size of the pie slices it is possible to quickly identify how the different activity types compare to each other. The selective characteristics of colour is used to separate the different types of activity from each other. Since there are only three different type of activity, it is easy to distinguish between the different colours.

### Pie chart

The pie chart is a standard way of showing the amount of time spent in each activity state. Due to the familiarity of the pie chart it will be easy to understand for both users and patients. A legend shows which colour represents each type of activity. The exact percentage for each activity state is also displayed.

### Symbolic

A more symbolic approach (see Figure 7.3) is to remove the legend and instead use illustrations to convey which colour corresponds to which activity. To get more space for the illustrations the diagram uses boxes instead of pie slices to represent the distribution of each activity level. Though the box chart is not as much used as the pie chart, humans can intuitively compare sizes of different types of shapes as long as they are placed in close proximity.

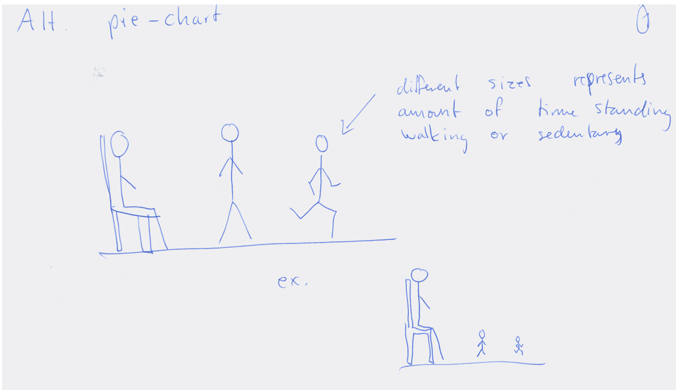



**Figure 7.3:** Our first idea for a symbolic "pie chart".

### Ball chart

An alternative to the previous aggregated charts is to include more detail into a pie chart style, by using balls instead of normal pie slices. The balls are colour coded so that each colour reflects an activity state, while the size of the ball represent the continuous amount of time spent in the corresponding state. Each ball represents an interval of one of the classifications, so that many balls of one colour both represents the amount of that behaviour and shows how long each period of that behaviour was. This can also be used to identify if a user is active during the night, which is requirement IR-7. Figure 7.4 shows an example of such a graph. The benefit with this type of graph is that one can easily identify long periods of sedentary behaviour. Taking small breaks with movement can help "split up" those balls, which is beneficial for ones health. By adding interactivity to the chart the user can select each ball and see what time it corresponds to. Overall the chart allows for the large balls to be easily spotted and efficiently discovery when the incident occurred.

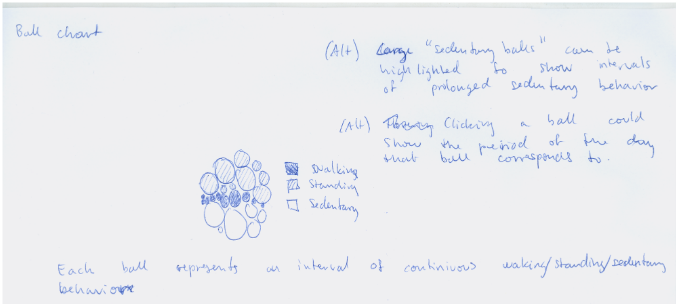



**Figure 7.4:** Rough drafts of the Ball chart.

### 7.2.3 Timeline Charts

Timeline visualisations are effective at illustrating when various activities occurred during the day. Timelines use a long horizontal bar that has different colours for different behavioural classification. These visualizations primarily address requirements IR-3, IR-4, IR-5 and IR-6, which state the need to show and compare minutes and hours during the day. Timeline charts can also be used to identify patients that are active during the night, which is requirement IR-7.

The timelines we sketched all make use of the visual variable position. The position on a rectangle or circle represents what time of the day activity occurred. Continuous timelines make use of the selective characteristic of colours to show what type of activity occurred at any point of the day. The blocked timeline, as seen in Figure 7.5, makes use of the visual variable value (colour gradient) to convey the amount of activity for each respective hour of the day. Since value can be ordered, it is easy to see which hours have activity, and that one hour has more activity than another. Value is not quantitative however, so finding one hour with twice as much activity as another is difficult.

#### Continuous

One approach to this visualization type is to create a continuous timeline that contains every little detail of activity. The continuous timeline is useful for quickly identifying periods of the day with unsatisfactory behaviour, but the detail can also be distracting and make it hard to read the diagram.

### Blocks

Instead of having a continuous scale, a blocked approach can be used, as seen in Figure 7.5. The timeline would be divided into 24 blocks, each block corresponding to an hour of the day. A gradient colour scale is used to represent the amount of activity inside the hour block. This makes it easy to identify hours of the day where the patient is sedentary.

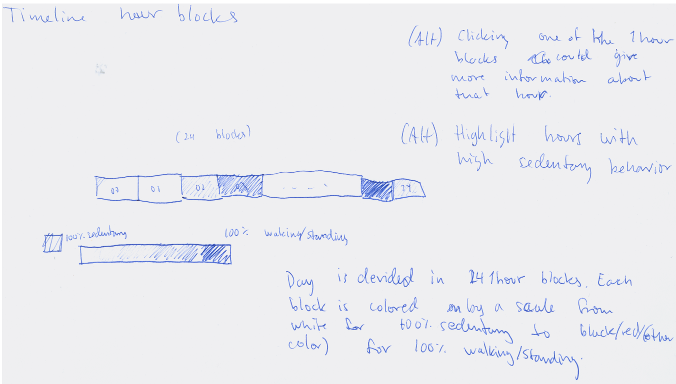



**Figure 7.5:** Timeline with hour blocks.

### Clock

A timeline may need some explanation before the user understands it properly. By creating two clocks instead of a long horizontal bar the user can more intuitively understand what the visualization is presenting. Since a clock has only 12 hours, two clocks are created to represent the entire day. To make it easier to identify day and night, a descriptive background is necessary, see Figure 7.6.

Another approach is to use one 24 hour clock. This makes it easier to see the transition between AM and PM, but 24 hour clocks are not natural, so it might be problematic for the user to understand.

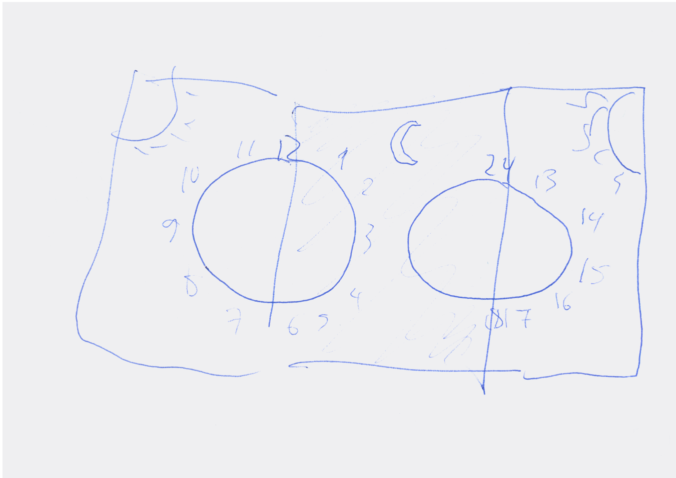


**Figure 7.6:** Two 12 hour clocks show the activity of the day.

## 7.3 Programming Framework

The task was to create custom visualizations from data gathered by the activPAL sensor. The choice of programming tools fell on HTML5 and an open source JavaScript framework called D3js.

### 7.3.1 HTML5

HTML is a markup language for the creation of web pages. HTML describes the structure and the contents of the web page. In later years, the need for advanced styling and complex interaction with web pages has made CSS and JavaScript increasingly popular. HTML5 was created as a response to this, HTML5 is an umbrella term for creating web pages using HTML5, CSS3 and JavaScript.

HTML5 has simplified the syntax compared to earlier versions. New tags have been added to better represent the modern web page elements. Other features include media tags which greatly simplifies adding multimedia content, such as playing audio and video files. More importantly for our project is the extensive support for interactive and animated graphics through the *canvas*- and *svg*-tag.

The new features of HTML5 and CSS3 make it much easier to create web applications for multiple platforms and screen sizes. After the smartphone and tablet revolution, creating responsive and adaptable websites has become more important. Additional new features in HTML5 give a large amount of flexibility with respect to the user interface and graphical visualizations.

*Cascading Style Sheets* (CSS) is a language used to describe the styling of an HTML document. CSS documents describes the size, color and look of HTML elements. A new feature in CSS3, which is part of HTML5, is *Media Queries*. With Media Queries it is possible to specify different styling relative to the size of the screen. This functionality is useful when creating applications that target devices with different screen sizes, such as smartphones, tablets and laptops.

### 7.3.2 Data-Driven Documents

JavaScript is the main scripting language for web pages. It is a client-side scripting language that allows programmers to add functionality to otherwise static HTML-pages. While CSS3 takes care of the styling of HTML-elements, JavaScript is used to create customized behaviour. All modern browsers have JavaScript engines/interpreters that compile and run JavaScript code.

JavaScript is now an industry standard maintained by ECMA International. The standardized version of the script is named ECMAScript. Today, the names ECMAScript and JavaScript are used interchangeably, and JavaScript is often used to refer to ECMAScript. Because different browsers have different implementations of the JavaScript engine, slight variations in the way JavaScript code will run on these browsers exists.

Together with HTML5 and CSS3, JavaScript is great for creating web applications that can be designed to run on both mobile and stationary devices. JavaScript has a multitude of useful open source libraries that can be used to create complex user interaction, animation, and custom graphics.

One of the challenges in this project was to create different visualizations to represent the activity patterns of patients. Creating custom graphics in HTML5 can be done using both the canvas- and the svg-tag. In this project Scalable Vector Graphics (SVG) is used. SVG is an image format that uses XML encoding to define shapes, lines, colors, and text. One benefit of svg, compared to other image formats, is that details in SVG-images will not be lost when zooming. All popular browsers, and most mobile devices, support rendering of SVG-images.

Creating graphics using svg-tags directly is cumbersome and time consuming. Data-Driven Documents (D3) is an open source framework that greatly simplifies this task. D3 is written in JavaScript and designed to be used in combination with HTML5. The framework can be used both to create new SVG images from scratch or modify and edit existing images. Another feature is the ability to easily add interactivity and animation to the SVG-elements. HTML5 in combination with D3 gives us flexibility to create almost any type of visualization and adding interactivity and animation to it.

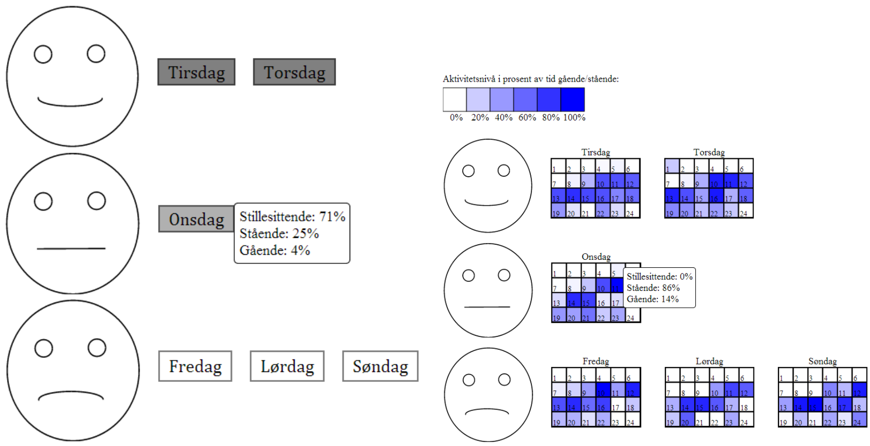
## 7.4 Running Prototype

Nine of the paper sketches were selected for implementation, so they could be presented to the first focus group. Some changes were made and additional functionality was added to the implemented versions of the visualizations, such as highlighting and different view modes. All diagrams were given IDs as seen in Table 7.1.

| ID | IR | Description |
|---|---|---|
| U1 | 1 | Classifies each day of the week into one of three categories: High, medium and low activity. |
| U2 | 1, 3, 4, 7 | Classifies each day of the week as in U1. Also shows 24 squares for each day, each square representing an hour. The activity level for each hour is displayed using a gradient. |
| F1 | 2 | Pie chart showing the distribution of activity for each day. |
| F2 | 2 | Same as F1, but with boxes instead of pie slices and descriptive figures inside each box. |
| F3 | 2, 7 | Ball chart. Divides the pie slices of F1 into bubbles, each bubble representing one interval of activity. |
| T1 | 3, 4, 7 | Timeline of 24 squares, each square represents one hour of activity. The amount of activity in that hour is displayed using a gradient. |
| T2 | 5, 6, 7 | Rectangle shaped timeline, showing the activity type using colour coding. |
| T3 | 5, 6, 7 | Two 12-hour clocks showing the activity type using colour coding. |
| T4 | 5, 6, 7 | One 24-hour clock showing the activity type using colour coding. |

**Table 7.1:** Visualizations implemented in the first prototype.

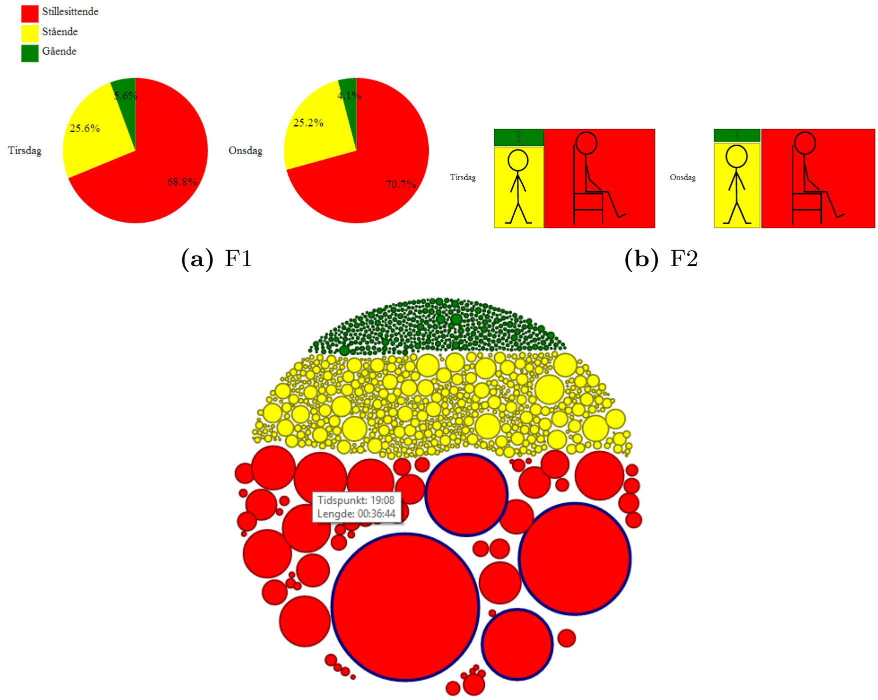
The two diagrams U1 and U2 (see Figure 7.7) are overview charts. These are designed to give a quick overview of the week. U2 experiments with adding more detail, and contains 24 small squares for each day that represent the activity of each hour. Holding the mouse cursor over a day in U1 will show the percentage of each type of activity for that day. Holding the mouse cursor over a square in U2 will show the percentage of each type of activity for the hour that the square represents. These diagrams satisfy requirement IR-1, which states that the visualizations should give an overview of the week. U2 also shows the hourly activity level for each day, meaning patients that are active during the night can be identified, and lets the user compare hours from multiple days as stated in requirement IR-7, IR-3, and IR-4.




**(a)** U1 **(b)** U2

**Figure 7.7:** Overview charts.

Diagrams F1, F2 and F3 (see Figure 7.8) are the aggregated charts. These diagrams shows the fraction of each type of activity for a day, requirement IR-2. F1 and F2 are similar, F1 is a standard pie diagram while F2 uses boxes with figures describing the activity. F1 and F2 has two types of view modes: one day or the entire week. F3 is more complex, this diagram shows each interval of activity as a ball. Long intervals of activity are represented by a larger ball than small intervals of activity. This graph can therefore be used both to see the distribution of the different activity types and, more importantly, the length of continuous activity, or sedentary behaviour. This is useful for identifying if the patient has very long periods of sedentary behaviour, or if the patient walks continuously for a long time. Holding the mouse cursor over a ball shows the time on which the activity interval occurred as well as the length of the interval. This enables the user to see if patients are active during the night as stated in requirement IR-7. F3 also offers a highlighting mode, where sedentary intervals longer than one hour are highlighted.



