NTNU - NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Using Mobile Technology to Treat Asthmatic Children

by

Esben Aarseth and Aleksander Gisvold

Supervisor: Pieter Jelle Toussaint

A thesis submitted in partial fulfillment for the
degree of Master of Science
- Computer Science

in the
IME - Faculty of Information Technology, Mathematics and Electrical Engineering
IDI - Department of Computer and Information Science

November 2013

Declaration of Authorship

We, Esben Aarseth and Aleksander Gisvold, declare that this thesis titled, 'Using Mobile Technology to Treat Asthmatic Children' and the work presented in it are our own. We confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where we have consulted the published work of others, this is always clearly attributed.
- Where we have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- We have acknowledged all main sources of help.
- Where the thesis is based on work done by ourselves jointly with others, we have made clear exactly what was done by others and what we have contributed ourself.

Signed: ______________________________

Signed: ______________________________

Date: ______________________________

“Don’t put all your Anns in the same basket”

- George Michael Bluth

NTNU - NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Abstract

IME - Faculty of Information Technology, Mathematics and Electrical Engineering
IDI - Department of Computer and Information Science

Master of Science

by Esben Aarseth and Aleksander Gisvold
Supervisor: Pieter Jelle Toussaint

20 per cent of the Norwegian population has or has had asthma before the age of 10. Treating children for asthma is often a cumbersome task. Research has shown that TUIs and mobile applications have been useful in medical care in a number of different settings. . . .

Keywords: *Asthma, Self-management, Gamification, Serious games, Tangible User Interfaces, Healthcare Informatics, Mobile Technology*

Acknowledgements

We would like to thank Pieter Jelle Toussaint for excellent guidance and advice throughout the run of the project. We would like to thank Ole Andreas Alsos for advice, ideas and lending of his UX-skills to the project. Thanks to Elin H. Bergene, Marikken Høiseth and Jonas Åsheim. Thanks to Aaberg, Dahle and Svalestuen. Thanks to NILU for providing air quality readings.

Contents

Declaration of Authorship **i**

Abstract **iii**

Acknowledgements **iv**

List of Figures **viii**

List of Tables **ix**

Abbreviations **x**

1 Introduction **1**
1.1 Purpose . . . 1
1.2 Motivation . . . 1
1.2.1 Asthma among children . . . 1
1.2.2 Ways asthma affect the parents . . . 2
1.3 Research Questions . . . 2
1.4 Research Method . . . 2
1.4.1 RQ1 . . . 2

2 Background **4**
2.1 BLOPP Project . . . 4
2.2 About Asthma . . . 4
2.3 CAPP, KAPP and GAPP . . . 5
2.3.1 CAPP . . . 5
2.3.2 KAPP . . . 8
2.3.3 GAPP . . . 8
2.3.4 Known areas for improvement . . . 10
2.4 Existing Research . . . 11
2.4.1 Monitoring Asthma with Mobile Technology . . . 11
2.4.2 Children and Mobile Devices . . . 11
2.4.3 Children and Gestures . . . 11
2.4.4 Assessment of Existing Applications . . . 12
2.5 State of the art . . . 12

2.5.1 Sisom . . . 13
2.5.2 Meassuring Blood Preassure . . . 13
2.5.3 Controlling Your Diabetes . . . 13
2.5.4 Quit Smoking . . . 13
2.5.5 Wii Fit Plus . . . 14

3 Gamification **15**
3.1 What is Gamification? . . . 15
3.2 What is Serious Games? . . . 16
3.3 Discussion about Gamification . . . 17
3.4 Use of Gamification in [INSERT APPNAME] . . . 17

4 Tangible User Interfaces **19**
4.1 About Tangible User Interfaces . . . 19
4.2 Examples of Use . . . 19
4.3 Effects of Robots . . . 20
4.4 Are Tangible Interfaces more fun? . . . 20
4.5 How to create a TUI . . . 21
4.5.1 Token + Constraint Approach . . . 21
4.5.2 Design Approach to TUI's . . . 22
4.6 Co-design . . . 22
4.6.1 What is co-design? . . . 23
4.6.2 Using co-design to build AsthmaBuddy . . . 23
4.7 Challenges when creating TUI . . . 23

5 Usability **26**
5.1 What is usability? . . . 26
5.2 How to test usability . . . 27
5.3 How to test usability on children and toddlers . . . 30
5.4 Usability testing on mobile devices . . . 31
5.4.1 Emulator versus device . . . 31

6 Introducing: AsthmaBuddy **33**
6.1 Introduction . . . 33
6.2 What do we want to create? . . . 34
6.2.1 A basic scenario . . . 34
6.2.2 Components . . . 35
6.2.3 Handling Bellotti's Challenges . . . 35
6.3 Planned modifications of existing system . . . 36

7 Usability Tests **38**
7.1 Purpose . . . 38
7.2 Test Method . . . 38
7.2.1 Scenario and tasks given to the users . . . 39

8 Conclusions **40**

A Norwegian SUS form **41**

B Further Work **43**
B.1 Improvements 43
B.1.1 Rewardsystem 43
B.1.2 Distraction sequence for children 44
B.1.3 User testing of the guardian application 44
B.1.4 Web application 44
B.1.5 Support for more children 45
B.2 Ideas and minor improvements 45

C Questionnaire. Demographics **46**

D Interview conducted before usability testing **47**

E Scenario and tasks **48**

F Asthma Traffic Light System **50**

G Manuscript **51**

H Constraints **53**
H.1 The Health Register Act 53
H.2 Measures for Anonymization 53

List of Figures

2.1 Starting a treatment . . . 6
2.2 Inside the treasure chest . . . 6
2.3 CAPP main menu . . . 6
2.4 Instructions 1 . . . 7
2.5 Instructions 2 . . . 7
2.6 Instructions 3 . . . 7
2.7 Instructions 4 . . . 7
2.8 Instructions 5 . . . 7
2.9 Instructions 6 . . . 7
2.10 Instructions 7 . . . 7
2.11 Karotz . . . 8
2.12 GAPP main menu . . . 8
2.13 Register treatment . . . 10
2.14 View plans . . . 10
2.15 Information 1 . . . 10
2.16 Information 2 . . . 10
2.17 Medicine log . . . 10

5.1 Number of users needed to find percentage of errors according to J. Nielsen[1] . . . 29
5.2 The Android Emulator running an emulation of Android 4.1 . . . 32

List of Tables

4.1 The eight questions stated by Champoux [2] 22
4.2 The challenges of interacting with TUI [49] 24

5.1 Methods of user-centered feedback 28

6.1 Intended modifications and their rationale 37

Abbreviations

API	**A**pplication **P**rogramming **I**nterface
BLOPP	**B**arns **L**egemiddel**OPP**levelser
CAPP	**C**hild **APP**lication
GAPP	**G**uardian **APP**lication
GUI	**G**raphical **U**ser **I**nterface
KAPP	**K**arotz **APP**lication
NAAF	**N**orges **A**stma- og **A**llergi-**F**orbund
MMO	**M**assive **M**ultiplayer **O**nline game
NTNU	**N**orwegian **U**niversity of **S**cience and **T**echnology
REK	Regional Comittees for Medical and Health Research Ethichs
RFID	**R**adio **F**requency **ID**entification
TUI	**T**angible **U**ser **I**nterface

To Tony Wonder! "Did someone say Wonder?"

Chapter 1

Introduction

This chapter will give an introduction to our thesis. It will state the purpose, motivation, research questions and the research method for the study.

1.1 Purpose

The goal of this project is to evaluate the use of mobile technologies in the treatment of asthmatic children. The project is based on a system made by Aaberg, Aarseth, Dale, Gisvold and Svalestuen in 2012 [3]. We intend to improve their versions of CAPP and GAPP (see Chapter 2), in addition to create a Tangible User Interface from scratch.

The evaluation of the project will be done through usability testing and diary studies of different versions of the system, augmenting the functionality from cycle to cycle.

1.2 Motivation

1.2.1 Asthma among children

According to NAAF, 20% of the Norwegian population has or has had asthma at the age of 10, and 8% of the adult population suffers from asthma [4]. Many of the children find it unpleasant to use their medicine as they often do not understand why the medicine must be taken. Research done by Åsheim showed that children suffering from HRS-virus [1] were easily distracted and motivated to finish treatments when shown a non-interactive flash-video during the treatment [5]. We aim to research whether use of

[1] Center for Disease Control : HSRV

mobile technology may make the children more aware of their asthma and thus make them better understand why they must take their medicine on a daily basis.

1.2.2 Ways asthma affect the parents

In an already hectic everyday life, remembering to give their children medication may be cumbersome. Often the children do not enjoy taking their medicine, and the children may start an argument not wanting to finish their treatment. This may result in parents applying the medication incorrectly, applying the wrong treatment, or even forgetting to give the medicine, which in turn have a negative effect on the overall treatment.

1.3 Research Questions

The main goal for this study is to figure out ways technology can help children taking their medication. The objective has been composed into the following research questions:

RQ1: How can gamification be used for motivating children to take their asthma medicine?

RQ2: How will the presence of a Tangible User Interface affect children's medication habits?

1.4 Research Method

1.4.1 RQ1

We want to test the system on 5-7 asthmatic children at the age of 3-7 year old. In order to test this using a systematic approach, we plan to take the following steps, which will be explained in further detail below.

1. We will start out by interviewing parents and domain experts to find out more about children's medication habits.
2. Give parents a mobile application which instructs children during their medication. This will be a simplified version of our final application.
3. Give parents a mobile application which has gamification elements to it, in addition to the instructions in Step 2.

4. Give the test persons a custom built TUI.

The rationale for doing Step 1 is to create a foundation to build upon on the later steps. Collecting information about how children take their medicine under normal conditions give us a set of control data which we may use for comparison with the developed technology.

The rationale for doing Step 2 is to see if it is actually enough to have a minor avatar system where the avatar tells the child what to do, and when to do it. This might give some ideas for further research from BLOPP.

The rationale for doing Step 3 is to answer whether gamification have a motivational effect on children, i.e. motivating children to take their medicine on a continuous basis.

The rationale for doing Step 4 is to see if a relational artifact can give children proper motivation for taking their medicine.

During Step 2-4, we want parents to fill out a diary. We will prepare a set of control questions which should be answered in this diary. The answers to these control questions might give us additional insight into how the process went.

An example of such a question is *"Did the child have problems using the TUI?"*. The answer to this question might improve over time, once the child has gotten used to the applications or the TUI.

Through the conducted studies we will evaluate and compare the usage and opinions the parents and children had regarding use of our system. Through the data gathering in the diaries we will be able to directly compare how the children and parents reacted to the arrival and use of a TUI. We will also conduct interviews to get feedback on how the use of the TUI affected the children. The interviews will mainly be conducted on the parents, since small children may not give reliable data.

Chapter 2

Background

This chapter will give a brief introduction to the history behind the BLOPP project (2.1). Section 2.2 will give an overview of asthma, and how it affects people. Section 2.3 will go into details of the applications that were developed by Aaberg, Aarseth, Dale, Gisvold and Svalestuen during the Autumn 2012. Section 2.4 will give an introduction to some of the current research that has been performed on mobile technology in combination with children and health.

2.1 BLOPP Project

Barns LegemiddelOPPlevelser (BLOPP) is a project group working for "Sykehusapotekene i Midt-Norge" (Hospital Pharmacies in Mid-Norway). Their purpose is to create easier medical treatments for children through use of technology.

2.2 About Asthma

Asthma is a disease that affects the lungs. Asthma causes wheezing, breathlessness, chest tightness, and coughing. It is a chronic disease, but asthma attacks will only occur when something is bothering the lungs. It may be hard to tell if someone has asthma, especially in children under age five. An asthma attack may include coughing, chest tightness, wheezing, and trouble breathing. The attack happens in the body's lungs, the airways become smaller.

Asthma can be controlled and asthma attacks avoided by taking medicine at regular intervals. Some of the medicines are taken as a preventive measure to avoid asthma attacks from occuring. These medicines are Seretide and Flutide. Ventoline is taken in front of exercise or when an asthma attack occurs, in order to stop/shorten the length of the attack.

People suffering from asthma are often given an asthma control plan, which tells them how often they should take their medication, and what to do if an attack occurs. These plans are often parted into three separate health zones, corresponding with how the user feels. In order to make these health zones understandable, a traffic light system is often used. A green light tells what that the user should do when all is normal. A yellow light indicates what to do when the user is feeling a bit ill, there may much pollen or poor air quality or that the user is recovering from a cold. A red light what to do when the user is feeling ill, or there is an extreme amount of pollen or extremely poor air quality.

2.3 CAPP, KAPP and GAPP

In the autumn of 2012 Aaberg, Aarseth, Dale, Gisvold and Svalestuen were engaged by the BLOPP Project group through the course "TDT4290 - Customer Driven Project" at NTNU [1] . During the period of August 2012 to December 2012 they developed a prototype of a mobile information system consisting of two Android applications and a TUI. One application was developed for parents of a child (GAPP), and one application were developed for children (CAPP). Additionally, they created a Karotz Application(KAPP) targeted towards children. In this section, we elaborate on these applications, while a full report of their work is available at [3].

Their prototype is the foundation for our work in this project.

2.3.1 CAPP

CAPP is an Android application targeted towards the children[2]. It's main purpose is to guide children through the medication process. Figure 2.3 shows the main page of CAPP. As the target group for the application is children below the age of 8, it is reasonable to assume that not all of them are able to read, this application consists mainly of pictures and animations.

In CAPP, it is possible to start a medication in one of two ways. A parent can either set alarms in GAPP (See Section 2.3.3) for preventive medicines, or a child can directly access the medication process by pressing the Karotz showed in Figure 2.3, which is the way to start a by-need-treatment.

[1] Course Description of TDT4290 - Customer Driven Project
[2] All applications have norwegian as their main language

One of the objectives towards CAPP was to introduce a gamification experience to the medication process. Accordingly, the child gets a golden star in his/her treasure chest once the child is done. However, these stars are not useful for anything else but showing them off.

By clicking the treasure chest, the child is able to see how many stars he/she has aquired. A screenshot showing the inside of the treasure chest is included in Figure 2.2

The last part of this application is an Information-section, where children has a quick reference as to how to take a medicine. A part of the functionality that has not been implemented is voice over for these instructions. Thus, a parent should be close by in order to read the information contained in this functionality. 2.4-2.10 shows the information-part of this application.

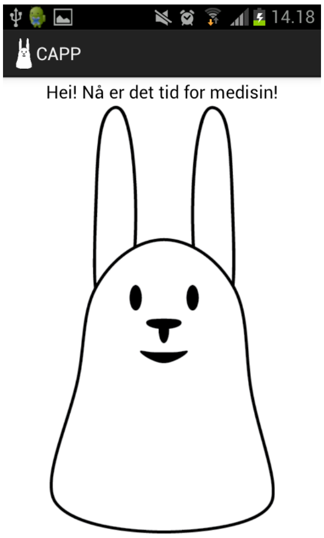


Figure 2.1: Starting a treatment

Figure 2.2: Inside the treasure chest

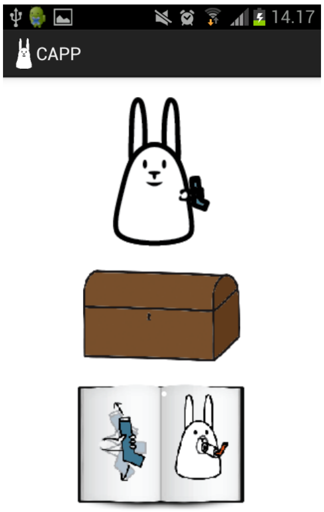


Figure 2.3: CAPP main menu

FIGURE 2.4: Instructions 1

FIGURE 2.5: Instructions 2

FIGURE 2.6: Instructions 3

FIGURE 2.7: Instructions 4

FIGURE 2.8: Instructions 5

FIGURE 2.9: Instructions 6

FIGURE 2.10: Instructions 7

2.3.2 KAPP

KAPP is the TUI-application targeted towards children. The application runs on a Karotz[6], which is a small robot bunny (see Figure 2.11). The purpose of the KAPP is similar to CAPP, namely to remind children when it is time to take their asthma medicine and give instructions during treatment. In order to interact with the Karotz, children may use either a Nanoz (a small bunny with an integrated RFID) or by pressing a button on the top of the Karotz' head. It is not possible to do a by-need treatment with a Karotz as a companion.