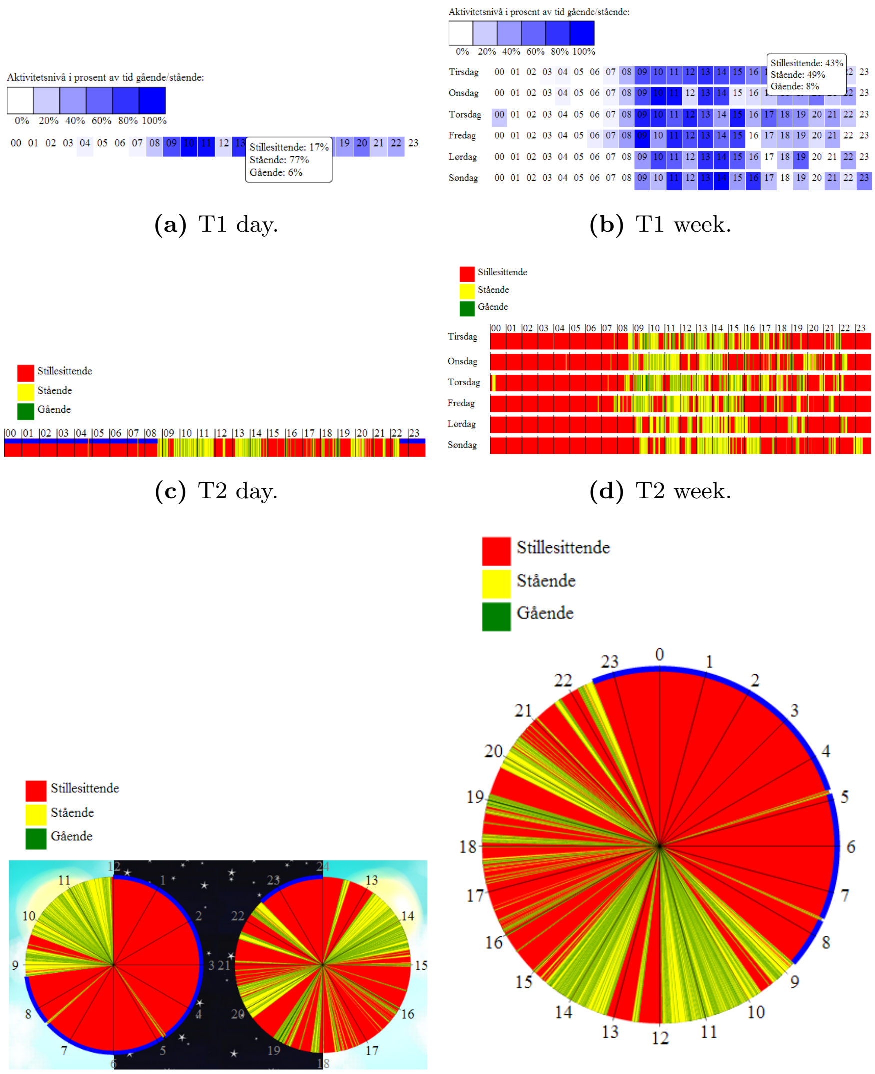

**(a)** F1

**(b)** F2

**(c)** F3

**Figure 7.8:** Aggregated charts.

T1, T2, T3 and T4 (see Figure 7.9) are diagrams that show timelines or clocks. These diagrams are useful to see when the patient was active during the day. T1 shows 24 squares each representing an hour of the day, as stated in requirement IR-3. The percentage of activity (walking and standing) is shown as a gradient in each square. Holding the cursor over a square displays the percentage of each type of activity. T2 is also a timeline, but here the data is not aggregated so the timeline is continuous and shows the activity at a much more detailed level, as stated in requirement IR-5. This is useful if the user needs to see when in a particular hour the activity was performed. It also distinguishes between standing and walking activity. T3 and T4 also show the activity continuously, but they use a clock instead of a rectangle to illustrate when on they day the activity occurred. T3 uses two 12-hour clocks, while T4 uses a single 24-hour clock. Diagrams T2, T3 and T4 can toggle highlighting. When highlighting is toggled sedentary behaviour longer than one hour is highlighted with blue. All T-diagrams can be viewed one day at a time or the entire week all at once, so they all satisfy IR-4 or IR-6. The diagrams can also be used to identify patients that are active during the night, as stated in requirement IR-7.




**(a)** T1 day.

**(b)** T1 week.

**(c)** T2 day.

**(d)** T2 week.

**(e)** T3 with highlighting

**(f)** T4 with highlighting

**Figure 7.9:** Timeline charts.

# Chapter 8
# Focus Group 1

The primary purpose of the first focus group was to receive feedback on the visualizations we had created, and see if the participants had any ideas of their own. A small part of the focus group was dedicated to understanding what kind of technology and visualizations the participants used in their line of work. This chapter starts of by describing the participants and explains how the focus group session was conducted. The results of the focus group are presented at the end of the chapter.

## 8.1 Participants

The focus group session consisted of five physiotherapists who were all employed at Trondheim Kommune (municipality of Trondheim) physiotherapy department, but are responsible for different districts within the municipal. We had originally invited six, but one of them could not make it due to a sudden conflict in their schedule. Their work involves visiting patients that are too old or unable to show up at a regular physiotherapist for other reasons. Four of the participants were female and the last one was male, and the ages were primarily between 34 and 36, with one participant being 46. The participants represented a portion of potential users, but no patients were present.

## 8.2 Location and Process

The session was held in a meeting room at St. Olav's Hospital. The participants were seated together around a table facing a live demonstration of the visualizations that was controlled by the assistant moderator. The primary moderator was responsible for conducting the session, providing explanations, and asking questions while not influencing the participants. Video recordings were made of the entire session, so that the participants feedback could be viewed at a later time. The entire session lasted for two hours including a ten minute break.

The agenda for the session:

1. Introductions
2. Opening questions
3. Review of visualizations
4. Short break
5. Discussion and drawing
6. Thoughts about session

The introductions was used to learn names and to explain how a focus group works. The participants were informed that they could be critical to the visualizations presented and that the whole idea of a focus group is to get everyones individual opinion, not only the opinion of the group. Though the participants had been informed of project in the invitation, some time was used to explain about the project as well as answer any questions related to the project. The introduction was also used to go through the agenda.

The opening questions were used to get an idea of the participants familiarity with the technology used in this project. This phase was also used to get the participants to talk, to warm them up for the more important review of the visualizations.

After the opening questions the visualizations were presented one by one. In general each visualization was reviewed before the next one was shown, but we did switch between visualizations when this was relevant for comparison or requested by the participants. A few questions were prepared for each visualization to ensure a nice flow in the discussion.

Once the review of the visualizations was concluded the participants were allowed to take a short break. During the break we explained about the technical aspects of the project in more detail as well as showing the participants another data set than the one used under the review phase.

Next, the participants were asked to discuss how they would create the perfect visualizations for their practice. Afterwards the drawings were discussed and reviewed by the other physiotherapists. When this was completed, we discussed some of our findings to clarify if we had interpreted the participants correctly.

The last part of the focus group was used to summarize the session and ask the participants about the experience of participating in a focus group. They were also asked if they would be willing to participate in the next focus group.

## 8.3 Results

This section contains the results of the first focus group. New sets of scenarios and requirements are presented, and the participant's feedback and comments on the visualizations is covered in some detail. The last section contains a discussion on colour choices and the possibility of printing the visualizations.

### 8.3.1 Scenarios

The first part of the focus group session was used for discussing how the technology could be used in practice. After going through the video and analysing the discussions, we modified the initial scenarios and created two new scenarios where visualizations would be a helpful tool:

| Id | Scenario |
|---|---|
| S1-1 | Analysing patients current activity level either individually or in cooperation with other physiotherapists. |
| S1-2 | In consultation with the patient. |
| S1-3 | In communication with other health care personnel. |
| S1-4 | In consultation with next of kin. |

**Table 8.1:** The scenarios after the first focus group.

### 8.3.2 Requirements

Analysing the discussion and feedback on the visualizations, we revised the initial requirements and created a new set of requirements to be used for the second prototype. The new requirements were divided into the functional requirements and user experience requirements shown in Table 8.2 and Table 8.3.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| R1-1 | give the user an overview of the week where the days are classified based on national or personal goals |
| R1-2 | show the activity level for each hour of the day |
| R1-3 | make it simple to identify periods of inactivity |
| R1-4 | make it possible to compare multiple days |
| R1-5 | make it easy to identify hours of the day where activity can be added |
| R1-6 | show the activity level compared to national or personal goals |
| R1-7 | let the user identify patients that are active during the night |
| R1-8 | let the user compare two separate weeks to see the patient's progress |
| R1-9 | be printable in grayscale |

**Table 8.2:** Functional requirements from the first focus group.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| R1-10 | not be judgemental towards the patient's activity level |
| R1-11 | be honest about the patient's activity level |
| R1-12 | motivate the patient to be more active |
| R1-13 | be intuitive and easy to understand for the user |
| R1-14 | be easy to explain to the patient |

**Table 8.3:** User experience requirements from the first focus group.

### 8.3.3 Visualizations

A large part of the focus group session was used to review the visualizations from prototype 1. Each visualization was reviewed one at a time, and the participants gave positive and negative feedback. We will now go through the most important parts of the feedback for each visualization group.

#### Overview charts

U1 was generally well received as a good way to get an overview of the week. There was some confusion as to how the days were classified, and it was suggested that one should be able to set custom goals to be used in the classification. One of the participants stated that the use of sad smilies would be judgemental toward the current activity level of the patient. Because a lot of the patients that receive help from physiotherapists have a low level of activity it was a fear that all days would be classified as sad smilies reducing the motivation of the patient. Using colours instead of smilies was suggested.

U2 was not well received. The participants did not like the way the 24 hour blocks were divided into four rows. This made the them look like days in a calendar, which was confusing for participants. U2 contained too much information and it was hard to get a feel for the overall activity of the day because the hours were split on four rows. The participants also had a hard time comparing days in different categories because the day-boxes were too far apart.

In general the participants liked the idea of an overview chart. Classifying the days should be made clearer by adding customizable goals. Smilies should be removed because they can be judgemental toward the current activity level of the patient. The overview charts should not show more detail than classifying the days.

### Aggregated charts

F1 was seen as easy to understand because of the familiarity of pie charts. Several of the participants did not like the fact that nighttime was added because the patients are supposed to be inactive during the night and the chart gave an unnecessary bad impression of the day as a whole. It was also perceived as hard to separate good and bad days because the percentage of activity always remained very small compared to inactivity. They liked the ability to see the entire week at once.

F2 was not as well liked as F1. Though the participants like the figures that illustrated the different types of activity, they did not like the box approach for visualizing the percentages. The participants thought it was easier to see the distribution using the pie chart compared to the box chart. One of the participants suggested adding the illustrations to the pie chart. The participants wanted to remove nighttime for this chart also.

The participants were positive to F3, the ball chart. They liked the fact that the visualizations showed the length of the intervals. Some participants wanted nighttime to be removed, while others felt that it was interesting to see if a patient walked during the night. The participants agreed that this type of visualization is too complex to be show to patients, however it could be shown to other health care personnel. The highlighting functionality was perceived as redundant, since it was already easy to identify the largest periods of inactivity.

The participants felt the F2, box chart, was hard to understand. They liked the illustrations of the F2 and wanted to add them to F1, the pie chart. There should be an option to see the entire week simultaneously. F3 was a good way to get an overview of the length of activity intervals. Highlighting was not needed for F3. Nighttime should be removed from the dataset.

#### Timeline and clock charts

T1, blocked timeline, was very well received by the participants, especially in week view. The participants praised the ability to easily see the patients habits. It was also stated that nighttime no longer got a negative impact on the visualization because it could easily be identified and ignored. One of the participants liked to have the ability to see if the patient was awake during the night (in the example data one can see the 10 minutes of activity at 4 AM). The participants stated that it was very easy to get a quick and detailed overview of the entire week, and it was easy to identify hours where more activity could be added. The participants suggested using different type of colours to make the gradient clearer.

T2 was not well received. The participants felt that the red colour, representing inactivity, was way to dominating. The periods of activity were hidden by all the red. They also stated that it was hard to see periods of walking activity, because they were hidden by all the red and yellow (standing activity). When asked about the need for more detail, the participants answered that it was not useful with greater detail than the 24 hour blocks provided in T1.

T3 displayed two clocks instead of a timeline. The participants did not like this visualization. They felt it was hard to identify when different events were occurring. They also stated that it was hard to compare multiple days because the circles could not be placed directly below each other like the timelines.

T4 was better received than T3. Some of the participants felt it was confusing that the clock had 24 hours. It was also expressed concern that the red portions representing inactivity stood out too much, making it hard to see the periods of activity. Also it was seen as hard to compare multiple days.

The participants liked T1 because it was easy to get an overview for both the day and week. The participants felt that there was no point in providing greater detail than 24 hour blocks. T2, T3 and T4 was seen as too hard to read, both because it was too detailed and because the active periods were buried by periods of inactivity.

### 8.3.4 Colours and Printouts

The participants were critical to some of the colour choices used in the visualizations. Several of the participants were critical to the use of red to represent a sedentary position, because the colour became too dominant which might demotivate patients.

Several participants also complained that it was hard to see the gradient colours in T1. When the participants were shown the same visualization on a laptop instead of the projector, they saw the gradient much better. For visualizations utilizing gradients it is important to test the screen quality before they are used. Otherwise the diagram might be misinterpreted.

One of the participants asked if the visualizations could be printed out, as they currently are not provided with portable laptops or tablets. Though the visualizations can be printed, they were not designed to be used other than on a computer. The participants also informed that they do not have access to colour printers. This means that the visualizations also should have grayscale versions for printing.

# Chapter 9
# Prototype 2

Changes were made to the prototype based on the feedback and requirements that surfaced after the first focus group was conducted. This chapter details what changes were made and explains why they were necessary. Large screen shots of the visualizations can be found in Appendix B.

## 9.1 Running Prototype

Feedback from the first focus group was used to improve the visualizations, Table 9.1 shows a list of the changes made to the original system. U2, F2, T2 and T3 were discarded by the first focus group and were removed from the system for the second prototype. Requirement R1-8 was not implemented for prototype 2, beacuse there was not enough time to implement this entirely new concept (parsing two data sets and comparing them).

A new concept introduces after the first focus group was goals. Requirement R1-1 and R1-6 state that classifications should be based on goals and that some visualizations should display how the patients activity compares to the goals set. Two types of goals can be set: Time spent walking and time spent in an upright position. The first goal refers to NDH's recommendation of a minimum of 30 minutes of activity each day, and 30 miutes is set as the default value for this goal. The second goal refers to the recommendation that an elderly person should be in a skeleton baring position for at lest 5 hours a day, to preserve the skeletal structure. 5 hours is the default value for the second goal.

New functionality added includes a new diagram T5, ability to set goals (default is national goals) and a small diagram, goal circles, that shows how active the patient was compared to the goals. The new diagram (see Figure 9.3c), T5, is similar to the visualization used by activPAL, but it does not show a bar for the amount of sedentary behaviour. The day is aggregated to 24 hour-blocks, the activity level for

**Change log**

| Nr | ID | R1 | Description |
|---|---|---|---|
| 1 | U1 | 10 | Replaced smiley faces with coloured squares. |
| 2 | U1 | 1 | Classify using national/personal goals for sitting and walking. |
| 3 | U2 | | Removed. |
| 4 | F1 | 13, 14 | Added pictures to illustrate which activity each slice represents. |
| 5 | F1 | | Removed nighttime from the dataset. |
| 6 | F2 | | Removed. |
| 7 | F3 | 10 | Changed sitting from red to white. |
| 8 | F3 | | Removed nighttime from the dataset. |
| 10 | T1 | 6 | Added goal circles for each timeline. |
| 11 | T2 | | Removed. |
| 12 | T3 | | Removed. |
| 13 | T4 | 10 | Changed sitting colour to white. |
| 14 | T4 | | Reduced inner radius of hour-ticks |
| 15 | All | 9 | Added option to switch between different colours including grayscale. |

**Table 9.1:** Changes made to the system after the first focus group.

each hour is represented by stacked bars. This means that an hour with no activity, other than seating, will show no bar.

Goal circles are small diagrams appended to T1 and T5, see Figure 9.3a and 9.3c. This was one of the new features in prototype 2 to satisfy requirement R1-6, which states that the users should be able to compare the patients activity to goals. The circles are used to indicate how much activity the patient accumulated compared to the goals set. A full circle means the patient reached his goal that day. Exceeding the goal will produce additional circles. For example, if the goal was walking for 1 hour each day, a full circle would indicate that the patient walked exactly 1 hour, a half circle would indicate the patient walked 0.5 hours, and two circles would mean 2 hours of walking.