A basic breakdown of the CAPP and KAPP manuscript is included in Appendix G.

FIGURE 2.11: Karotz

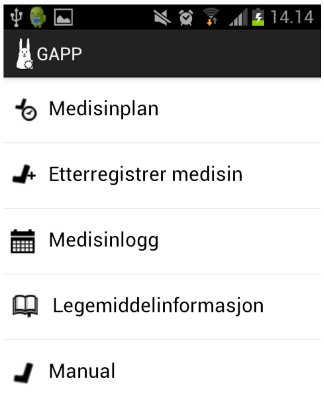


FIGURE 2.12: GAPP main menu

2.3.3 GAPP

GAPP is an Android application targeted towards the guardians or parents of the children. Some parents are having problems with remembering how often their children have taken their medication the last couple of days, when they should take them and how their children's disease has evolved over the a period of time. Thus, GAPP's main puropose is to make parents more aware of their children's disease.

Figure 2.12 shows a screenshot of the main menu of GAPP. The main functionality is separated into *Medical Plan*, *Register Treatment*, *Medicine Log*, *Medical Information* and *Manual*.

Medical Plan *Medical Plan* gives parents the option to set up reminders at particular times. It is divided according to the Traffic-Light system (See Appendix F). A child has three separate plans, such that an alarm that is set on the *Healthy*-plan is not automatically set on the *Sick*-plan.

Register Treatment The *Register Treatment*-option gives parents possibility to register a treatment that is taken in case the child for some reason did not go through the process in CAPP or KAPP. This way, children will be rewarded with stars accordingly. Figure 2.13 shows a screen shot of this process.

Medical Information *Medical Information* gives general information about different medicines, what they do, and what they are used for. The three medicines that are currently in the system is Flutide, Seretide and Ventoline. Figures 2.15 and 2.16 shows screenshots from this functionality.

Medicine Log *Medicine Log* shows how many times a child has taken their medicine the last couple of days. Figure 2.17 shows a screen shot of this functionality. A red circle marks the current day. A child's health state is displayed by the Green/Yellow/Red bar at the top of each day. In the bottom left corner, it is possible to show how much medicine were taken at a given day. In the bottom right corner, Aaberg et. al. intended to show the pollen distribution for a given day. However, the pollen distribution data is only available during spring and summer, and thus created an artificial pollen distribution for demonstration purposes.

Manual The *Manual* is to help "newcomers" to medicate children. For instance, if an aunt was watching children with asthma, she could use the application as a reference on how to do the process. At the time being, the manual shows Figures 2.4-2.10.

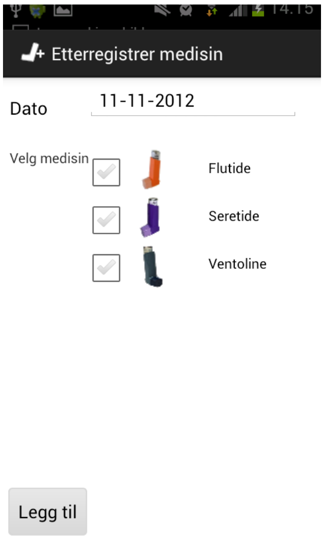


Figure 2.13: Register treatment

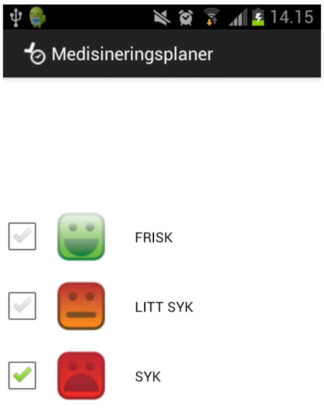


Figure 2.14: View plans

Figure 2.15: Information 1

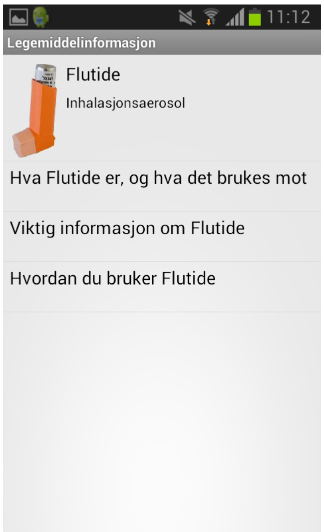


Figure 2.16: Information 2

Figure 2.17: Medicine log

2.3.4 Known areas for improvement

As Aaberg, Aarseth, Dale, Gisvold and Svalestuen finished their work, they commented on several areas of potential improvement for CAPP, GAPP and KAPP. This document is reprinted in its entirety in Appendix B (after permission from Aaberg, Aarseth, Dale, Gisvold and Svalestuen). The main topics for improvement were

- Reward System
- Distraction sequence for children
- Web application

These comments are used as a basis when we decide what to improve in this project.

2.4 Existing Research

This section will give a foundation on some of the reserach performed on using technology in combination with diseases and children.

2.4.1 Monitoring Asthma with Mobile Technology

There exists some research on self-management of monitoring your asthma condition. A lot of this research works used SMS (Short Messaging System) technology. In 2009, Andhøj et. al.[7] did a feasability study to check how users would respond to a SMS-reminder study. Their methodology was to send SMS a couple of times a day, and have the users respond to their peak flow and answer yes/no questions. Users could then access a web page to see different statistics on peak flows, how they've felt the last couple of days, etc.

They concluded that SMS is a feasible solution for collecting asthma diary data, mainly because the SMS technology was a big part of the participant's everyday life. Although SMS is a great technology to be used for this purpose, few children in our target group are able to use this technology, for obvious reasons. According to *Senter for IKT i utdanningen* (Center for ICT in education), about 40% of Norwegian children below the age of 3 years old have used a tablet, and 6 out of 10 children below the age of 6 have used a touch screen device [8]. Thus the technological background should be somewhat familiar for our target group.

2.4.2 Children and Mobile Devices

In 2013, `www.babies.co.uk` posted results on a poll they had posted on how many toddlers are using smartphones or tablets each day[9]. Over 1000 participants responded, and according to the survey, 14% of the responders allowed children to use smartphones or tablets more than 4 hours a day. Considering the normal awake time of a child between 9 and 12 months old is approximately 10 hours, they spend a considerable amount of their day on the smartphone.

2.4.3 Children and Gestures

Abdul Aziz et. al. [10] performed a study on which gestures children are able to comprehend when playing with an iPad. She tested 33 children's abililty to do gestures on a variety of applications suited for children. The children were in the range of 2-12 years old, 3 children per age. The study showed the following restrictions:

- 2 year old children have difficulties with pinching, and are unable to drag and drop, spread and rotation of the device, and are not able to focus on the application.
- 3 year old children have difficulties to drag and drop until they are told to do so, in addition to having problems with pinch and spread.
- 4 year old children have difficulties to drag and drop.

Children at age 5 and above are able to do all the normal gestures at a tablet. As CAPP is currently only available for mobile devices, this is reason for some discussion. The main part to notice is pinching and drag and drop. An iPad is fairly large relative to the size of these children's hands. There is reason to believe that gestures may be more difficult on smaller screens, however, we were unable to find research supporting this claim. In order to make [INSERT APPNAME] as child friendly as possible, it only uses "swiping" gestures and button presses for navigation.

2.4.4 Assessment of Existing Applications

In 2012, Huckvale et. al. [11] conducted an assesment on the existing applications on both Google Play [3] and App Store [4]. They assessed 103 different apps with english as the native language. Out of these applications,

"No apps for people with asthma combined reliable, comprehensive information about the condition with supportive tools for selfmanagement" [11].

They concluded that doctors should be careful when recommending apps for patients with the purpose of self management of asthma.

2.5 State of the art

Mobile computing is evolving at a rapid pace, and finding new ways to use it in health care is a rising research problem. This section covers the state of the art of some of the areas in which mobile technology is being used with a combination of either gamification or tangible interfaces.