Table 9.2 shows an overview of the visualizations included in the second version of the system. A functionality added to all the visualizations was the ability to switch between colours, including grayscale. The grayscale versions were used to create printouts for focus group 2, in accordance to requirement R1-9. U2 was discarded by the first focus group. U1, see Figure 9.1, is the only overview chart available in the second prototype. The smilies were replaced with coloured squares because the sad face would be demotivating for the patients. U1 was also changed to classify the days compared to goals, as stated in requirement R1-1. The goals can be set manually, the default values are the national goals. Reaching both goals will classify the day to the green square, one goal to the yellow square, and no goals to the red square.

| ID | Description |
|---|---|
| U1 | Classifies each day of the week into either of three categories: Both goals reached, one goal reached and no goals reached. |
| F1 | Pie chart showing the amount of activity for each day (Excluding what is assumed to be sleep during nighttime). |
| F3 | Ball chart. Divides the pie slices of F1 into bubbles, each bubble representing one interval of activity (e.g. 2 hours of non-stop sedentary behaviour). |
| T1 | Timeline of 24 squares, each square represents 1 hour of activity. The amount of activity in that hour is displayed using a gradient. |
| T4 | One 24-hour clock showing the activity type using colour coding. |
| T5 | Similar to T1, but instead of using a gradient the amount of activity is represented by stacked bars. |

**Table 9.2:** Visualizations included in prototype 2.

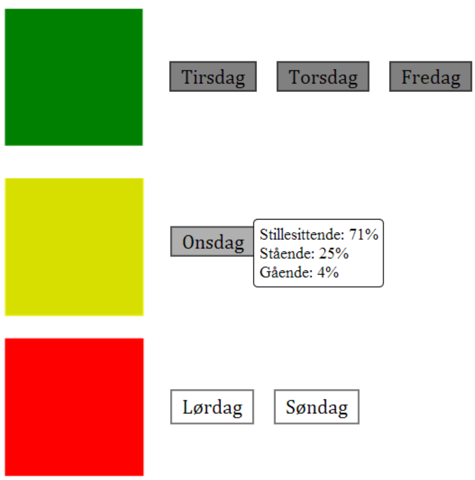
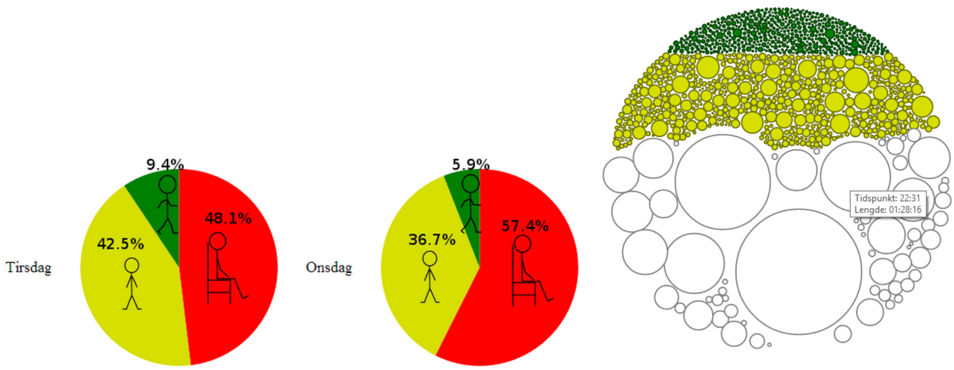



**Figure 9.1:** U1, the only overview chart in prototype 2.

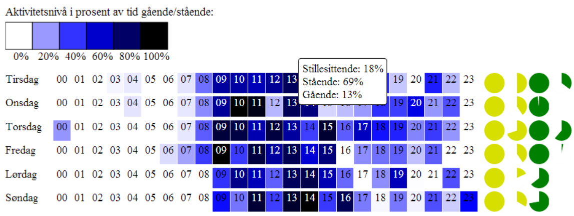
F2 was discarded and removed. The pictures from F2, illustrating the activity type, were added to the new version of F1, see Figure 9.2a. Changes made to F1 were not implemented, instead they were illustrated by an image file so that the planned changes could be shown to second focus group. The feedback on F3 was less concise, in the first focus group the participants expressed some concern that all the red in the visualization would be demotivating for the patients. We therefore changed the colour of sedentary activity from red to white, as seen in Figure 9.2b. One of the comments from the first focus group regarding aggregated charts was that nighttime distorted the visualizations, nighttime was therefore removed from the data set for these charts in prototype 2.



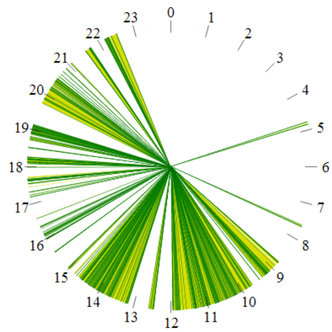

**(a)** F1 **(b)** F3

**Figure 9.2:** Aggregated charts included in prototype 2.

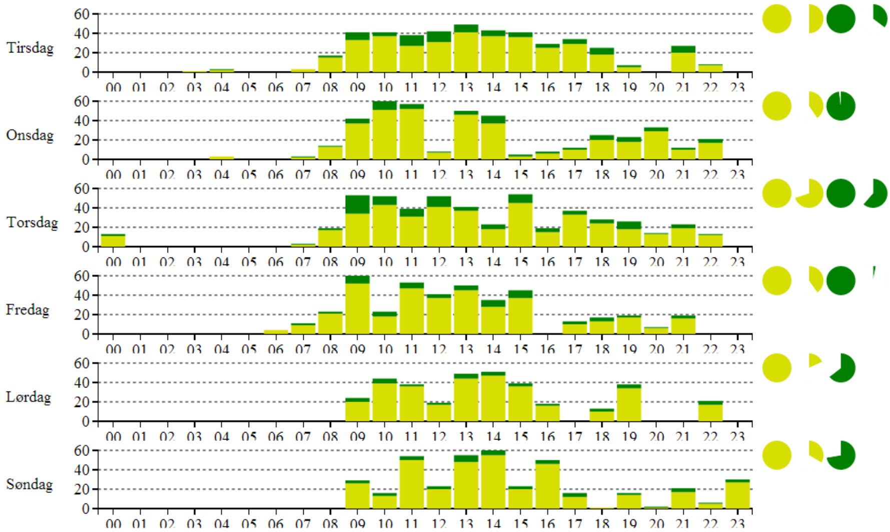
T2 and T3 was discarded and removed. T1 was not changed other than the goal circle being appended to the right of each timeline, see Figure 9.3a. T4, see Figure 9.3b, received a colour change from red to white for sedentary activity, to further highlight actual activity. The inner radius of the hour-ticks, lines that marks each hour, was reduced to make the visualization look more like a normal clock. T5, see Figure 9.3c, was the only new visualization added. T5 uses stacked bars to show the activity level of each hour, and uses the goal circle to illustrate the patients activity compared to the goals set.




**(a)** T1




**(b)** T4




**(c)** T5

**Figure 9.3:** Timeline charts included in prototype 2.

# Chapter 10
# Focus Group 2

The second focus group had several goals: Verify the scenarios and requirements created after the first focus group, review and get feedback on prototype 2 and interview the participants about a normal work day. Much like the previous focus group chapter this one starts with introducing the participants and the process, before presenting the results.

## 10.1 Participants

Participants from the previous focus group session were invited, but due to conflicts in the schedule only four out of the five could make it. For this session there were three females and one male present. The ages were between 34–36. Table 10.1 provides more detailed information about each participant.

The information gathered by the questionnaire showed that all the participants used laptops and smartphones on a daily basis. One of the participants also used tablets daily. All the participants were very positive to using new technology in their practice. They also agreed that new technology would improve the quality and effectiveness of their work.

| ID | Gender | Age | Position |
|---|---|---|---|
| P1 | Female | 35 | Physiotherapist |
| P2 | Female | 35 | Physiotherapist |
| P3 | Female | 34 | Physiotherapist |
| P4 | Male | 36 | Physiotherapist |
| P5 | Female | 45 | Head of group |

**Table 10.1:** Basic information about the participants in the focus group.

One of the participants is referred to as *head of group*, a translation of the Norwegian term “fagleder”. 20% of her work is with patients, the rest of her job involves increasing the knowledge and expertise of physiotherapists working with the elderly. She makes sure national plans and guidelines are incorporated into their daily work, and acts as an advisor in cases where additional assistance is required. She is also responsible for looking at new research and technology that could be used in physiotherapy.

## 10.2 Location and Process

The focus group was conducted at St. Olav’s Hospital, but we were unable to obtain the exact same room. Much like the first session the participants were seated around a table facing a projector canvas. The visualizations were controlled by the assistant moderator while the primary moderator was responsible for conducting the session. Like the previous session it was video recorded and lasted for two hours.

The agenda for the session:

1. Introduction and questionnaire
2. Discuss scenarios
3. Review of visualizations
4. Review the requirements
5. Discussion
6. Interview about physiotherapy in practice

The introduction phase was brief, since we were already acquainted with the participants. After the agenda was presented the participants were asked to fill out a questionnaire about their familiarity with technological aids such as smartphones and tablets, as well as how they felt about using information visualizations in their work.

After the questionnaire, scenarios created after the first focus group were presented to the participants so that feedback could be received. They were asked to provide additional scenarios if they felt that the existing ones did not cover all the relevant uses of the technology presented.

The visualizations were presented one by one as in the first focus group. The participants then gave feedback on the modifications made as well as the new features. When all the visualizations had been presented and discussed, the participants were given different colour choices for visualization T1. Laptops were used for this purpose as it was hard to differentiate between the colour gradients on the projector. A printed black and white version of visualizations T1 and T5 were provided to the participants, while the rest were shown on the computer in grayscale.

Requirements created based on the feedback received from the first focus group were then presented to the participants. After a brief introduction to software requirements, the participants were asked to go through them and comment if they felt something was missing or unclear.

After the requirements had been reviewed the findings of the session were discussed so that there were no ambiguities. The last part of the session was used for an unstructured interview with the physiotherapists about how physiotherapy is practised in Norway.

## 10.3 Results

This section contains the results of the second focus group. New revisions of the scenarios and the requirements are presented, and the participant's feedback and comments on the visualizations in the second prototype are covered in some detail. The last two sections contain a discussion about colour choices and printouts of the visualizations, and a description of how physiotherapy is practices in Norway.

### 10.3.1 Scenarios

The scenarios created after focus group 1 were reviewed in the second focus group. After discussing the scenarios with the participants we created a new version, as seen in the Table 10.2:

| Id | Scenario |
|---|---|
| S2-1 | When analysing patients activity level, either individually or in cooperation with occupational therapists or other physiotherapists. |
| S2-2 | In consultation with the patient. |
| S2-3 | In communication with nursing homes and home care personnel. |
| S2-4 | In consultation with next of kin. |
| S2-5 | For educational purposes. |

**Table 10.2:** Table showing the scenarios after the second focus group.

S1-1 was changed to include occupational therapists. Occupational therapists are the colleagues that are most often consulted according to the physiotherapists.

S1-2 was not changed. It is important to note that the physiotherapists estimated that maybe half of the patients would be cognitively capable of understanding the visualizations.

S1-3 was changed to include nursing homes as the most important partner to communicate with. Patients in nursing homes are in general much less active than those that live at home and there is therefore a greater need to inform the personnel about how inactive some of their patients are.

S1-4 was not changed.

S2-5 was a new scenario added on the request of the focus group. An increasing part of their work consists of tutoring home care personnel about exercises that patients can perform to increase their activity. The participants felt using visualizations in this setting would be useful.

### 10.3.2 Requirements

The new revision of functional requirements can be seen in Table 10.3. One requirement which all of the participants wished to clarify was R1-1. They were specific about the fact that it should not be national goals, but national recommendations, this was rectified in the new requirements. Two of the participants mentioned that an overview of the week was good, but receiving a summary of the daily activity was equally important. This was provided by the pie chart but was never explicitly stated as a requirement, R2-15 was added to reflect this.

Being able to include or exclude certain hours of the night was also discussed due it being brought up during several visualizations, R2-16 has been added as a response to this. There was disagreement on what counted as "night", and if a certain time interval should be set by the user or a pre-set value should be used.

One of the things the participants felt was useful with visualizations F3 was the ability to detect how short the intervals of walking activity were, no other visualizations gave them this ability. R2-3 was changed to include the interval of any type of activity, not just inactivity.

When the participants were presented with the user experience requirements they were initially a bit confused of what exactly these requirements entailed. Some time was used to explain the meaning of UX requirements to the participants. The revised UX requirements can be found in Table 10.4. R1-13 was clarified to include not just the user, but other non medical partners as well, this is now reflected in R2-13. According to the participants some patients are simply not well enough cognitively to understand the visualizations no matter how simple they are, R1-14 was therefore changed accordingly.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| R2-1 | give the user an overview of the week where the days are classified by national recommendations or personal goals |
| R2-2 | show the activity level for each hour of the day |
| R2-3 | make it easy to identify the length of activity intervals |
| R2-4 | make it possible to compare multiple days |
| R2-5 | make it easy to identify hours of the day where activity can be added |
| R2-6 | show the activity level compared to national or personal goals |
| R2-7 | let the user identify patients that are active during the night |
| R2-8 | let the user compare two separate weeks to see the patient's progress |
| R2-9 | should be printable in grayscale |
| R2-15 | show the activity distribution for a day (sedentary, standing, walking) |
| R2-16 | allow the users to toggle if nighttime should be included or not |

**Table 10.3:** Functional requirements from the second focus group.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| R2-10 | not be judgemental towards the patient's activity level |
| R2-11 | should be honest about the patient's activity level |
| R2-12 | should motivate the patient to be more active |
| R2-13 | should be intuitive and easy to understand for the user and third parties |
| R2-14 | be easy to explain to cognitively capable patients |

**Table 10.4:** User experience requirements from the second focus group.

### 10.3.3 Visualizations

The second prototype contained six visualizations, where five of them were modified versions of visualizations present in the first prototype and one was new. Other features that were added were the ability to set goals and a small chart in the form of circles for displaying how far the patient was from reaching his or her goal.

#### Overview chart

U1 was the only overview chart left after changes were made for the second prototype. Participants of the focus group were pleased with the fact that the smilies had been replaced with coloured squares. The new way of classifying days based on how close they were to their set goals was well received by all the participants. One of the participants stated that it was important to be able to set custom goals, because how active patients are differs greatly. Another participant suggested adding the current goal to the visualization to make it easier to determine what each classification means. Most of the participants liked the simplicity of U1 and said that this was a type of diagram that many of their patients would understand, however one of the participants felt that the lack of detail in the diagram made it useless in practical situations.

Most of the participants like the new overview chart. The currently set goal should be displayed so it is clear how the days are being classified.

#### Aggregated charts

F2, the box diagram, was discarded in the second prototype, but the illustrations used to show each type of activity was added to F1. Nighttime was also removed, as requested in the first focus group. The participants were satisfied with the changes and liked the fact that the illustrations were now added to the pie chart, F1. All the participants agreed that the F1 was a good way to see the overall activity of the day, and that excluding nighttime increased the practical use of this chart.

F3 was not changed other than the colour for sedentary activity being white instead of red. The participants did not like the colour change particularly, and felt that the red would be better than white. All the participants agreed that this was a good way to visualize interval length. Some of the participants suggested that one should have the ability toggle nighttime on and off. They stated that nighttime is relevant for some patients that are active during the night, but for most patients displaying nighttime would just be in the way.

Both F1 and F3 were well received by the physiotherapists. F3 should have functionality for toggling nighttime on and off.

#### Timeline and Clock

T2 and T3 were discarded after focus group 1, because the participants felt the amount of detail was unnecessary, as well as the active periods being hard to identify. T1 was the favourite visualization from focus group 1 and was not changed much for the second prototype. Goal circle diagrams were added to each day to display how the patient's activity level compared to the goal set. The participants did not like the addition of the goal circles. One suggested being able to toggle the goal circles on and off, or be able to look at the goal circles as a separate visualization. As in U1 the participants felt that the current value of the goal should be displayed, so that it is clear what a circle represents.

T4 was not particularly well received in the first focus group, but it was added to the second prototype with a colour change of the sedentary activity from red to white. Even with the colour change the participants all agreed that this type of chart was too detailed and was not useful in practice. The visualization should be discarded.

T5 was the only new visualization added for prototype 2, if not counting the goal circles. Though this visualization was made on the request of the participants, they were not overly enthusiastic about it. Most of the participants preferred T1 to T5. However when asked if they would like the option of having both visualizations available, they all agreed that T5 could be useful in some cases and should be kept. Also here the participants felt that the goal circles made the chart overly complex, and that this should be a toggle option.

T4 should be removed as it has no practical use. T1 and T5 should be kept, but the user should be able to toggle the goal circles on and off. The current goal should be shown when the goal circles are displayed. Goal circles should be its own visualization.

### 10.3.4 Colours and Printouts

Different colour choices were discussed with the participants. Because the projector did not handle gradients well, a laptop was used to show different colour choices. For the gradient colour the participants preferred white to blue to black, and white to black. For representing the different activity types (sitting, standing, walking) the participants liked red, yellow and green. One participant expressed some concern with the fact that red, yellow and green was used for sitting, standing and walking for F1, F3 and T5, but in U1 it was used for classifications. Using the same colours with different meanings can be confusing. An alternative to the coloured boxes in U1 should be found.

Because physiotherapists working for Trondheim Kommune do not have access to a colour printer, grayscale printouts were showed to the participants. The participants found it hard to use T1 effectively when printed, because the printer did not handle grayscale gradients well. In this situation the participants preferred T5 over T1 since bars were used instead of colour for displaying the activity level. U1 and F1 was found to work well on printouts, however F3 was less useful when printed because the functionality to hold over a ball for more information about the interval is lost.

### 10.3.5 Physiotherapy in Practice

To get an overview of how physiotherapy is conducted in Norway we performed an interview with the participants of the focus group. The physiotherapists that were recruited for the focus groups work with elderly and patients that otherwise needs to be helped from home (e.g. patients suffering from Cerebral Palsy). The seven step process below describes what happens when a patient is referred to a physiotherapist:

1. A general practitioner or other healthcare personnel can fill out an application for their patients to see a physiotherapist.
2. The application is then evaluated and placed into a priority queue. Applications may be prioritized if the matter is time sensitive, such as recovery after a fracture or surgery.
3. When a physiotherapist is available they are given the application on top of the priority queue.
4. The physiotherapist then makes a house visit to the patient so that they may get an understanding of the current activity level. The activity level is mapped through several different types of exercises and through conversations with the patient. The checklist that physiotherapists use is provided in Appendix D. Overall posture and the speed of movements help assess the general state of the patient.
5. The next step is to create an exercise plan for the patient in order to increase the activity level. During conversations with the patient the physiotherapist discusses what kind of improvements are realistic to achieve considering the current activity level, motivation, physical health, etc. All of this data is then used to create an exercise plan that the patient can follow to reach his goals.
6. When an appropriate plan has been created the physiotherapist returns to the patient to explain how the exercises are executed as well as motivating the patient to reach his goals. The plan may also include other types of activity, for many patients something as simple as walking to the store to buy groceries can be enough to make a difference in the overall activity.
7. Physiotherapist will return regularly to check up on the patient. The interval between check-ups will vary in respect to how well the physiotherapists expects the patient to follow the agreed upon plan. Some patients lack motivation, and will need more regular check-ups. During such meetings the physiotherapist will get an idea of how much the patient has improved. Emphasizing on the improvement made is an important factor in motivating the patient to stick to the plan. If there has been little or no change in the activity level, the physiotherapist may want to make changes to the plan so better results can be achieved.

# Chapter 11
# Discussion

This chapter is dedicated to summarizing and discussing our thesis. Each section covers a specific research questions and shows how our findings helped shape the answers to the questions posed. The research questions are discussed in the order they were posed in Section 1.3. The chapter finishes with looking at how our research questions can be applied to other media.

## 11.1 Scenarios and User Group

Our first research question states:

> *What are the relevant scenarios for visual presentation of accelerometer data in physical therapy, from the physiotherapist's perspective?*

Initially we designed the first prototype for two scenarios as seen in Table 11.1.

| Id | Scenario |
|---|---|
| IS-1 | Mapping the activity level of patients |
| IS-2 | In consultation with patients |

**Table 11.1:** Table showing the initial scenarios.

These are the most obvious scenarios for the system. After the first and second focus group three more scenarios emerged, as well as the initial ones being heavily modified. The new and reviewed scenarios can be found in Table 11.2.

The first scenario was changed to include the cooperation with other physiotherapists or occupational therapists. During the second focus group the participants informed us that if they were to discuss a patient with colleagues it would usually be with

| Id | Scenario |
|---|---|
| S2-1 | When analysing patients activity level, either individually or in cooperation with occupational therapists or other physiotherapists. |
| S2-2 | In consultation with the patient. |
| S2-3 | In communication with nursing homes and home care personnel. |
| S2-4 | In consultation with next of kin. |
| S2-5 | For educational purposes. |

**Table 11.2:** Table showing the scenarios after the second focus group.

an occupational therapist or in rare cases another physiotherapist. Normally the physiotherapists would not consult their colleagues about specific patients.

Currently a set of exercises and the physiotherapists subjective opinion of the patient are the only ways physiotherapists can map the patient's activity level. With sensor technology such as the activPAL and detailed visualizations to display the sensor data, physiotherapists can get a much more accurate impression of patients activity patterns. This would be a great help when creating a treatment plan for the patient, as they can pinpoint when the patient is least active, the length of intervals of sedentary behaviour, and if the patient is active during the night. This valuable information is hard or impossible to acquire with the current methods for mapping patient activity.

The second scenario is one of the most important uses the system can have. Showing the visualizations to the patient can be useful in many cases, for example when explaining to the patient their current activity level, and why exercise or more movement is needed. Visualizations are also useful for motivating the patients, by showing them detailed figures on their progress they can see that the exercises they have to do are helping. Many of the patients treated by the physiotherapists who working for Trondheim Kommune are elderly and not as cognitively capable as they once were, especially those living in nursing homes. The participants estimated that about half of their patients would be capable of understanding the visualizations presented. Some of the visualizations are very simple and could probably be used on a larger patient group, but less detailed visualizations will often be less helpful in motivating the patient.

For patients that can not understand the visualizations themselves, scenario 3 and 4 become increasingly important. Patients living in nursing homes receive help throughout the day, and often do not perform trivial tasks like making breakfast or going shopping. During the focus groups the participants were concerned that when patients stopped doing such tasks the little activity they previously had was lost, leading to an inactive and unhealthy lifestyle. To combat this, the participants were eager to be able to monitor the activity of such patients, and in cooperation with personnel working there increase the activity of the patients.

In many cases the patients next of kin can be consulted after or during evaluation of the patients activity level. Next of kin can be an important motivator for the patient, and help the physiotherapists persuade patients to follow the agreed upon treatment plan. Next of kin are normally interested in the well being of the patient. The system can be used to help them get a picture of the overall activity level of the patient as well as how they are progressing if they have started treatment. In cases where the patients are not capable of understanding the visualizations themselves, it can be helpful to show them to the next of kin to give them an idea of what needs to be done for the patient to achieve an acceptable level of activity. Next of kin are able to spend more time with the patient than the physiotherapists and can thus help the patient achieve their goals by motivating them to take a walk or perform household tasks.

The focus group participants believed that the visualizations could be helpful for educational purposes. A project currently ongoing in Trondheim is teaching home care personnel how to perform physiotherapy exercises with their patients. This will give elderly patients living at home better access to help when they have been asked to perform exercises by the physiotherapists. The participants of the focus groups suggested that visualizations could be used in training of both physiotherapy students and home care personnel to show them how performing different exercises can help improve the overall activity of the patient.

## 11.2 Requirements

The second research question states:

> *What are the functional and user experience requirements for visualizations of accelerometer data in the scenarios identified by the physiotherapists?*

Requirements gathering is an important part of any software development project. Because the initial requirements were created in cooperation with a domain expert and not the participants of the focus groups we saw a lot of changes to the requirements after the first focus group. The requirements aim to give instructions as to what types of visualizations should be created, and with all the feedback and changes to the visualizations after the first focus group, it is not surprising that the requirements also changed substantially.

| Id | Requirement |
|---|---|
| The visualizations should . . . | |
| IR-1 | give an overview of the week |
| IR-2 | give a summary of the daily activity |
| IR-3 | show the activity level for each hour of every day |
| IR-4 | let the user compare hours from multiple days |
| IR-5 | show the activity level for each minute of every day |
| IR-6 | let the user compare minutes from multiple days |
| IR-7 | let the user identify patients that are active during the night |

**Table 11.3:** Initial requirements.

Looking at the initial requirements in Table 11.3, requirements IR-5 and IR-6 were removed after talking to the physiotherapists in focus group 1. Visualizations showing the continuous activity pattern of users was seen as too detailed to be useful. The participants also felt that it was too hard to see the activity, because it was hidden by the inactive and standing periods. The other initial requirements were modified and rephrased, but still remain in the R1-version of the requirements, see Table 11.4.

Requirement R1-5 is a direct results of comments from the participants during the first focus group. They stated that one of the most useful features of the system is the ability to see when during the day the patient is inactive. This can be used to plan activity and exercises to specific hours of the day when the physiotherapist knows the patient will most likely be inactive. Having this type of detailed information can help the physiotherapists create an even more specific treatment plan for the patient, and possibly increasing the quality and effectiveness of the treatment. A functionality that was requested during the first focus group was the ability to set goals. The physiotherapists had a hard time identifying whether the patients data represented an active or an inactive person without comparing the data to some fixed goal. To satisfy this request, R1-6 was a new requirement added after focus group 1. IR-1 was also changed to R1-1 to make the classification in the overview charts take into consideration patient goals.

Another interesting addition was R1-9, which states that the visualizations should have printable greyscale versions. It was surprising to hear about how few technological aids were available to the physiotherapists working for Trondheim Kommune (municipality of Trondheim). For scenarios where the physiotherapists only have access to grayscale printouts, important system functionality such as interactivity, will be lost.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| R1-1 | give the user an overview of the week where the days are classified by national or personal goals |
| R1-2 | show the activity level for each hour of the day |
| R1-3 | make it simple to identify periods of inactivity |
| R1-4 | make it possible to compare multiple days |
| R1-5 | make it easy to identify hours of the day where activity can be added |
| R1-6 | show the activity level compared to national or personal goals |
| R1-7 | let the user identify patients that are active during the night |
| R1-8 | let the user compare two separate weeks to see the patient's progress |
| R1-9 | be printable in grayscale |

**Table 11.4:** Functional requirements from the first focus group.

Two requirements were added after the second focus group, R2-15 and R2-16, see Table 11.5. R2-15 is a clarification of the first requirement. The participants felt that there was no requirement specifying the need for aggregated charts, and R2-15 was therefore added. Another functionality that was requested was the ability to toggle nighttime on and off. In the first focus group many of the participants felt that including nighttime, especially in the aggregated charts, made the inactive part of the chart too large. Nighttime was therefore removed for some of these graphs in the second prototype. However, the participants were now uncertain as to what period of the night had been removed. It was therefore suggested that that the user should be able to toggle nighttime on and off, so that in cases where it would be helpful to see the entire dataset this option would still be available. The participants also wanted the ability to define the time interval that should be considered nighttime. For patients living in institutions nighttime is similar for all the patients, but for patients living at home nighttime might differ from patient to patient.

Talking with the physiotherapists also gave us the ability to explore User Experience (UX) requirements for the system, see Table 11.6. The UX requirements we created are important to keep in mind when creating visualizations, these requirements may not be intuitive without understanding how the physiotherapists work. One of the first responses we got when going through the visualizations in the first focus group, was that some visualizations had a negative attitude. For example using smilies to represent the classifications could demotivate and be judgemental towards the patient.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| R2-1 | give the user an overview of the week where the days are classified by national recommendations or personal goals |
| R2-2 | show the activity level for each hour of the day |
| R2-3 | make it easy to identify the length of activity intervals |
| R2-4 | make it possible to compare multiple days |
| R2-5 | make it easy to identify hours of the day where activity can be added |
| R2-6 | show the activity level compared to national or personal goals |
| R2-7 | let the user identify patients that are active during the night |
| R2-8 | let the user compare two separate weeks to see the patient's progress |
| R2-9 | should be printable in grayscale |
| R2-15 | show the activity distribution for a day (sedentary, standing, walking) |
| R2-16 | allow the users to toggle if nighttime should be included or not |

**Table 11.5:** Functional requirements from the second focus group.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| F2-10 | not be judgemental towards the patient's activity level |
| F2-11 | should be honest about the patient's activity level |
| F2-12 | should motivate the patient to be more active |
| F2-13 | should be intuitive and easy to understand for the user and third parties |
| F2-14 | be easy to explain to cognitively capable patients |

**Table 11.6:** User experience requirements from the second focus group.

These are issues we did not consider when first creating prototype 1. The physiotherapists also stressed that though the visualizations should not be judgemental it was just as important that they did not lie. They should give the patient an honest representation of their activity level, but without making the patient feel hopeless. Many patients are prone to give up before they have even started, and it is paramount that the visualizations do not contribute in discouraging the patient.

Motivating patients is another important UX requirements. One of the physiotherapists pointed out that patients like to see quantitative data to show that they are improving. Progress can be slow and hard to notice from day to day. This can in many cases discourage patients from doing their exercises. Seeing quantitative proof that one is constantly improving, can be a powerful motivational tool, as it gives the patient a reward for following the exercise plan. One of the physiotherapists also stated that patients tend to trust more in statistics and diagrams than they do in the qualitative judgement of the physiotherapist alone. Using visualizations in their work can therefore help them persuade patients who are otherwise distrustful or feel that the treatment plan is ineffective or pointless. For the patients to be motivated by the visualizations, they need to be able to understand them, and this is covered by the R2-12 requirement.

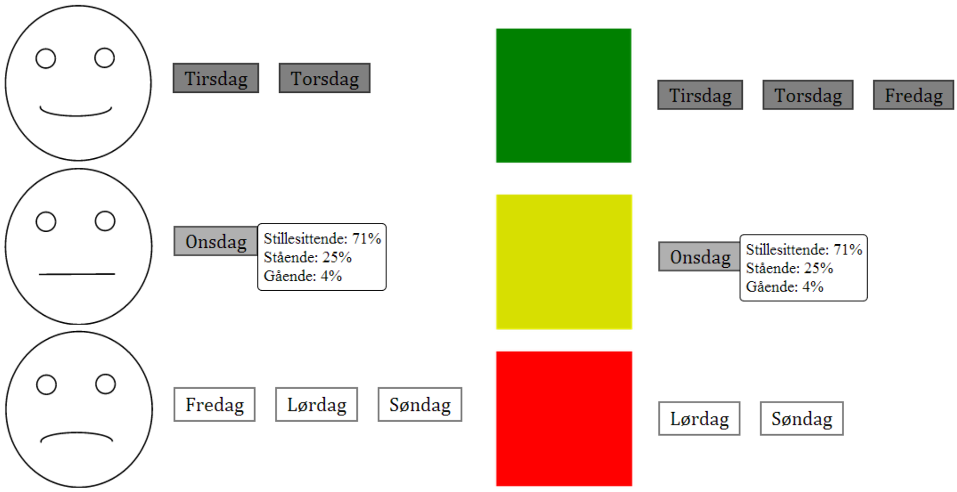
## 11.3 Visualizations

The final research question is concerned with visualizations and states:

> *What are the preferred visualizations by the physiotherapists for the scenarios and requirements?*

During the creation of the first paper sketches we created three groups of visualizations: overview charts, aggregated charts and timeline charts. The overview charts were designed to let the user quickly get an overview of the week as a whole. For the first prototype two such overviews were created, U1 and U2. U2 was quickly discarded because it contained too many details which only confused the participants of the first focus group. U1 was kept in the second prototype and received positive feedback by the participants in the second focus group. U1 uses personal or national goals to classify each day into one of three categories, making U1 very easy to understand. One of the physiotherapists stated that because it was so easy to understand this might be one of the visualizations that would be shown to the patients. The visualization also works well for printouts, both colour and grayscale. To further improve U1 an indication as to what the current goal is set to should be added, such information would help the physiotherapist and patient understand what the different classifications correspond to.

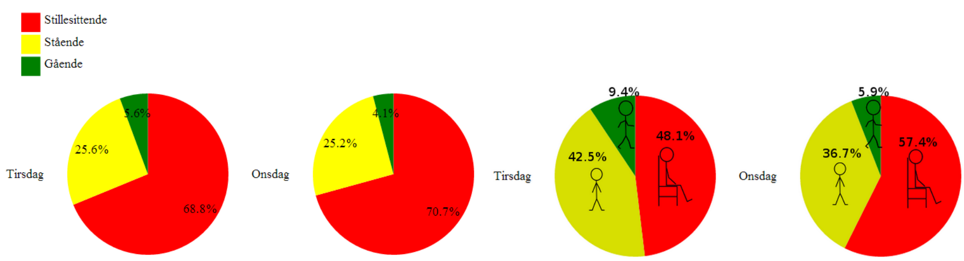
The aggregated charts sum up the day to show the distribution of different types of activity. Initially there were three types of aggregated charts: F1, F2 and F3. F1 and F2 were combined for the second prototype to become a standard pie chart with three slices, one for each activity type. The pie chart also contains illustrations that show what type of activity each slice corresponds to. Pie charts are easy to understand because most people will have seen them before, know what they mean and know how to read them. F1 can therefore also be shown to the patient when explaining their current level of activity.