[3] Google Play
[4] Apple App Store

2.5.1 Sisom

Sisom [5] is a software created to increase the communication level between physicians and children. It is an interactive game, where the user follows an avatar through different "worlds" of health care subjects. For instance, the avatar takes a boat to a hospital. Here, the user can look around in the room, and express their feelings about how they feel when they are taking a blood sample. The results showed that when children played the game before a consultation with his/her physician, children were better prepared, and the communcication had a better quality, where children were more communicative[12].

2.5.2 Meassuring Blood Preassure

iHealth [6] , Withings [7] and other companies has created blood preassure monitors which are synchronized towards mobile applications. They allow easy monitoring over periods of time, and makes it possible to share meassurements to both friends, family and doctors.

2.5.3 Controlling Your Diabetes

Cellnovo [8] has created a system that helps controlling diabetes. It consists of a hand-held device for meassuring blood sugar level, a pump that controls the flow of insulin and a web interface that allows you to access the information. The interface helps users to check for trends and patterns in their blood sugar level, which motivates users to continue their focus on applying the correct treatment. It also allow users to send information to physicians, which helps them make decisions further regarding how patients are managed.

2.5.4 Quit Smoking

There are lots of mobile applications that are helping people to quit smoking. For instance, *The Norwegian Heart and Lung Patient Organization* has an app for helping people to quit smoking [9] . The application shows which effects your body is going through after a specific amount of days, which is a huge motivational factor, considering what we have read in the reviews of the application. Additionally, they show how much

[5] Sisom
[6] iHealth
[7] Withings
[8] Cellnovo
[9] Røykeslutt

money a user has saved at a particular time, which can be seen as "gamifying" the element of money in order to motivate users.

2.5.5 Wii Fit Plus

Nintendo Wii has gamified the way people train at home with Wii Fit and later Wii Fit Plus [10] . It gives a user the ability to choose their own training programme, including Yoga, Strength and Aerobics. Users can easily track their progress over several months. Additionally, it allows children to stay healthy, by having games that depend on their movement. For instance, if a child flaps their arms up and down, they fly a bird on the screen.

[10] Wii Fit

Chapter 3

Gamification

This chapter will give a description of the term "Gamification", describe some of the uses of Gamification and how we plan to use Gamification in our solution.

3.1 What is Gamification?

"Gamification" as a term was first mentioned by Currier in 2008[13], but did not become a wide-spread term before 2010.

There are many different ways of describing gamification. Deterding, Dixon, Khaled and Nacke[14] define Gamification as:

Gamification is the use of game design elements in non-game contexts.

Huotari and Hamari[15] defines gamification as:

Gamification is a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation.

Deterding, Dixon, Khaled and Nacke's definition is often commonly referred to, because of it's simplicity and understandability for people who have little or no connection to traditional games or game consoles.

Today gamification is a much used term both in programming and in the spoken language. Smartphone applications and manufacturers have helped make the term gamification a widespread notion. Examples of this is the application Foursquare, which is built around gamifying "checking in" at restaurants, historical sites and similar places [16]. Apple developed a Game Center for iOS in 2010, giving every iPhone/iPod and iPad user a hub for challenges, awards and other gamelike activities[17], which made every iOS user a potential target for Gamification. Lately there has been many games built singularily around gamification, such as Cookie Clicker [18] or Farmville [19]. Even game consoles like Playstation 3 and XBox contain gamification support per default, with their achievement/trophy systems [20, 21]. While there are many users of such games, they are often critiqued for using gamification to lure players into playing.

3.2 What is Serious Games?

The term "serious game" became a concept with the emergence of the Serious Game Initiative in 2002 [22]. Their website defines serious games as:

"The Serious Games Initiative is focused on uses for games in exploring management and leadership challenges facing the public sector. Part of its overall charter is to help forge productive links between the electronic game industry and projects involving the use of games in education, training, health, and public policy."

This definition has been critiqued for being to narrow, and not including any reason as to why businesses should care. An anonymous author[1] posted an essay on www.lostgarden.com criticizing the definition and suggesting the following definition:

"Serious Games: The application of gaming technology, process, and design to the solution of problems faced by businesses and other organizations. Serious games promote the transfer and cross fertilization of game development knowledge and techniques in traditionally non-game markets such as training, product design, sales, marketing, etc."

Since it's debut in 2002, serious games has later grown to becoming a multi-billion industry. Pilots are being trained in simulators, lecturers make lecture quizzes for students[23], swedish firefighters have used serious games for training [24] and persons suffering from diabetes have the ability of using serious games for learning about the illness. These are just a few of the many ways of using serious games.

Foldit is a very interesting example of how a serious game may lead to knowledge and solving bigger problems than the game itself[25]. Foldit is a massive multiplayer online game (MMO). The objective for the player is to fold protein following a set of rules. The system records how players fold protein and learns patterns for interaction. Humans have much higher skills at interacting with 3D objects than computers, and the system

[1]The essay is only signed with the name 'Danc'. Still, we regard this essay interesting and relevant, and it has been mentioned in several scientific publications.

learns patterns and techniques from the players. By playing Foldit, researchers were able to solve the crystal structure of the M-PMV retroviral protease [2] [26].

Serious Games and gamification have many similarities, whereas serious games are mainly targeted towards making education or learning more fun, gamification is used in a number of different ways. We seek to learn from the successfull uses of serious games when developing [INSERT APPNAME].

3.3 Discussion about Gamification

Gamification is a much discussed theme, where there does not seem to be an agreement as to which gamification is a useful or not. Antin and Churchill argues that gamification may be used for goal setting or instruction [27]. Goal setting challenge the users to meet the mark that is set for them, and is known to be an effective motivator [28].

Bogost goes as far as naming gamification as “marketing bullshit”, used as a way of moneytizing bad business [29].

McGonigal’s studies on how rewards are perceived over time show that:

After three hours of consecutive online play, gamers receive 50 percent fewer rewards (and half the fiero[3]) for accomplishing the same amount of work. [31]

Steinung arguments for gamification not being powerful enough to make a task interesting [32]. Simply adding points, badges, a leveling system or similiar, won’t make a task interesting on its own. Since gamification is based on behavioural pshychology, poor design may be perceived as interesting, for a shorter period of time [32]. Zichermann makes a similar statement, saying gamification needs to take ethical precautions [33].

While McGonigal’s research dives into how rewards are percieved when playing over a longer consecutive time, our intent is to make the user spend only small amounts of time using the application. [INSERT APPNAME] is a tool, not a time-waster.

In order to achieve a meaningful use of gamification Nicholson[34] suggests using a user-centered design approach[35] when developing system with elements of gamification.

3.4 Use of Gamification in [INSERT APPNAME]

Stapleton argues that:

[2] Mason Pfizer Monkey Virus

[3] Fiero is an italian term for personal triumph[30]

A variety of [serious game] applications can be thought of here [in Health Care] such as games as a form of motivation and reward for patients undergoing some form of treatment. Games could also be to distract patients during certain procedures such as dental work, for example.[36]

We agree with Stapleton with the fact that serious games can create a motivation factor for children in order to take their medicine, as children do not necessarily understand why they take it.

In [INSERT APPNAME] we aim to use gamification as a distraction and rewarding element for the children. Instead of putting a lot of predefined badges, rewards, experience points or other rewarding elements, we let the users choose their own rewards, which implies that users can decide what works best for them.

The children are rewarded with stars based on their health state. The rationale behind for this is that the children may have to take more medicine when they have a cold or there is much pollen in the air. The parents have access to a administrator menu where they may set new rewards for the children. The children will then be able to order the rewards when they have earned enough stars. This way the parents and their children create their own gamification environment. Examples on possible rewards could be to give their child an extra 10 NOK in allowance, taking them to soccer matches or even take them to the local amusement park. It is an option where the only boundary is the imagination and how much cost and effort parents want to put into it.

The rewards will appear at a "milestone" basis. We do not want children to feel they lose something if they buy a reward, which some probably could feel if stars were taken away from them. We do not want to force parents into giving away rewards they can not afford or do not wish to use. Therefore we will be testing the application without the gamification elements, in order to find how introduction of gamification elements will affect the use. The use of rewards is also optional and decided by the user, making them in control of how they wish to gamify the experience. We do not wish to have the children spending too much time using the application, since using a tablet or phone at such a young age is considered unhealthy, which is taken into consideration with making an application which is mostly used "outside" the digital application itself. The children may recieve rewards and use the TUI without touching the smart phone.