**(a)** U1 in prototype 1. **(b)** U1 in prototype 2.

**Figure 11.1:** First and second version of U1

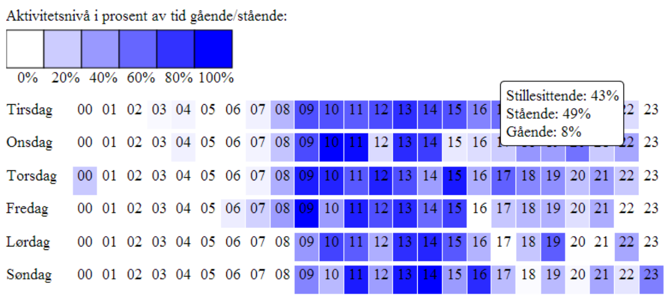
F3 is a bubble chart, most people will not have seen this type of chart before and it is not as intuitive as F1. The physiotherapists like the chart because it can be used to see intervals of activity, for example the longest walk a patient took during a day. This type of graph would most likely not be shown to the patients as most of them would not understand it. F3 could be used in communication with nursing homes and home care personnel, for example if the patient needs to be walking for longer periods of time not just in small intervals.



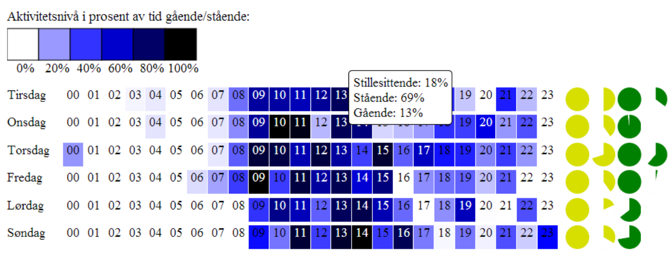

**(a)** F1 in prototype 1. **(b)** F1 in prototype 2.

**Figure 11.2:** First and second version of F1

Timeline charts show the activity during the day continuously or in aggregated blocks. Four timeline charts were initially created: T1, T2, T3 and T4. T2, T3 and T4 showed activity during the day minute for minute without aggregating it into hours. These visualizations were discarded because the physiotherapists felt that the amount of detail was unnecessary and only made the visualizations harder to read and less useful. T1 uses 24 blocks where the activity of each hour were aggregated and displayed using a gradient. T1 was the preferred graph, as it was easy to get an overview of the day as a whole, as well as the entire week by stacking multiple days on top of each other. This meant that the physiotherapists could easily get an overview of the overall activity pattern of the patient. This made it easy to find inactive hours where the patient could be motivated to do exercises or move around. Noticing patients who are active during the night is also easy due to the way hours with activity gain increase in colour intensity. During the focus group one of the physiotherapists told us that a common problem for elderly patients is that they can not sleep and therefore walk around during the night, leading to less activity during the day. Such patterns can easily be detected using T1, as an example we were able to see from the example data that the patient would walk for a few minutes most nights at 4 am, probably to go to the toilet.




**(a)** T1 week view in prototype 1.




**(b)** T1 week view in prototype 2.

**Figure 11.3:** First and second version of T1

T1 is not very hard to understand, but requires higher cognitive capabilities than U1 and F1, therefore it could most likely only be displayed to the more cognitively capable patients. Another issue with T1 is that the gradient colours it uses do not translate well when printed. T5 was created for the second prototype and like T1 divides the day into 24 blocks, but instead of using gradient to display the distribution of activity stacked bars are used. This visualization is also similar to the chart used in the activPAL software, but in T5 seated or lying activity is not displayed, which increases the readability of the graph. Despite this T1 was still the favourite because it is easier to stack days on top of each other when using gradient colouring instead of stack bars to represent activity within an hour. One benefit of T5 compared to T1 is that is works much better when printed, as it does not rely on a colour scale.

For the second prototype personal and national goals were added. This addition was heavily requested by the physiotherapists after the first focus group. To show how the patient's activity compared to the goals that had been set, a visualization called goal circles was created. As the name suggests the visualization uses circles to display how far the patient is from reaching the goal or how far they have exceeded it. The goal circles were appended to each day of T1 and T5. The participants of the second focus group did not like this, and felt that the goal circles should have been its own visualization, used only to see if the patient were reaching the goals set. The goal circles are also intuitive and easy to understand, and they could be shown to some patients. An issue with the goal circles is that they do not display the currently set goals, all graphs using the goals should display what the current goals are set to. Goals are an important motivational factor when patients are attempting to become more active.

Table 11.7 shows which requirements are satisfied by each visualization. Each row represents a visualization and each column corresponds to a functional requirement. A − means that the requirement is not satisfied by the visualization and a + means that it is satisfied. As we can see there are two requirements, R2-8 and R2-16, that are not covered by any of the visualizations. R2-8 says that the user should be able to compare two different weeks to see if there has been progress. Comparing weeks is important for the system to function as a motivational tool. This requirement was suggested after focus group 1, but was not implemented due to lack of time. R2-16 states that the visualizations should let the user toggle nighttime on and off. This requirement was suggested in focus group 2 and was therefore not implemented for prototype 2.

| | R2-1 | R2-2 | R2-3 | R2-4 | R2-5 | R2-6 | R2-7 | R2-8 | R2-9 | R2-15 | R2-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| U1 | + | − | − | + | − | − | − | − | + | − | − |
| F1 | − | − | − | + | − | − | − | − | + | + | − |
| F3 | − | − | + | − | + | − | − | − | − | + | − |
| T1 | − | + | − | + | + | + | + | − | − | − | − |
| T5 | − | + | − | + | + | + | + | − | + | − | − |

**Table 11.7:** The table shows which requirements each visualization satisfies.

Table 11.8, see below, shows which visualizations satisfy each scenario. The first scenario is physiotherapists using the visualizations to analyse the patients activity level. In such cases all the visualizations can be utilized to get the best overview of the patients activity situation. For the most part T1 and T5 would be used as these give the best overview of the week and it is easy to identify where more activity can be added.

| | S2-1 | S2-2 | S2-3 | S2-4 | S2-5 |
|---|---|---|---|---|---|
| U1 | + | + | − | + | + |
| F1 | + | + | + | + | + |
| F3 | + | − | + | − | + |
| T1 | + | − | + | − | + |
| T5 | + | + | + | + | + |

**Table 11.8:** Table showing which scenarios each visualization satisfies.

The second scenario is using the visualizations in consultation with the patient. For many of the patients it will not be possible to show any of the visualizations, but for those that are cognitively capable most of the visualizations can be used. F3 was excluded because it can be hard to explain, and it does not contain information that is critical to convey to the patient. T1 will not work on paper printouts, but could be used if the physiotherapists have access to laptops or tablets.

The third scenario is concerned with communication with nursing homes and home care personnel. All visualizations can be used for this purpose, but U1 will probably not be effective in conveying information of interest and was therefore excluded. F3 and T1 can be helpful tools when discussing the activity level of patients with other health care personnel.

Consulting the next of kin is the fourth scenario. Most visualizations can be used for this purpose. F3 was excluded because it will probably be more confusing than helpful in explaining the patients current activity level. T1 was also excluded as it will does not work well for printouts.

For educational purposes, S2-5, all the visualizations can be used. Each visualization serves different functions and to get a complete overview of the patients activity level it can be useful to look at multiple visualizations. T1 and F1 are probably the best for this purpose. F3 can be used in situations where it is helpful to see the length of different type of activity.

## 11.4 Visual Variables

Five visualizations were accepted by the physiotherapists: U1, F1, F3, T1 and T5. The visualizations make use of different visual variables, see Section 2.2.1. U1, as seen in Figure 9.1, uses position, size, colour and value (a type of visual variable) to illustrate how the patient fared compared to the set goals. The vertical position of each day in combination with the coloured squares, is used to show how each day is classified. Position is associative, which means that the position of the elements makes humans look at each horizontal level as a group of elements. Elements on the same level also have the same colour gradient, which increases this association. Because every rectangle representing a day has the same size, it is easy to compare how many days there are in each horizontal level by looking at how long it is.

The aggregated charts F1 and F3, see Figure 9.2, make use of the visual variables size and colour. F1 uses the quantitative characteristic of size to show the distribution of different types of activity for a day. F3 can also be used to show the distribution of each type of activity, by summing the size of all the balls for each colour, but the main function of F3 is to show the interval length of each activity event using the size of each ball. The different types of activity are distinguished by the selective property of colours. F3 also uses the associative characteristics of colour and position to group balls corresponding to the same activity together. One possible drawback with using the area of balls to represent the length of an interval, is that humans often tend to think that the area of a circle is proportional to the radius, this is not the case. Because this relationship is not proportional, it is much harder to compare the area of two circles than, for example, the length of two lines.

The most popular visualization was T1, see Figure 9.3a. It uses the position of elements to represent the hour of the day that each block corresponds to, and value (colour gradient) to represent the amount of activity for that hour. The advantage of using value is that each day gets very compact, allowing all the days to be stacked on top of each other. This creates a matrix which shows the patients entire week in a lucid way. Using the matrix activity patterns are easy to see. The disadvantage of using value to represent the amount of activity is that it is not quantitative. This means that it is difficult to compare how much more activity there is in one hour compared to another. This is partially solved by the addition of interactivity, since you can hold the cursor over an hour of interest to get the numerical value of activity. T5, see Figure 9.3c, is similar to T1, but uses size to represent the activity for each hour instead of value. This makes it easier to say something about the quantitative values behind each hour, but it also makes it harder to stack the charts on top of each other. For the physiotherapists it seems getting an overview of the week is more important than displaying the exact activity values for each hour.

## 11.5 Mediums for Presentation of Visualizations

During the focus groups many different types of devices for displaying the visualizations were discussed. Currently the physiotherapists only have access to grayscale printers. Though adjustments were made to the prototype in order to resolve this problem some of the visualizations, like T1, does not work well on most printers. The loss of interactivity with the charts can also make the visualizations less useful.

One option is to invest in tablets. Tablets are less expensive than laptops and desktop computers and can easily be brought to the patient. A physiotherapist using a tablet will have access to all the visualizations. The touch screen may also give the user the ability to interact with the visualizations. However, our implementation makes use of hover interactivity. This means that information is displayed when the mouse hovers over a certain object. Since a tablet does not use a mouse, the interactivity would need to be changed, for example to clicking/touching objects. Precision can also be problem with tablets. It is hard to select objects that are smaller than ones finger, for example selecting small bubbles in F3 would be nearly impossible using a tablet. F3 would therefore most likely not be very useful if a tablet solution is used.

Laptops or desktop computers is the solution that was used during the focus group. Laptops can also be brought to the user, and this will give more precision and the ability to use hover selection. Most laptops are usually more powerful than tablets, though performance has not been an issue during the implementation, more complex visualizations might need more processing power than what is currently supported by tablets. Laptops are also faster to write on, and it will be much easier to take notes than on a tablet. The drawback with laptops are that they are more cumbersome to carry, show to patients and often have shorter battery life than tablets.

It is our opinion that a combined solution, using tablet in the field and laptops or desktop computers in the office, would be optimal. This would give the physiotherapists access to high quality visualization in the field, using them to explain a patient's current activity or to motivate the patient by showing them a visual representation of their progress. The data could also be viewed in more detail and using other, more complex visualization, such as F3, in the office. This solution would give access to all the suggested visualizations and give great flexibility to use the system in all the scenarios.

## 11.6 Certification

As mentioned in Section 3.5 the Norwegian government requires all medical equipment to be certified to ensure that it does not present a danger to the patient or users of the equipment. Software is included in this definition of medical equipment. This means that if the system was to be used in practice, it would first have to be CE-certified. Reading the requirements to get the certificate it is our opinion that the system would pass all the requirements with ease, however we have not studied the certification process in detail.

# Chapter 12 Validity and Reflection on Method

Addressing and reflecting upon the validity of our research methods is vital in order to show that we are not unaware that no method or execution is without its flaws. This chapter starts off by reflecting over the research methods and finishes off by addressing their validity in accordance to possible threats presented in Section 2.9

## 12.1 Reflection on Research Method

An analysis and reflection on how the research methods were executed are contained in this section. The purpose of this chapter is to identify any improvements, mistakes and compare our execution to the theory presented in Chapter 2.

Our overall methodology was based on ISO 9241-210 and its guidelines for performing human-centred design. This standard is primarily intended as design process when creating commercial interactive systems, but also mentions that it complements a broad variety of development methods. We used an iterative process that was heavily design and user oriented in order to answer our research questions.

In the end we believe this was the correct choice of method, given that we ended up with results that both the participants and researchers were pleased with. After only two focus groups we were able to converge on five visualizations that we and the focus group participants felt could be helpful in aiding physiotherapists complete their tasks more efficiently and with higher quality. Given more time and two or three more iterations with user involvement, we believe that a field ready prototype could be developed and tested.

### 12.1.1 Interviews

Both of our interviews were unstructured as we had several larger topics we wished to explore. An unstructured interview gave us freedom to pursue relevant topic that might have emerged during the interview, or ask the interviewee to explain their answers further. The downside of not having a clear set of questions is that sub-topics might be overlooked. Once a topic has been discussed and passed, one rarely comes back to it unless some specific questions have been missed. This increases the risk of important information and answers not being pursued enough, or simply overlooked. Unstructured interviews are also hard to compare, generalize and reproduce due to there being no set questions or predefined answers.

The first interview was performed so that we could gain more domain knowledge and assistance in creating a set of initial requirements. The interviewee was a physiotherapist with a MSc in Human Movement Science and works at St. Olav's hospital conducting a research project. She is not in direct contact with patients and the data is primarily used in communication with other healthcare personnel. It might not have been the ideal subject in concern with our intended user group, but we felt that domain expert was satisfactory for a set of initial requirements. She does however have a great deal of experience with representation of data and communicating through visual aids.

The second interview was conducted immediately after the final focus group. The purpose of this interview was so that the authors could learn how the participants conducted physiotherapy. One of the participants was interviewed, but due to it being immediately after the focus group, two participants were still presented and wished to provide input. Once we had finished with the original interviewee the other two elaborated on things they felt we missed or wished to explain in more detail. Because there were other participants present during the interview it might have made the interviewee biased because he did not want to look bad around his peers, or it might have altered his behaviour. Interviewing them one at a time may perhaps have been ideal, but it would in turn have broken the open environment created by the focus group and felt more artificial.

### 12.1.2 Focus Group

Nielsen (see Section 2.7) states that a focus group should have at least six participants. We had originally invited six, but only five were able to attend the sessions. Even with five participants there were no issues with keeping the discussion flowing and the participants were all quite forward when they saw something they disliked. We were unable to represent all the relevant user groups as the participants only represented state employed therapists that visited patients at their residence. We did not include possible patients, or privately employed therapists who have elderly patients.

We deliberately chose to control the navigation through the visualizations ourselves during the focus group, even though Nielsen mentions this as one of two pitfalls that may occur in a focus group. He specifies that by using a demo the user will never have to consider the meaning of screen options or what to do next. In our case the prototype is not an application with intractable buttons, but the prime focus are the visualizations themselves. At least one more focus group should have been conducted as new requirements did surface which should ideally have been prototyped and evaluated due to time constraints this was not possible.

A possible mistake might have been to give a short description of the visualizations to the participants, rather than letting them figure it out on their own, in order to verify if they were intuitive enough. Providing them with a mouse to test the interactivity themselves might have been more beneficial. One of the participants talked more then the others, and might have partly influenced the other participants to some degree. There were situations where other participants disagreed with the dominant one and was even swayed in some cases, so complete influence over other members was not the case.

### 12.1.3 Brainstorming and Prototype

A guideline given both by ISO 9241-210 and Section 2.5 that we failed to follow was to include participants from a wide range of disciplines and potential users in the Brainstorming. This mistake became apparent after the first focus group was conducted where we were forced to completely discard certain visualizations because the presentation style was not useful to the physiotherapists. Had this been identified earlier we would not have had to spend time and resources implementing high fidelity prototypes that would be quickly discarded.

According to Houde and Hill a prototype should be placed in the triangle (see Section 2.6.2) based on what questions and design decisions it seeks to answer. Our running prototypes have been primarily focused on the look and feel, but have sufficed in answering any implementation uncertainties we might have had. This means that design questions relating to the role of our product remain unproven. We know what the role of our final system is and what the physiotherapists expect of it based on feedback received in the focus groups, but the prototype was never tested as part of the potential users routine and workflow. This means that there might still be undiscovered potential as to how it can be used, and possible design issues remain undiscovered.

## 12.2 Validity of Research

This section discusses the validity of our research methods based on the threats presented in Section 2.9.

### 12.2.1 Construct Validity

Focus groups are a common technique to provide feedback on ideas or prototypes, as well as provide new ideas and suggestions for improvement. Given the fact that there are few similar systems to compare with, and the small amount of information about the practice of physiotherapy in Norway, focus groups are in our opinion a good method to use given the time constraints and circumstances.

One common factor that causes threats to construct validity in focus groups and interviews are participants or interviewees misinterpreting questions being asked by the moderator or interviewer. To reduce this threat we tried to make sure that the participants understood the questions, and encouraged them to repeat them or provide a response to confirm that this was the case.

### 12.2.2 Internal Validity

Participants answering questions in a way that make them look better (social desirability bias), leading questions by the moderators and cues unconsciously given to the participants all contribute to hurting the internal validity of the research methods. We have tried to avoid leading question by wording ourselves carefully during the interviews and focus groups, and encouraged participants to be as honest as possible, but can not exclude that unconscious influence by us or other participants has taken place.

### 12.2.3 External Validity

Factors such as bias, group thinking, and an artificial setting make focus group results hard to generalize and suffer from low external validity. The two main factors that hurts our external validity, other than the choice of research method, are the unstructured nature of our interviews and the small amount of participants in our focus groups. The focus groups were the main source of our results, and having more participants would improve their validity.

As hard as it is to generalize unstructured qualitative methods, we believe that our findings hold some merit. Considering the positive feedback we got from the participants of the focus groups, we think that the results presented in this report can be generalized for physiotherapists who perform home or clinical visits. We are however unsure if our results can be applied to physiotherapists that have office hours, as they were not included in any of the focus groups or interviews.

### 12.2.4 Reliability

The issue with focus groups is that they are not very reliable, because it is based on subjective opinions and interpretations made by the researchers and participants. We have done our best to make the research methods as reliable as possible. Our interview process was highly unstructured, we are aware that this hurts the external validity and makes it hard to reproduce, but we hope that the description in Section 6.1 will make up for this.

How the research methods are executed is well described throughout the report, and our prototype has also been handed in as a part of the deliverables as an attempt to increase the overall reliability. The reliability of our prototypes should be quite high, as the code is provided with this thesis, and both versions of the running prototype are included.

# Chapter 13

# Conclusion

This chapter contains a short summary of our results and a conclusion to the research questions and topics discussed in Chapter 11. The final section gives suggestions on further work that can be done.

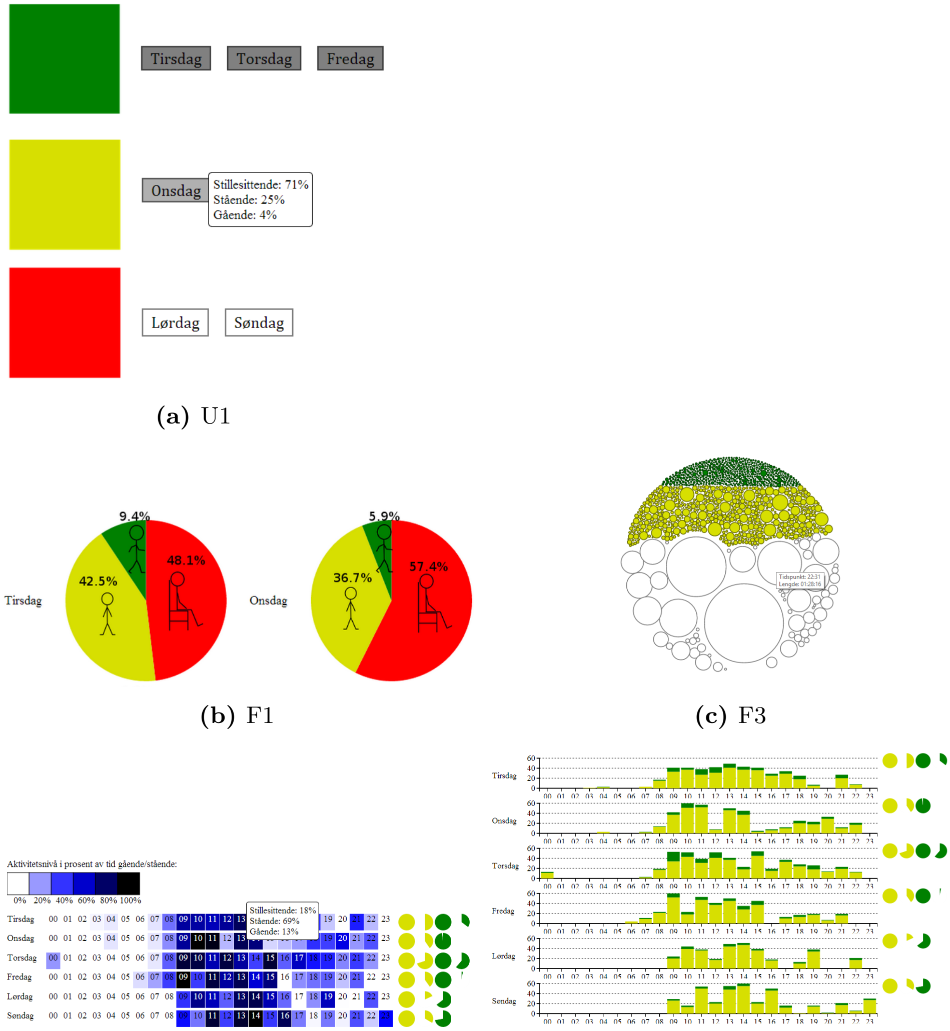
## 13.1 Conclusion

During the project we conducted two focus groups and created two prototype systems, see Chapters 7–10. These form the basis for most of our results. The first research question asked what types of scenarios physiotherapists saw as relevant when using visualizations to display quantitative data from sensors such as the activPAL. To answer this question we created a set of initial scenarios, as seen in Chapter 6, by talking to a domain expert at St. Olav's Hospital. These initial scenarios were then discussed with the participants from the two consecutive focus groups to create five scenarios (see Table 13.1) that all the physiotherapists agreed upon.

| **Id** | **Scenario** |
|---|---|
| S2-1 | When analysing patients activity level, either individually or in cooperation with occupational therapists or other physiotherapists. |
| S2-2 | In consultation with the patient. |
| S2-3 | In communication with nursing homes and home care personnel. |
| S2-4 | In consultation with next of kin. |
| S2-5 | For educational purposes. |

**Table 13.1:** Table showing the scenarios after the second focus group.

The second research question was concerned with the functional and UX requirements for visualizations of data from sensors such as activPAL. The initial requirements were created after an interview with a domain expert at St. Olav's Hospital, see




(a) U1

(b) F1

(c) F3

(d) T1

(e) T5

**Figure 13.1:** The five visualizations accepted by the participants of the second focus group.

Chapter 6. The requirements were then discussed and revised in the two focus groups, details can be found in Chapter 8 and 10. The result after the two revision can be seen in Table 13.2 and Table 13.3.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| R2-1 | give the user an overview of the week where the days are classified by national recommendations or personal goals |
| R2-2 | show the activity level for each hour of the day |
| R2-3 | make it easy to identify the length of activity intervals |
| R2-4 | make it possible to compare multiple days |
| R2-5 | make it easy to identify hours of the day where activity can be added |
| R2-6 | show the activity level compared to national or personal goals |
| R2-7 | let the user identify patients that are active during the night |
| R2-8 | let the user compare two separate weeks to see the patient's progress |
| R2-9 | should be printable in grayscale |
| R2-15 | show the activity distribution for a day (sedentary, standing, walking) |
| R2-16 | allow the users to toggle if nighttime should be included or not |

**Table 13.2:** Functional requirements from the second focus group.

| Id | Requirement |
|---|---|
| The visualizations should ... | |
| F2-10 | not be judgemental towards the patient's activity level |
| F2-11 | should be honest about the patient's activity level |
| F2-12 | should motivate the patient to be more active |
| F2-13 | should be intuitive and easy to understand for the user and third parties |
| F2-14 | be easy to explain to cognitively capable patients |

**Table 13.3:** User experience requirements from the second focus group.

The third research question asked what types of visualizations would be preferred by the physiotherapists for the scenarios and requirements stated above. Two set of prototypes were created to answer this question, the five visualizations accepted by the physiotherapists can be seen in Figure 13.1. The first prototype had a total of nine different visualizations, whereof four were discarded after the first focus group, see Chapter 8. For the second focus group a new prototype was created using the feedback from the first focus group, as can be seen in Chapter 9. The second prototype contained six visualizations, one was discarded after the second focus group. Time did not permit to create a new prototype using feedback from the second focus group, so not all of the requirements were covered by the visualizations. Table 13.4 and Table 13.5 show which visualizations satisfy which requirements and scenarios.

| | R2-1 | R2-2 | R2-3 | R2-4 | R2-5 | R2-6 | R2-7 | R2-8 | R2-9 | R2-15 | R2-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| U1 | + | − | − | + | − | − | − | − | + | − | − |
| F1 | − | − | − | + | − | − | − | − | + | + | − |
| F3 | − | − | + | − | + | − | − | − | − | + | − |
| T1 | − | + | − | + | + | + | + | − | − | − | − |
| T5 | − | + | − | + | + | + | + | − | + | − | − |

**Table 13.4:** Table showing which requirements each visualization satisfies.

| | S2-1 | S2-2 | S2-3 | S2-4 | S2-5 |
|---|---|---|---|---|---|
| U1 | + | + | − | + | + |
| F1 | + | + | + | + | + |
| F3 | + | − | + | − | + |
| T1 | + | − | + | − | + |
| T5 | + | + | + | + | + |

**Table 13.5:** Table showing which scenarios each visualization satisfies.

In the researchers opinion a combination of laptop and tablet would be the most efficient way to use the system. The tablet would be used for scenarios where the physiotherapists needs to show the visualizations to the patients or next of kin, while the laptop would be used for deeper analysis of the patients activity data when creating a treatment plan for the patient, or when showing interesting patient data to colleagues or partners.

## 13.2 Further Work

Visualizations have a great potential to help users understand complex sensor data in a simple and intuitive manner. We have merely scratched the surface in terms of the potential of visualizations in physical therapy. Below are some of the authors suggestions on possible areas that should be investigated further:

- Further improve the prototype to implement the final requirements and developing it into a full application ready for user and patient interaction.
- Conduct focus groups, usability tests, or interviews to receive feedback from potential patients, and investigate how they perceive and react to visualizations based on personal sensor data.
- A field study would be of great interest, seeing how a prototype can be used in their daily work with patients. The focus group participants were eager to try the system in the field, and the findings might greatly influence future requirements and guidelines.
- Investigate how available screen space will affect the visualizations and presentation. Is it possible to create an application that will be user friendly on smaller systems, such as tablets and smartphones.
- Investigate the effect of using quantitative data and information visualizations to motivate patients to be more active.