Chapter 4

Tangible User Interfaces

This chapter will introduce the reader to Tangible User Interfaces, and elaborate on some existing research that has been done on the concept.

4.1 About Tangible User Interfaces

In 1997, Ishii et. al. presented an article called “Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms”. They established the term “Tangible User Interface” (TUI) as a way to move beyond the dominant model of Graphical User Interfaces. The objective of TUI was explained to *augment the real physical world by coupling digital information to everyday physical objects and environments* [37]. Thus, TUIs are about giving physical objects a digital meaning.

Additionally, combining augmented reality (AR) with objects have been proven to improve children’s cognitive learning [38].

The Karotz is an example of a tangible user interface. It lets the user interact with a rabbit instead of a desktop or tablet, which contains digital information about whether it is time to take medicine, and can send digital information when a child has taken his/her medicine.

4.2 Examples of Use

Using TUIs instead of GUIs have been proven to work in several different settings. In this section, we will give an overview on some of the domains in which the concept has been proven to work.

Learning Terrenghi et al. designed a cube for learning, giving children quizzes where answers had the shape of text or images [39]. Children could then rotate the cube in order to get the correct answer pointing upwards, sort of like a dice. They concluded that the TUI gave children a different set of affordances that prompted a great initial engagement [39].

Collaborative Learning Scarlatos et. al. created a system called TICLE (Tangible Interface in Collaborative Learning), which are used to help children solve a Tangram [40].

Interactive Storytelling Zhou et. al. designed a cube for storytelling, using a head mounted display and a "Magic story cube" in order to let children explore the world while being told a story [38]. Stanton et. al. created a "Magic Carpet", giving children possiblity to influence a story in the classroom [41].

Social Context Marble Answering Machine is an invention by Durrell Bishop, dating back to 1992[42]. The interface allows users to drop marbles into a play-back indent on the system, which plays a recorded message.

4.3 Effects of Robots

In 2003, Wada et. al. conducted a study on how the introduction of robotics affected the elderly. [43]. They conducted a study at a day service center in Japan, where they placed a robotic seal, named Paro, together with the elderly. It had recently been found that animals have a positive effects on blood preassure, depression and loneliness. They placed a robotic seal in the care center, and analyzed the reactions from the elderly.

The results showed that their mood was better after interacting with Paro over five weeks, and became worse once Paro was no longer there. In addition, nurses burnout rate decreased during the experiment, which implied that the subjects had easier days whenever Paro was there. The study shows that their quality of life was improved after Paro was introduced.

4.4 Are Tangible Interfaces more fun?

In 2008, Xie et. al. performed a study on how children reacted using different interfaces in order to solve a jigsaw puzzle [44]. The different interfaces were a physical interface (i.e. a standard jigsaw puzzle), a TUI and a GUI. Their findings were mainly that children enjoyed playing with the different interfaces similarly. However, the children were more likely to start a puzzle over again if the interface were physical or tangible, which implies that a repeated task is more likely to be performed if they're playing with a tangible or physical interface, while it becomes boring to do the same task over and over again on a graphical user interface. It is worth mentioning that the puzzles were being solved by groups of two, and considering the GUI was a computer with one mouse, they didn't get the same sharing experience as with the other interfaces.

4.5 How to create a TUI

Ullmer states four different properties a system should have in order to be a tangible user interfaces[45]:

1. Physically embodied
2. Physically representational
3. Physically manipulable
4. Spatially Reconfigurable

Ullmer states that these four properties describe systems that use spatially reconfigurable physical artifacts as representations and controls for digital information.

Ullmer proposes three different classes of TUI's: Interactive Surfaces, Token and Constraints, and Constructive Assemblies. These classes are partly based on varying degree of support for continuous and discrete forms of interaction [45].

4.5.1 Token + Constraint Approach

The "Token + Constraint" approach centers on a hierarchical relationship between tokens and constraints. Tokens may be placed within or removed from the compatible constraints. The physical shape of the tokens and constraints display whether or not the tokens are compatible or not. This approach support a combination of continuous and discrete interactions.

Strenghts of token + constraint approach Ullmer states that interpretive constraints will help to express which of the physical tokens that can take part within a given interpretive constraint, which physical configurations these physical tokens can take and the demarcation between interaction regions with different computational interpretation.

These interpretive constraints may help to simplify the human perception since humans are good at compare shapes and forms. It may help human manipulation since interpretive constraints provide an increased sense of kinesthetic feedback from the manipulation of tokens.

4.5.2 Design Approach to TUI's

A lot of material exists on the potential benefits of TUI's, but few exists on how to actually create them. Champoux proposes a mechanism to design TUI's based achieving fitness between the form and its context [2]. He proposes three classes of questions, which corresponds to the different development phases of TUIs:

- Defining the boundaries
- Orienting the components
- Fitting the components

By answering the questions in Table 4.1, his mechanism will ease the development phase.

Defining the Boundaries	**Orienting the Concepts**	**Fitting the Components**
BO1: What should the user experience? **BO2**: What are the human task? **BO3**: What would the artefact represent and control? **BO4**: What are the conventions? (Physical ergonomics vs electromechanical)	**OC5a**: What is the nature of the interaction for each sub task? (Continuous vs Discrete vs Assembly) **OC5b**: What are the electromechanical and physical ergonomic constraints for this task? **OC6**: Does the sub-task need any relational interaction?	**FC7**: What are the relations between the objects and the actions? **FC8**: What is the task order when using the artefact?

TABLE 4.1: The eight questions stated by Champoux [2]

We consider Question **OC5b** as irrelevant for our purposes, as we will have a stationary device without any electromechanical and phyical ergonomic properties, i.e. moving arms, waving ears, etc.

4.6 Co-design

This section will describe co-design and how we plan to use a co-design approach when developing our TUI.

4.6.1 What is co-design?

Co-design is a product, service, or organization development process where design professionals empower, encourage, and guide users to develop solutions for themselves. Co-design encourages the blurring of the role between user and designer, focusing on the process by which the design objective is created [46]. By encouraging the trained designer and the end user to create ideas and solutions together, the final result will be more appropriate and acceptable to the end user [47]. Albinsson et al [47] discovered that having a co-design approach to development of a e-mail sorting system lead to the ability of easier conflict management, ability to centre innovation on the client/customer and made it easier to manage a project with an unknown outcome. While co-design has been around for over 40 years, it draws it's roots from user-centered design and participatory design. Co-design differs from user-centered design approaches in that it acknowledges that the client or beneficiary of the design may not be using the artifact itself [48].

4.6.2 Using co-design to build AsthmaBuddy

Based on the research we have read, and recommendation from domain experts, we have chosen to try a co-design approach to develop our TUI; AsthmaBuddy. We will build a low-fidelity prototype which we can show to a group of test persons and domain experts. These sessions will take place at a usability lab in order to make sure we record all answers we get during the sessions. A session will consist of us showing the functionality and design of the current prototype, a test where the test persons may use the prototype in order to get to know it better and an interview/brainstorming where the test persons may give feedback. In order to achieve useful feedback we will answer the questions stated in Table 4.1 beforehand, thus limiting the options of the participants to a reasonable level.

Based on the feedback and ideas from the co-design session we will build a new prototype which we will bring back to the next co-design session. These sessions will be arranged at regular short intervals, so we may get much feedback and ensure that we do not go off track when developing AsthmaBuddy.

4.7 Challenges when creating TUI

Working with GUI's are somewhat easy from a usability point of view. Assuming that every potential user has used some sort of GUI-based application before, there should not be any fundemental affordance problems when creating a desktop application. What a user expects from a computer mouse is simply given beforehand. However, with TUIs, no such expectations from the user exist. Bellotti et. al. [49] has found several research challenges with creating usable TUIs and ubiquitous systems. This section will elaborate on some of the questions we have to ask ourselves when we are creating our TUI.

Bellotti et. al. found five basic issues considering communication between a human and a system; Address, Attention, Action, Alignment and Accident. These issues were then asked as questions, which exposed several challenges. Some of the challenges they found considered ubiquitous computing, i.e. assuming there are several possible target systems at the same location. Table 4.2 shows an appropriate subset of their findings, with our project in mind.