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Appendix A

# Prototype 1 Visualizations

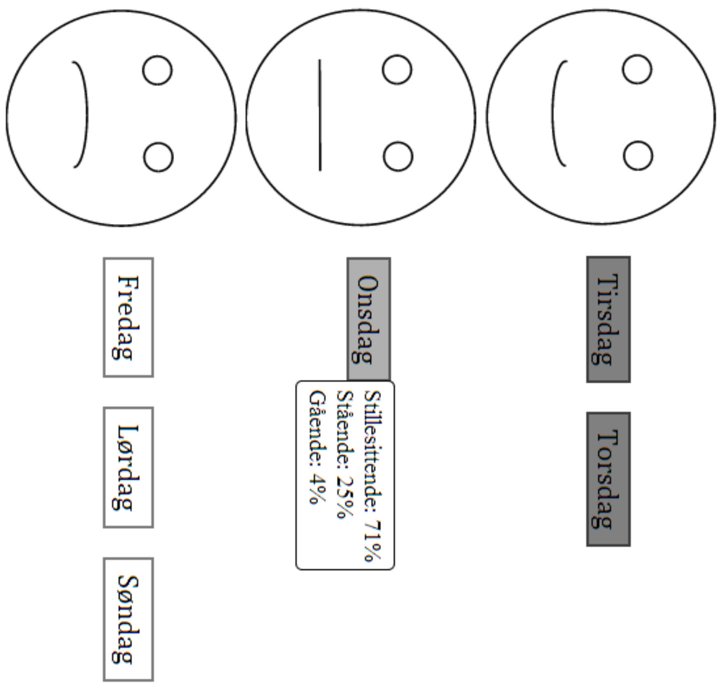


**Figure A.1:** First version of U1.

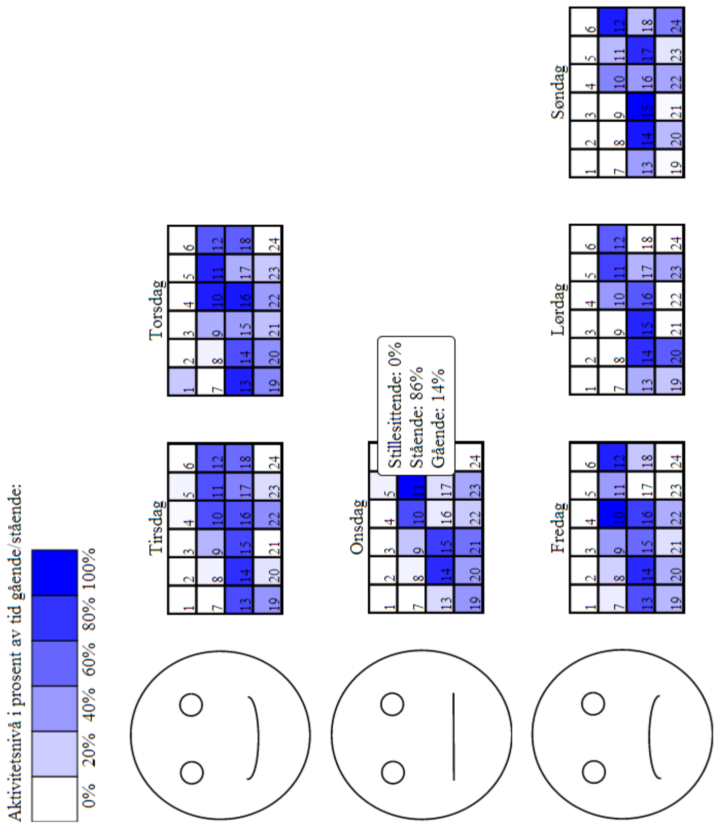


**Figure A.2:** First version of U2.

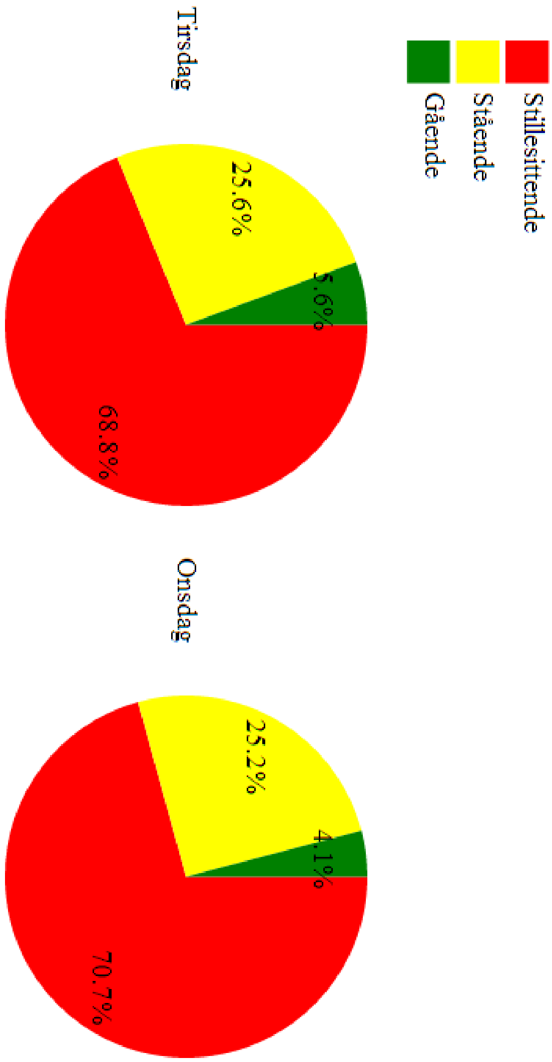


**Figure A.3:** First version of F1.

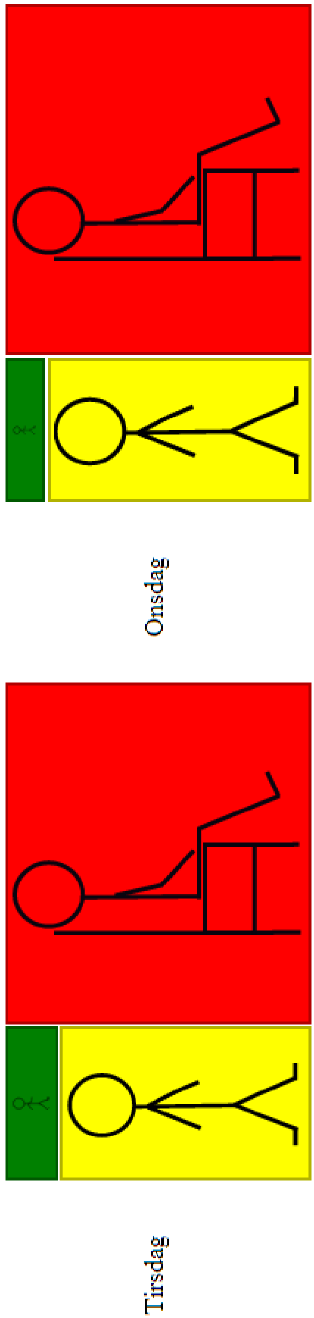


**Figure A.4:** First version of F2.

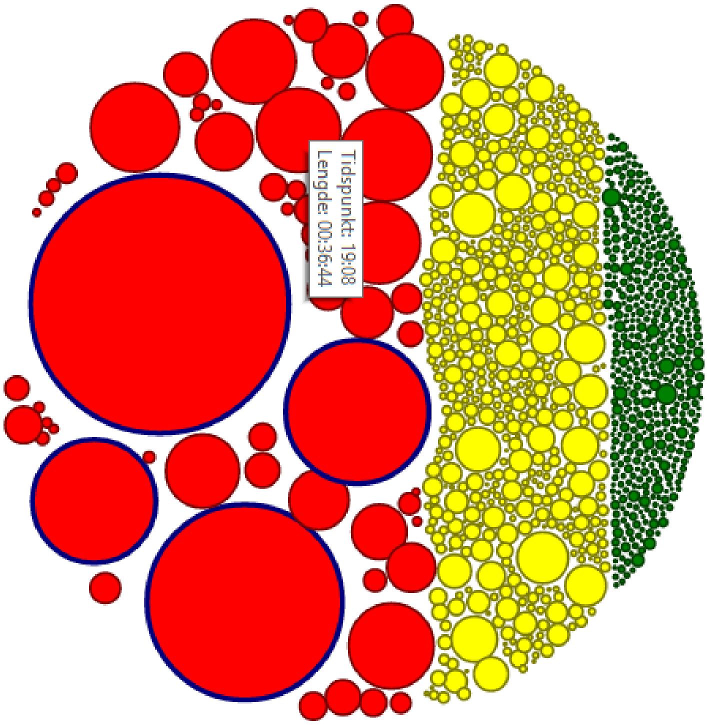


**Figure A.5:** First version of F3.

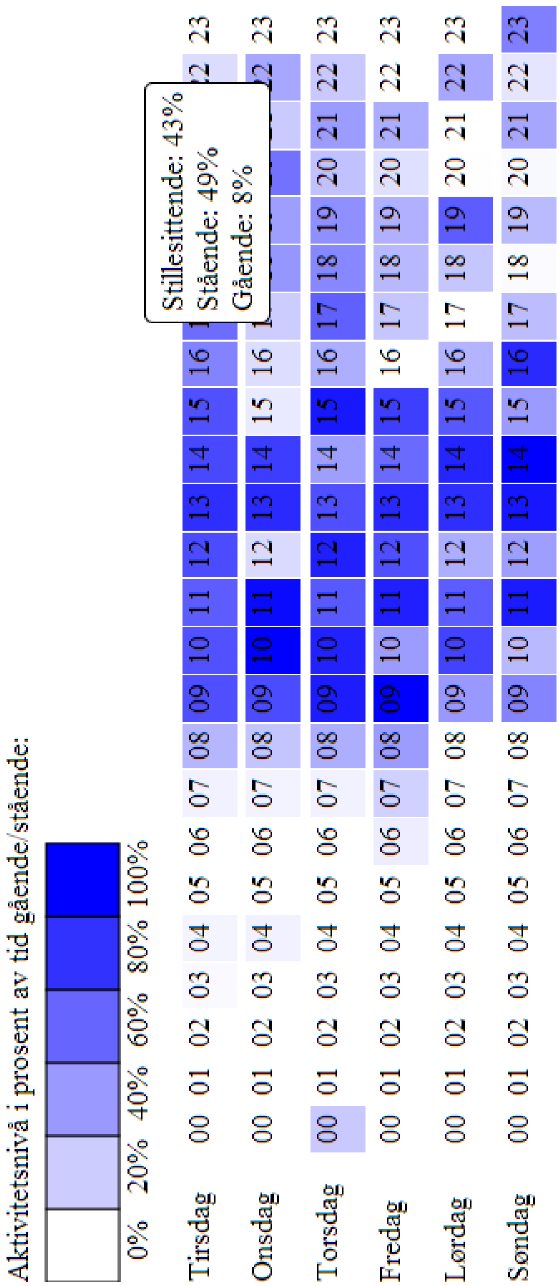


**Figure A.6:** First version of T1 in week overview.

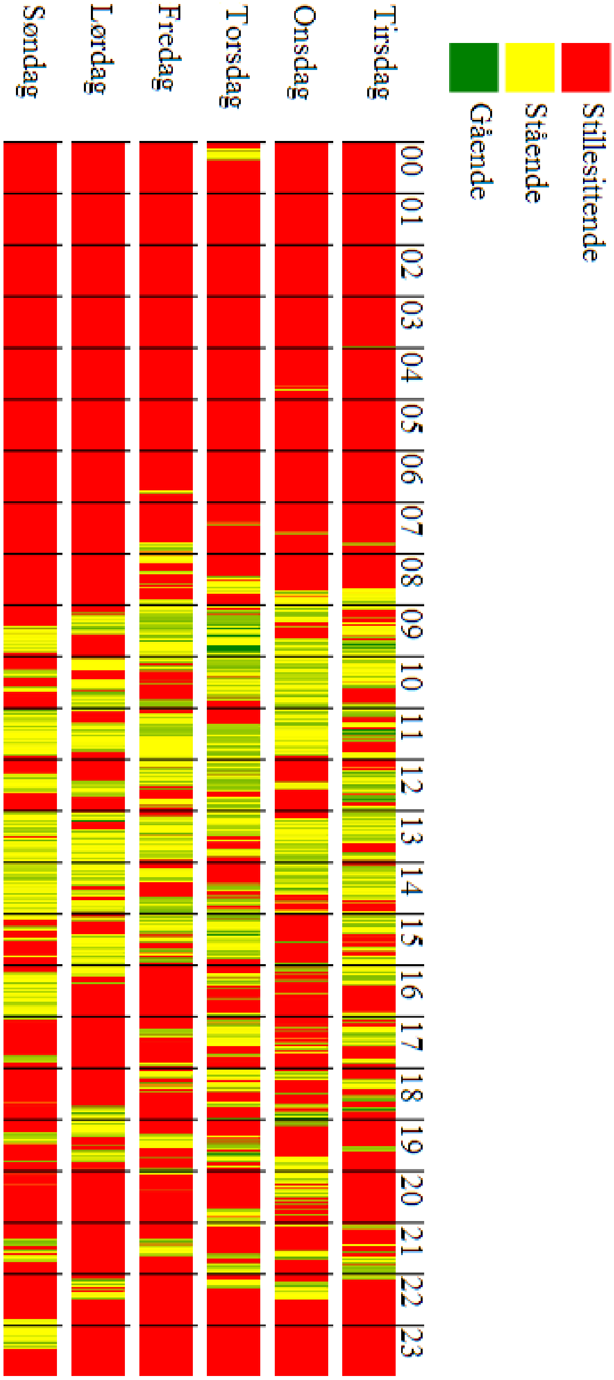


**Figure A.7:** First version of T2 in week overview.

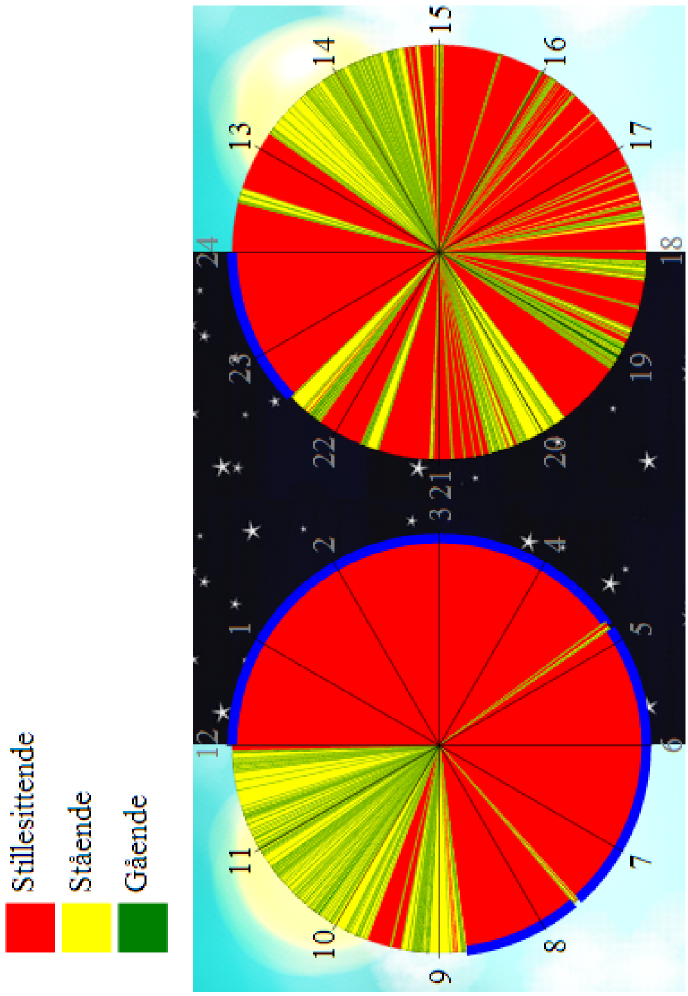


**Figure A.8:** First version of T3

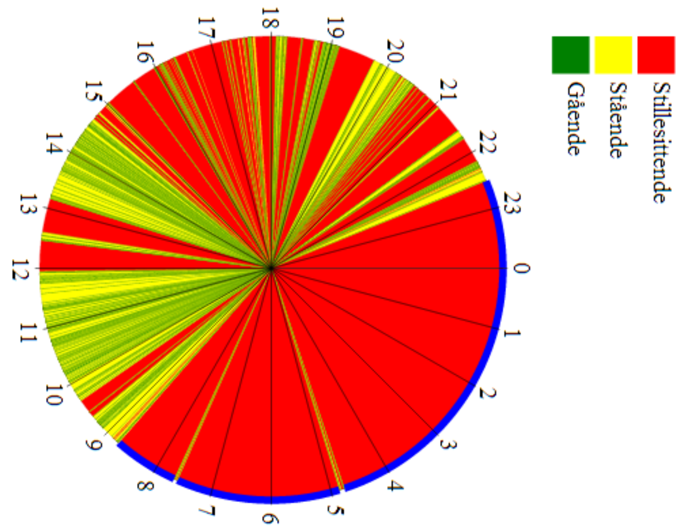


**Figure A.9:** First version of T4.

Appendix B

# Prototype 2 Visualizations

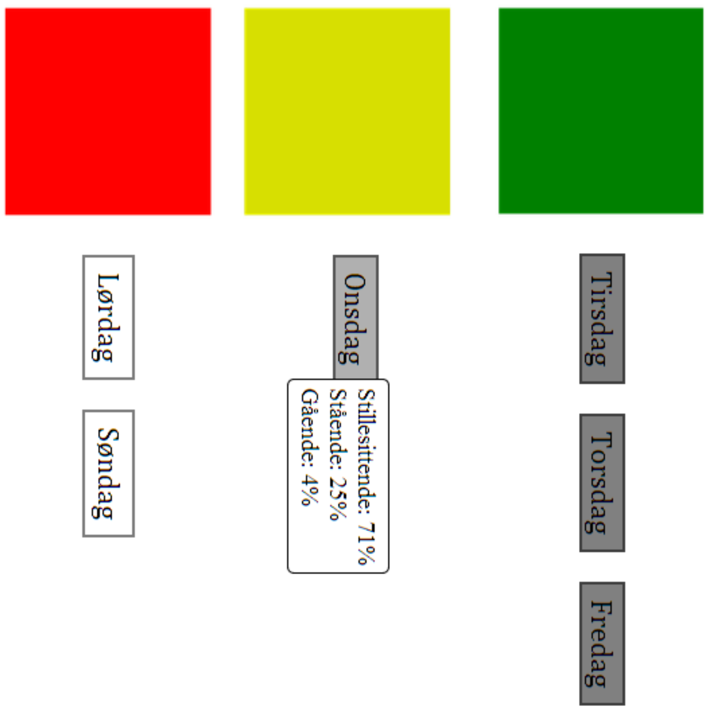


**Figure B.1:** Second version of U1.

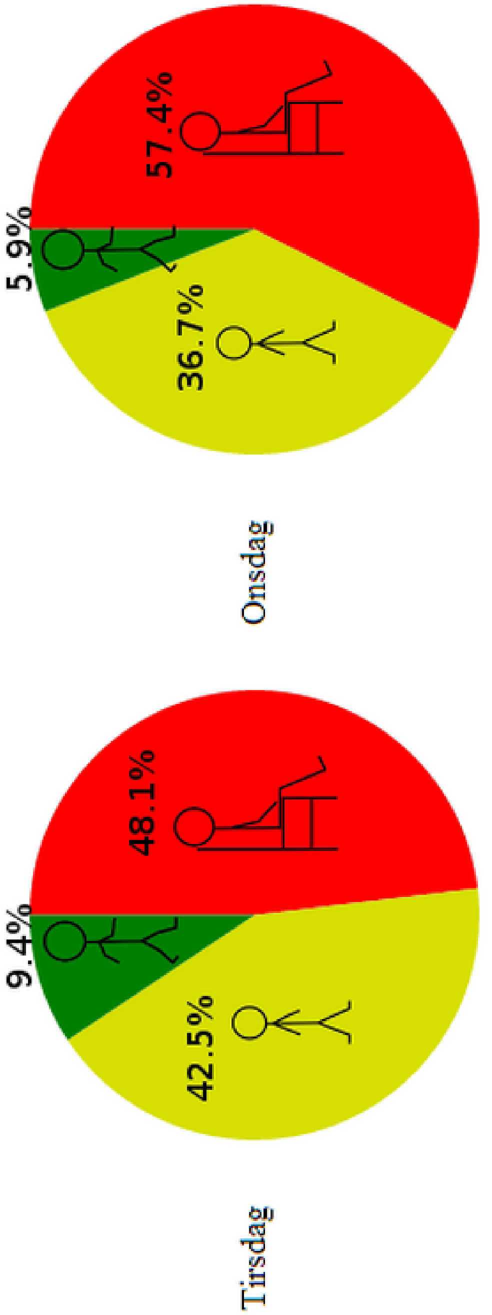


**Figure B.2:** Second version of F1.

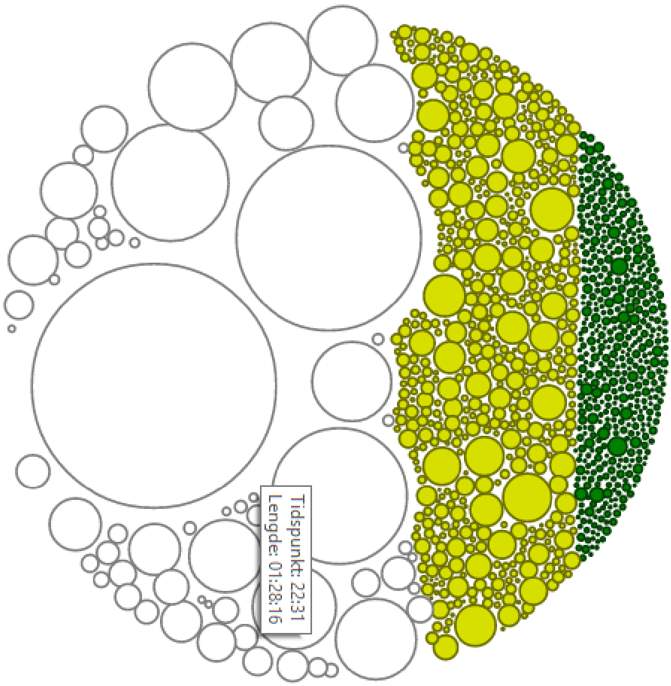


**Figure B.3:** Second version of F3.

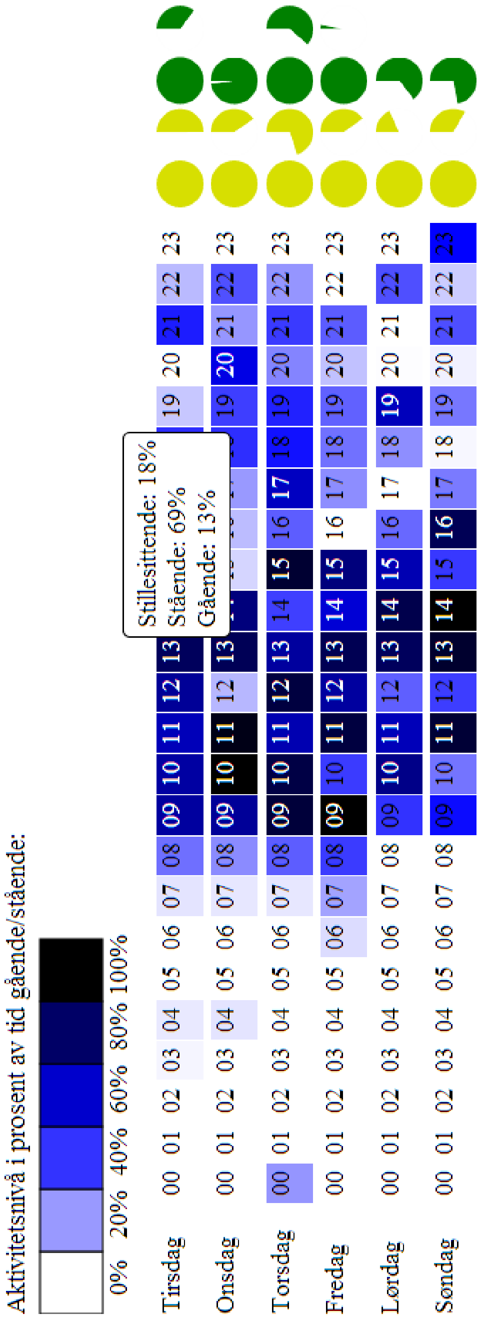


**Figure B.4:** Second version of T1 in week overview.

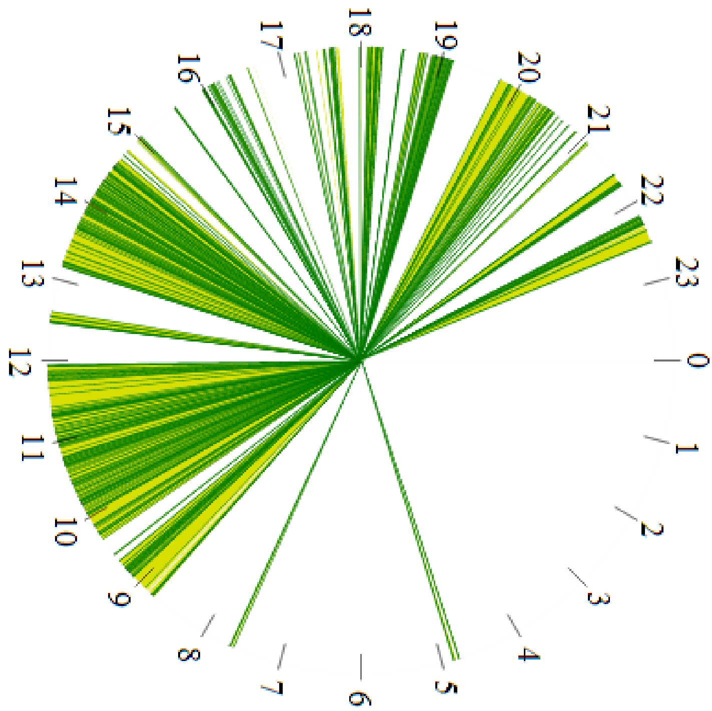


**Figure B.5:** Second version of T4.

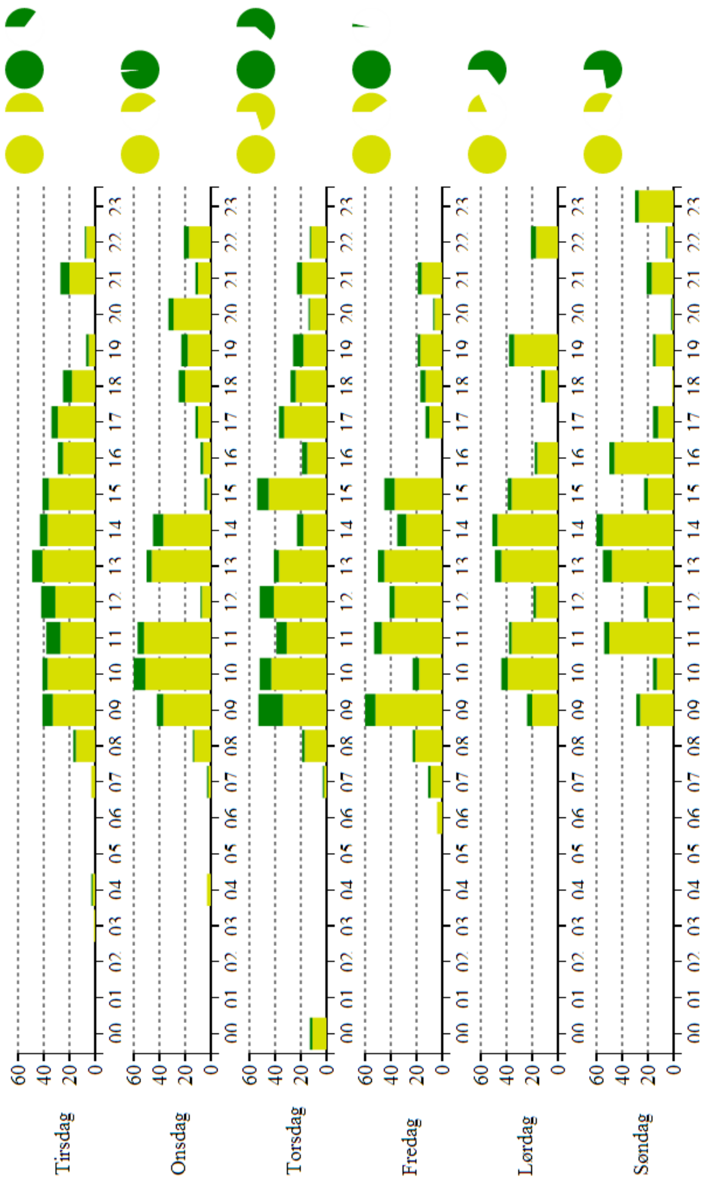


**Figure B.6:** First version of T5 in week overview.

# Appendix C
# CSV Document

| Time | DataCount (samples) | Interval (s) | ActivityCode (▸ | CumulativeStepCount | Activity Score (MET.h) | Abs(sumX) |
|---|---|---|---|---|---|---|
| #1899-12-30# | 0 | 0 | 0 | 0 | 0 | 0 |
| #2013-02-22 07:59:50# | 0 | 2177 | 0 | 0 | .7559028 | 0 |
| #2013-02-22 08:36:07# | 21770 | 1 | 1 | 0 | 3.888889E-04 | 0 |
| #2013-02-22 08:36:08# | 21780 | 1.2 | 2 | 1 | 1.188889E-03 | 126 |
| #2013-02-22 08:36:09# | 21792 | 1.2 | 2 | 2 | 1.188889E-03 | 270 |
| #2013-02-22 08:36:10# | 21804 | 2.1 | 2 | 3 | 1.538889E-03 | 195 |
| #2013-02-22 08:36:12# | 21825 | 1.1 | 2 | 4 | .00115 | 100 |
| #2013-02-22 08:36:14# | 21836 | 1.3 | 2 | 5 | 1.227778E-03 | 136 |
| #2013-02-22 08:36:15# | 21849 | 1.4 | 2 | 6 | 1.266667E-03 | 153 |
| #2013-02-22 08:36:16# | 21863 | 1.2 | 2 | 7 | 1.188889E-03 | 148 |
| #2013-02-22 08:36:17# | 21875 | 1.2 | 2 | 8 | 1.188889E-03 | 206 |
| #2013-02-22 08:36:19# | 21887 | 10.4 | 1 | 8 | 4.044444E-03 | 0 |
| #2013-02-22 08:36:29# | 21991 | .9 | 2 | 9 | 1.072222E-03 | 103 |
| #2013-02-22 08:36:30# | 22000 | 1.2 | 2 | 10 | 1.188889E-03 | 170 |
| #2013-02-22 08:36:31# | 22012 | 1.3 | 2 | 11 | 1.227778E-03 | 137 |
| #2013-02-22 08:36:32# | 22025 | 1.4 | 2 | 12 | 1.266667E-03 | 85 |
| #2013-02-22 08:36:34# | 22039 | 6.9 | 1 | 12 | 2.683333E-03 | 0 |
| #2013-02-22 08:36:41# | 22108 | 1.2 | 2 | 13 | 1.188889E-03 | 94 |
| #2013-02-22 08:36:42# | 22120 | 1.4 | 2 | 14 | 1.266667E-03 | 119 |
| #2013-02-22 08:36:43# | 22134 | 3 | 2 | 15 | 1.888889E-03 | 77 |
| #2013-02-22 08:36:46# | 22164 | 2.7 | 2 | 16 | 1.772222E-03 | 98 |
| #2013-02-22 08:36:49# | 22191 | .3 | 1 | 16 | 1.166667E-04 | 284 |
| #2013-02-22 08:36:49# | 22194 | 76.7 | 0 | 16 | 2.663194E-02 | 0 |
| #2013-02-22 08:38:06# | 22961 | .7 | 1 | 16 | 2.722222E-04 | 0 |
| #2013-02-22 08:38:07# | 22968 | 1.1 | 2 | 17 | .00115 | 86 |
| #2013-02-22 08:38:08# | 22979 | 1.2 | 2 | 18 | 1.188889E-03 | 201 |
| #2013-02-22 08:38:09# | 22991 | 45.5 | 1 | 18 | 1.769444E-02 | 0 |
| #2013-02-22 08:38:55# | 23446 | 1.5 | 2 | 19 | 1.305556E-03 | 103 |
| #2013-02-22 08:38:56# | 23461 | 1.5 | 1 | 19 | 5.833333E-04 | 105 |
| #2013-02-22 08:38:58# | 23476 | 278 | 0 | 19 | 9.652778E-02 | 0 |
| #2013-02-22 08:43:36# | 26256 | 26.2 | 1 | 19 | 1.018889E-02 | 0 |

**Figure C.1:** The CSV document as seen in Libre Calculator

| **Row Title** | **Description** |
|---|---|
| Time | Time when the state started. |
| DataCount | The amount of sensor readings the event interval is based on (not used in this project). |
| Interval | Duration for the event interval presented in seconds. |
| ActivityCode | Represents the activity of the user either sedentary (0), standing (1), or walking (2). |
| CumulativeStepCount | The total amount of steps taken since movement tracking was started (not used in this project). |
| Activity Score | Activity score rating (not used in this project) |
| Abs(sumX) | Acceleration intensity (not used in this project). |

**Table C.1:** A short description of the rows in figure C.1.

Appendix D

# Checklist

This appendix contains a copy of the checklist the physiotherapists use when mapping patients health and activity level.

**Trondheim kommune, Enhet for ergoterapitjenester og Enhet for fysioterapitjenester.**

# Sjekkliste - Eldre med begynnende funksjonssvikt

| Navn på bruker: | Dato for kartlegging: |
|---|---|

**BRUKERS PROBLEMSTILLING, ØNSKER, BEHOV:**

**Svares JA på flere enn 2 spørsmål merket med grått *, indikeres at fastlege bør vurdere henvisning til geriatrisk poliklinikk.**

Sjekk opplysningene som kommer frem under besøket opp mot risikofaktor-listen; Bør bruker henvises til andre?

**HELSETILSTAND:**

| | |
|---|---|
| Har brukeren Parkinson eller gj.gått hjerneslag? *<br>Har brukeren 3 eller flere kroniske lidelser? *<br>Har brukeren kognitiv svikt? *<br>Tar bruker 4 eller flere medikamenter daglig? * | |

**KROPP:**

| | |
|---|---|
| **Mentale funksjoner - observér**<br>Orientert for tid og sted<br>Motivasjon for egenaktivitet<br>Hukommelse | |
| **Svimmelhet? I spesielle situasjoner?**<br><br>(Er det svimmelhet eller ustøhet?) | |
| **Bevegelsesfunksjoner**<br>Balanse, styrke, utholdenhet, leddbevegelighet | |

| | |
|---|---|
| **Sanser og smerte**<br>Begrenser evt nedsatt syn* huslige gjøremål og andre aktiviteter? Problemer med å lese eller se TV?<br>Høres dørklokka, telefon, TV, røykvarsler?<br><br>Smerteproblematikk? | |
| **Ernæring**<br>Drikker mer enn 1,5 l pr dag? (Dehydrering?)<br><br>Har brukeren nedsatt kroppsmasseindeks?*<br>(BMI : vekt i kg/ (høyde i m x høyde i m))<br><br>Tegn på B12 mangel?<br>Tegn på anemi? | |

**AKTIVITET & DELTAKELSE:**

| | |
|---|---|
| **Fall?**<br>Det siste året? *<br>Når, hvor og hvordan? Hvor ofte?<br>Hjelp for å komme opp?<br>Mistet bevisstheten?<br>Oppsøkt lege eller sykehus etter fall?<br><br>Redd for å ramle?<br>Endret noe i hverdagen pga redsel for å falle?<br>(sluttet med innkjøp, går ikke i trapp, går ikke ut, deltar ikke i sosiale aktiviteter? | |
| **Praktiske oppgaver** - **få bruker til å vise!**<br><br>1. Fra senga til toalettet om natta?<br>Ustø? Utrygg?<br>Slå på lysene som benyttes, selv om det er dag!<br><br>2. Hente posten?<br><br>3. Ta ut søppel selv?<br><br>4. Nå alle skap fra gulvet?<br>(”klatrer”, flyttet ned de viktigste tingene, etc)<br><br>5. Be brukeren reise seg fra kjøkkenstol –<br>mestrer brukeren det uten å bruke armene? * | |
| **Egenomsorg**<br>Personlig stell / påkledning<br>Husholdningsoppgaver (matlaging, rengjøring, klesvask)<br>Innkjøp | |

| | |
|---|---|
| **Sosialt**<br>Kontakt med familie/venner?<br>Deltakelse på sosiale aktiviteter?<br>Trim, mosjon, turaktiviteter?  Med hvem, hvor?<br>Ønsker bruker å delta i andre aktiviteter?<br>Noe som hindrer bruker i å delta? | |

**MILJØFAKTORER:**

| | |
|---|---|
| **Bolig**<br>Bor bruker alene?<br>Inngangsparti / adkomst?<br>Strødd og brøytet på vinteren?<br>Er alt på et plan?  Trapp / heis? | |
| **Hindringer /problemområder i boligen?**<br>Løse tepper / matter / glatte gulv?<br>Møbler?<br>Løse ledninger / varmovner?<br>Telefon langt unna?<br>Dårlig belysning?<br>Badematte (m/ sugekopper) på badet?<br>Trapp, trapperom, rekkverk? | |
| **Ganghjelpemiddel**<br>Benytter brukeren ganghjelpemidler (inne/ute)<br>Hvordan er inneskoene? (hæl, hælkappe/åpen, såle)<br>Hvordan er uteskoene? (Hæler, såler)<br>Brodder ? Fungerer de ? Brukes de? | |

**HVA ØNSKER BRUKER Å PRIORITERE?**

| |
|---|
| |

| **MÅL OG TILTAK:** | **ANSVAR:** |
|---|---|
| | |

Utarbeidet av ergoterapeut Fanny Kathrine Wilhelmsen  og fysioterapeut Sylvi Sand novemberr 2003
Etter ide fra "forebygge fallulykker" fra Fyns amt, DK,      samt erfaring fra "Fallprosjektet" Trondheim kommun 2003
Sjekklista inneholder alle punkter i fastlegens sjekkliste i f h t henvisning til fallklinikken.    Disse punktene er markert med stjerne.(*)
Sist revidert i  25.09  2008.

# Appendix E
# Questionnaire

This appendix contains a copy of the questionnaire answered by the participants.

## A. Bakgrunnsinformasjon

Alder:
Arbeidsgiver:
Stilling:
Kjønn: □ Mann □ Kvinne

## B. Spørsmål om teknologi

**1. Hvor ofte bruker du en PC/Laptop?**

□ Hver dag
□ Flere ganger I uka
□ Flere ganger I måneden
□ Aldri

**2. Hvor ofte bruker du et Nettbrett?**

□Hver dag
□ Flere ganger I uka
□ Flere ganger I måneden
□ Aldri

**3. Hvor ofte bruker du en Smarttelefon?**

□ Hver dag
□ Flere ganger I uka
□ Flere ganger I måneden
□ Aldri

**Vurder påstandene:**

**4. Jeg er interessert i å ta i bruk ny teknologi i mitt arbeid.**
□ Svært enig
□ Ganske enig
□ Litt uenig
□ Svært uenig
□ Vet ikke

**5. Jeg tror ny teknologi kan bidra til å gjøre kvaliteten på mitt arbeid bedre.**
□ Svært enig
□ Ganske enig
□ Litt uenig
□ Svært uenig
□ Vet ikke

**6. Jeg tror ny teknologi kan bidra til at jeg blir mer effektiv i mitt arbeid.**
□ Svært enig
□ Ganske enig
□ Litt uenig
□ Svært uenig
□ Vet ikke