Basic question	**Exposed Challenges**
Address: How do I address one of many possible devices?	How do disambiguate intended target system. How to not address the system.
Attention: How do I know the system is ready and attending to my actions?	How to embody appropriate feedback, so that the user can be aware of the system's attention. How to direct feedback to zone of user attention.
Action: How do I effect a meaningful action, control its extent and possibly specify a target or targets for my action?	How to identify and select a possible object for action
Alignment: How do I know the system is doing (has done) the right thing?	How to make system state perceivable and persistent or query-able. How to direct timely and appropriate feedback. How to provide distinctive feedback on results and state.
Accident: How do I avoid mistakes	How to control or cancel system action in progress. How to disambiguate what to undo in time. How to intervene when user makes obvious error

Table 4.2: The challenges of interacting with TUI [49]

Some of the challenges that we immedietely see will be especially hard for us to counter is:

- How to control or cancel system action in progress.
- How to make system state perceivable and persistent.
- How to embody appropriate feedback, so that the user can be aware of the system's attention.

An overview of how we plan to counter these challenges is included in Section 6.2.3

Chapter 5

Usability

This chapter will give a brief definition of what usability is, and how user tests can help us improve it. Since the applications are targeted towards both children and adults, we will give a description of how the usability tests for these groups will differ.

5.1 What is usability?

There are many ways to describe the term usability.

The International Organization for Standardization(ISO) uses the following definition of the term usability [50]:

Extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

The same document defines the term "context of use" as:

Users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used.

These definitions cover how the system is used, the user's thoughts about the use and the context of the system. This can be broken down further into several subgoals in order to achieve better usability, and to give a better insight as to what usability is. These subgoals are:

1. How precisely is the user able to perform a task by using the application?
2. How much resources(for example time, or number of tries) was used to perform the given task using the application?

3. How many errors occurred?
4. Did the user find the use satisfactory?

User-centered design is a way of taking extra precautionary measures by having the end user in mind throughout the process. By using this technique the aforementioned goals are achievable. User-centered design is about getting feedback from the users during the design and development process. Being able to imagine how the end user would solve this problem, and consolidate the users when in doubt is a fundamental part of user-centered design. The user's opinion is the measure of how good the system performs and the user's feedback defines how you score on usability.

Schneiderman stated eight golden rules in order to achieve a good usability of computer systems[51]. In his rules he mentions consistency, informative feedback, reducing short term memory load and permitting easy reversal of actions. These eight golden rules have since their publication become a central part of usability engineering.

In the technological world of today, usability is extremely important in other to achieve success for a system. The users expect a functional easy to use system. From the user's point of view, working with a product which is easily understood, leads to increased productivity, which may lead to increased sales/usage [52]. Proper usability engineering may also lead to lower costs for the developers and higher chances of projects being finished on time [53].

5.2 How to test usability

There are many approaches to creating a good user experience. Having knowledge of expert opinions is always a good idea, and using user-centered design techniques is also a choice. According to Rubin's handbook of usability testing [54], developers should get feedback from users by users tests at different stages of development. According to Rubin, having a user-centered approach will help the developers to address the weakest parts of their system, and give feedback on design decisions.

A user-centered design can be done in many different ways and at different stages of the product life cycle [55], as shown in Table 5.1:

Method	**Purpose**	**Phase of the project life-cycle**
Background interviews and questionnaires	To collect data and to understand the user better	When starting the project
Focus groups	Discover design issues and receive feedback	At an early stage
On-site observation	To both collect information of the context the system will be used in, and find the primary problems the users may have	At an early stage
Role playing / simulations	Will give a broader understanding of what the user expects from the system	Early to mid stage of the project
Automated evaluation	Gives feedback on deviations from standards or best practices. This method excludes actual users, but is based on well tested principles	Mid to end of the project
Usability testing	To measure the usability of the system and provide feedback on very specific elements that are badly designed	Abras [55] says it should be at the end of the project while others [56] think it should be done in iterations throughout the project.
Interviews and questionnaires	Gives a qualitative measurement of how good or bad the system is	End of the project

Table 5.1: Methods of user-centered feedback

Usability Testing The purpose of usability testing is to increase the usability of a system. At the same time, performing these usability tests may save the developers some time and reduce the cost of the project by removing errors and poor design at an early stage [57].

The usability testing can be performed in different ways [56]. At the early stages of the project, low-fidelity prototypes are a good option since they will provide feedback and take proportionally little time to make, making it easier to have more iterations of testing. The different testing methods include a potential user of the system performing

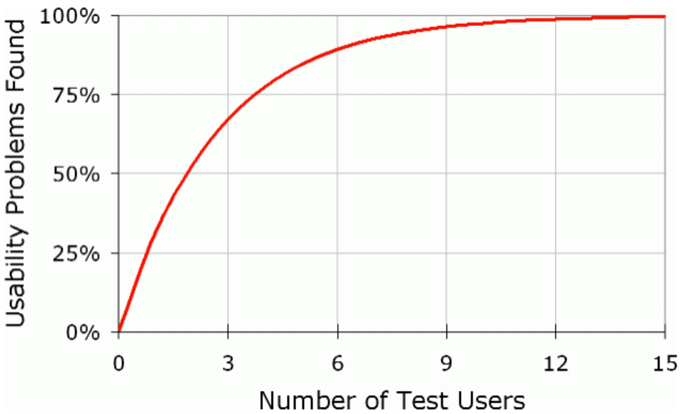


FIGURE 5.1: Number of users needed to find percentage of errors according to J. Nielsen[1]

tasks to provide real data. Observing and recording each usability test may help the developers to analyze their system, and correct the flaws [57].

Before starting the usability tests, the developers should plan goals for what they want to know about the system [58]. This will ensure that the purpose of the test is fulfilled. The developers should then plan tasks according to the desired results. These tasks should allow the user to explore the system, or the parts the developers wish to test, giving the test person some time per task, in order to not stress the test person.

After being planned, the test should be run on a number of different test persons. From Figure 5.1 , you can see that as the number of participants increases, the number of undetected errors decrease.

Nielsen states that after five user tests, 85% of the errors have been found [1]. Molich[59] states that six test persons is the ultimate number. Faulkner [60] states that while six test persons *may* find 85 % of the errors, they may also find considerably less. In Faulkner's research, a number of five test users found between 55 % and 100 % of the errors, while 20 test persons found between 95 % and 100 % of the errors.

In addition to the practical usability tests, we will use techniques such as background interviews, focus groups and on-site observations. The interviews will be performed in order to achieve a set of control data we can use for comparison when performing later usability test and codesign sessions. As mentioned in 4.6, we plan on arranging focus group sessions at an early and mid stage of the development of our TUI. These sessions will help us develop our TUI and eliminate usability issues at an early stage. We also plan on using the technique of on-site observation by letting children operate our TUI freely, in order to observe interaction between the children and the TUI.

Testing environment The next thing to consider when performing usability testing is the testing environment. It should resemble the environment in which the system will be used. To make the most of the tests, it is wise to perform videotaping of the tests. This will help when reviewing the results from the test If the test are being recorded, a consent from the test person or his/her parent will be required.

Before the test persons arrive, a test leader should be chosen, in order to have a person to guide the test persons through the process. The test leader should be in charge of testing and act as an interviewer to help the participant to "think-aloud"[61]. The test leader should answer questions from the participant, but be careful not to give away information that may affect the results of the test.

After the tasks are done, it is necessary to gather loose ends and get answers to all the questions that might be unanswered. A system usability scale(SUS)[62] may be a good way to grade the usability of the system together with the observations made during the test. The SUS scale will reflect on how satisfying the usability is in the eyes of the users. Bangor et. al. [63] have made a scale based on the SUS-forms from different system usability tests, in order to make it possible to compare the mean score of a system with what is an acceptable level of usability. In our testing, we will make use of a Norwegian version, developed by Svanæs (see Appendix A), which will be answered by the test users or the parent of the test user.

5.3 How to test usability on children and toddlers

While usability testing on children and toddlers have the same basic approach as testing on adults, there are many more precautions to be followed. Hanna et. al. [64] lays out some of these precautions. They recommend not using children that are skilled with computers since they may find the tasks too easy and will not produce useful data. Since children these days have a higher skill with computers thanks to the invasion of tablets and smart phones [9], this may not be as much of a concern.

Since our application is targeted towards children with Asthma, we want to test the system on children suffering from Asthma in addition to children from the same age group, not suffering from Asthma. These children will most likely have a different approach to the system and may give different feedback.

Hanna et. al. also point out changed that should be made to the testing environment as mentioned in 5.2. They recommend making the testing environment more suitable for children by placing colourful posters on the walls. Children of young age may be afraid of "The Doctor's Office" and we will need to make adjustments to avoid frightening the children upon their arrival at the test lab.

As mentioned by Donker and Markopoulos [65] talk-aloud is very useful technique when doing usability testing with children. Talk-aloud is a technique were the children talk about what they are doing instead of what they are thinking.

5.4 Usability testing on mobile devices

We plan on doing usability testing in testing lab or quiet testing office. The application's main environment for use will be at the user's home, which may be noisier and more hectic than our testing lab. Kaikkonen et. al. states that the similarity between testing environment and place of use is not too important, the test user will still be able to complete the tasks and find the same number of errors citekallio2005usability. This claim is supported by Beck et. al. who discovered that the test persons found more usability problems when sitting down, in difference to when walking on the street [66].

Schusterich et. al. [67] published a guide on how to build the perfect infrastructure for usability testing on mobile devices, in 2007. They describe how generic infrastructure issues, mobile device-specific issues and usability study context issues should be taken into consideration. Shcusterich et. al. recommends having a number of cameras recording from different angles in order to capture unbiased interaction patterns of the mobile device.

5.4.1 Emulator versus device

When developing for mobile devices such as Android, it is possible to run an emulator on a pc, instead of running the application on an Android device. The emulator emulates the use of a mobile device on screen. Input must be given by mouse-clicks on buttons/screen elements. The Android emulator emulates use of system resources corresponding to a given Android device, in order to not act faster or slower that a real device. While this may be true in theory, it is not always true in practice. The emulator is often much slower than an actual device.

The question arises, should one do usability testing on an emulator or on a real device? Using the emulator allows for easier capture of the interaction with the device, since it allows screen recording of user input and easier capture of the user when interacting with the emulator. Using a computer as a test object may be more positively perceived

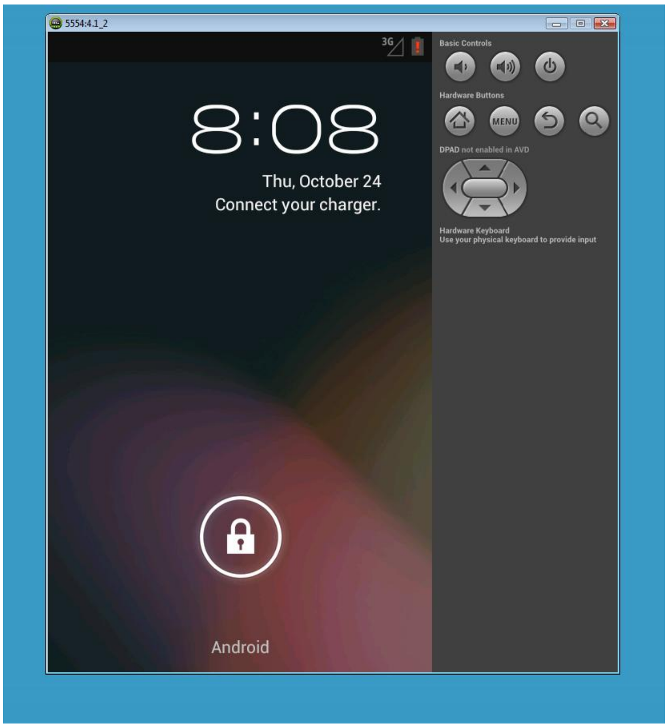


FIGURE 5.2: The Android Emulator running an emulation of Android 4.1

by the test user rather than installing the test application on their device or having them doing tests on our device.

Using a real device has the benefit of being an actual device, and may lead to a more realistic interaction pattern when using the application. While there exists a number of screen recorders for Android devices, these require that the device is rooted [1] , which is not an option for us. The use of a real device also allows the use of gestures, which is a benefit in contrast to the emulator which can simulate swiping.

Beitol and Cybis [68] compared doing usability testing on a tripod-mounted device to an emulator and using a device in the field. They found that many users found the tripod-mounted device difficult and unnatural to operate. The users found 80% of the usability issues on the emulator, but Beitol and Cybis points out that use of an emulator may depend on the similarity between the emulator and the device.

Based on the research we have read we decided to do the usability testing on a real device, in a usability test lab.

[1] Android Rooting

Chapter 6

Introducing: AsthmaBuddy

This chapter will give a brief introduction into the TUI we are planning to create, named AsthmaBuddy.

6.1 Introduction

From our experiences with Karotz [6], we have found that we do not want to go any further with it. The thought behind Karotz is great, but these thoughts are, in our subjective opinion, poorly executed. If we were to test the concept at people's homes, we would need to preconfigure the units down to the smallest details. Just the fact that we would have to ask families for their WiFi-credentials before testing a system, should be reasons enough. Additionally, the Karotz API is only documented in French, which makes it considerable harder to develop for. The largest challenge by using Karotz is it's price. A Karotz starters kit costs $200, not including customs to Norway. Making such a large investment on a product parents have no experience with is going to be quite difficult from a commercial standpoint.

We have also taken a brief look into Arduino, which is an open source electronics prototyping platform [69]. We have seen some of the projects that have been done in Ardunio, and have found that they require competence and knowledge we simply do not have, i.e. digital design and circuit boards.

The idea we have found most exciting, both for ourselves and as a solution, is Rasperry Pi [70]. It is a cheap computer with the size of a credit card, with the original intention of teaching british school children about computer programming [71]. Since the release early in 2012, it has sold more than 1 million units, and is highly popular among computer enthusiasts [72].

6.2 What do we want to create?

On a high level of abstraction, what we want to create here is a descrete artifact children can have at their rooms, which can remind them to take their medicine, and help them through the process. Our plan for the time being is basically to wrap the Rasperry Pi inside a toy, i.e. teddy bear, a doll, or some other popular, medium sized toy. We do not intend to answer the question of which wrapping is ideal for this product. For the time being, we have given the product the name *AsthmaBuddy*.

We consider the following as the minimum set of abilities for our TUI:

- Ability to connect to a network, either through ethernet or WiFi, though both are preferred.
- Play sounds through speakers
- Ability to read RFID-chips
- Display information about the color of the asthma medicine through LED-lights

6.2.1 A basic scenario

In order to get a basic understanding of what we are trying to achieve here, we have included a basic scenario below. Assume that we have our Rasperry Pi inside a teddy bear.

1. (AsthmaBuddy): Cough, cough. Come over here kiddo
2. (Kid approaches)
3. (AsthmaBuddy): I need my asthma medicine now. Could you please help me? The color of the medicine is displayed at my belly.
4. (Kid finds the medicine)
5. (When the child holds the medicine towards the mouth of AsthmaBuddy, the RFID chip on the medicine is read, which instructs AsthmaBuddy to continue).
6. (AsthmaBuddy): Thanks. Now it is your turn to take your medicine.
7. (AsthmaBuddy): By taking this medication, you make it easier for yourself to breathe.
8. (AsthmaBuddy): Now, find your mask and put it over your nose and mouth. You need to press the button at the top of your medicine before you start breathing.
9. (AsthmaBuddy): (Counts for the amount of seconds needed)
10. (AsthmaBuddy): Great job!

The idea behind having a voice to AsthmaBuddy is to establish a two-way communcation between children and the artifact. We want children to actually care for our product, which may be achieved through giving the artifact a sense of personality.

6.2.2 Components

RFID We will be using RFID-technology to let children interact with AsthmaBuddy. Our plan is to attach an RFID-chip to each of the childrens' medicines, which in turn can be read by AsthmaBuddy. For instance, during step 5 in the above scenario, a child can hold the medicine towards the mouth of the bear. The type of the medicine is read by AsthmaBuddy, who can notify the child if he/she is starting to take the wrong medicine.

Speakers The speakers will be used to play prerecorded messages from AsthmaBuddy.

Connect to network Ideally, we want to attach a WIFI shield to our Rasperry Pi, making it able to connect wirelessly. The benefits of this is that it makes the TUI portable. However, this might include having to preconfigure the system as with Karotz as mentioned in Section 6.1. This makes it a problem we will have to research further before deciding on a solution for our prototype. Information we want to send through the network consists mainly of alarm notifications set by parents, i.e. when AsthmaBuddy should giving signals that it needs medication.

LED-lights Through LED-lights, we intend to show the color of the medicine that is to be taken. As we cannot assume children are able to read, or to remember the name of the medicine, Aaberg et. al. have found that showing the color is a feasible solution to showing which medicine should be taken [3].

6.2.3 Handling Bellotti's Challenges

The main challenges Bellotti has identified (see Table 4.2) is *"How to control or cancel system action in progress"* and *"How to specify and select a possible object for action"*. We have previously stated that there are two cases in which a child will take their medicine, *by need* and *preventive*. An issue that could be rising is how to detect when a child needs to take a medicine by need. Preventive medicines will fire alarms on AsthmaBuddy, and the child automatically knows that the system is "awake". However, when a child needs to take it by need, there is no other intuitive way to show that the

AsthmaBuddy is awake than using LED-lights, which are key for the system to work out. Thus, the solution to the second challenge is usage of LED-lights. Cancelling operations however is really hard to find a "good" solution from a usability standpoint.

For instance, if AsthmaBuddy starts counting seconds on a treatment before a child is ready, there will be a need to reset this counter, or basically at any point during a treatment, go back to the last step. At the moment, the only solution we are able to see at this problem is to use RFID-chips to backtrack, modelling the treatment process as a statemachine.

6.3 Planned modifications of existing system

As far as the software goes, we intend to keep the main parts of the architecture Aaberg et. al. created, with the exception of Karotz being replaced by AsthmaBuddy.

We intend to improve the mobile applications by modifying the following:

Modification	**Rationale**	**Priority**
Modifying the mobile applications to become one single application. CAPP and GAPP will thus become [INSERT APPNAME]	Having two applications is hard to work with, especially when they're so closely connected. It is thus simpler both for us and the user to use one application	High
Support a reward system where parents are able to specify their own rewards	We need to give some sort of reward system in order to motivate children.	High
Support display of air quality meassurements provided by Norwegian Institute for Air Research	Asthma is a disease that is closely coupled with air quality in the area. Making these data easily accessible for parents will hopefully help parents to control their children's disease better.	Medium
Modify the GUI of the mobile applications to meet design guidelines	At the time being, there are little to no consistency among views. This is important to make it easier to use.	High
Improved distraction sequence for children	The current distraction sequence can easily become boring for children over time.	Medium
Support several medications during the same treatment sequence.	At the time being it is not supported. Taking more than one medicine at the time occurs more often than one might think	Low

TABLE 6.1: Intended modifications and their rationale

Chapter 7

Usability Tests

7.1 Purpose

Usability tests is usually performed for detecting errors in a system. We want to use usability tests in a slightly different approach. In addition to discovering errors, we will observe how children take their medicine in combination with technology. We will use the results of the usability tests in order to find potential for improvement and design ideas for the product.

The tasks given to the participants will be created with routine use of the application in mind. Usability tests will be performed with the help of participants with no prior knowledge of the application. These participants will be chosen in order to get valuable feedback on usability problems with the current design and structure, and to prevent invalid feedback from users who already know how to perform the tasks. In addition, this situation mirrors everyday life of the users.

7.2 Test Method

The execution of the usability tests will be based on the theory described in Section 5.2 and Section 5.3.

Before each test, we will perform a quick-and-dirty pilot test in order to discover critical errors that could make an impact on the result.

To ensure that the participants have the wanted background, we will ask them to fill in two forms when registering for the usability tests. These are added in C and D.

The participants will be given an Android mobile device to perform tasks on. The different tasks will be given one by one in order to complete. The participants will be introduced to the "think-aloud"-method, and will be told to ask questions during the process, even though the test leader is not allowed to answers these questions during the test. The main reason for gathering questions is for discussion afterwards or to facilitate the "think-aloud"-method.

Upon finishing the tasks, the participants will be asked to answer the forms in Appendix ?? and A. The test leader will finish the test by asking questions regarding what the participants thought of the system and answer the questions that may have occurred during the test. We will also ask parents how they felt the medication process went, so that they can compare it to their daily situation at home, and whether or not they got the impression that the product could be helpful.

The results will later be analyzed to work out the improvements needed to be done to the system. The errors will be rated after level of severity [57].

- Critical (Level 1) - Prevents the participant from completing the task.
- Siginificant (Level 2) - Generates significant problems when trying to complete the task.
- Minor (Level 3) - Have minor effect on the usability of the application.
- Non-essential (Level 4) - Enchancements to the system. When a participant states that "it would be nice to have this".

7.2.1 Scenario and tasks given to the users

We plan to use test users that speak fluent Norwegian, since the application has Norwegian as it's main language. Therefore the scenario and tasks will also be written in Norwegian. The exact scenario and tasks handed to the participants can be found in Appendix E, but for convenience the next paragraph gives a short summary of the scenario and tasks.

The scenario explained that the user was a parent of a 4-year-old child with asthma. They have recently been to the doctor's office, and will now have to set up treatment plans according to advice given by the specialist. Since they have little experience with asthma, they would have to look up information about the medicines and how the treatment will be done. In order to motivate the child to continue taking his/hers medicine, they will have to add a reward via the application menu. Finally, they would have to look through the calendar log in order to find correlations between the child's health state and use of medicines.

Chapter 8

Conclusions

20% of the Norwegian population has or has had asthma before the age of 10. Treating children for asthma is often a cumbersome task. Research has shown that TUIs and mobile applications have been useful in medical care in a number of different settings. By combining gamification with TUIs and mobile technology, we belive that children will be motivated to take their medicines and get greater awareness of their own disease.

Serious games has given us an idea of how to balance gamification elements properly. When developing a system targeted for children, it is important to use non-obtrusive gamification elements. By letting parents and their children decide upon what the rewards are going to be, we give an opportunity for better motivation factors for both children and their parents.

We have chosen to develop a TUI in addition the Android application. The rationale behind this decision is that TUIs often are percieved as more fun to operate when performing a repetetive task 4.4. We believe that a friendly looking TUI will be percieved in a more positive manner than a smartphone application by the children, while the parents will have more flexibility and easier keep of control with the smartphone application. Inspired by Ullmer [45] we have chosen a token+constraint approach for our TUI; AsthmaBuddy.

We are eager to continue our research.

Appendix A

Norwegian SUS form

This Norwegian version of the SUS form was developed by Svanæs, D. in 2006.

Noen spørsmål om systemet du har brukt.

Vennligst sett kryss i kun en rute pr. spørsmål.

	Sterkt uenig				Sterkt enig
1. Jeg kunne tenke meg å bruke dette systemet ofte.	1	2	3	4	5
2. Jeg synes systemet var unødvendig komplisert.	1	2	3	4	5
3. Jeg synes systemet var lett å bruke.	1	2	3	4	5
4. Jeg tror jeg vil måtte trenge hjelp fra en person med teknisk kunnskap for å kunne bruke dette systemet.	1	2	3	4	5
5. Jeg syntes at de forskjellige delene av systemet hang godt sammen.	1	2	3	4	5
6. Jeg syntes det var for mye inkonsistens i systemet. (Det virket “ulogisk”)	1	2	3	4	5
7. Jeg vil anta at folk flest kan lære seg dette systemet veldig raskt.	1	2	3	4	5
8. Jeg synes systemet var veldig vanskelig å bruke	1	2	3	4	5
9. Jeg følte meg sikker da jeg brukte systemet.	1	2	3	4	5
10. Jeg trenger å lære meg mye før jeg kan komme i gang med å bruke dette systemet på egen hånd.	1	2	3	4	5

SUS
Norsk versjon ved Dag Svanæs
NTNU 2006

Appendix B

Further Work

This chapter gives an overview of some of the ideas both the customer and the developers had for further development of the application. This includes a description of further development, analysis of the user groups and work towards NAAF and the health department. The main part of the work to be done after the end of this project is connected to requirements that has been taken out of this project due to limitation of time and resources. Other issues remaining is connected to the security and privacy of the patient's treatment log and storing sensitive information. Section **??** lists the overall requirements that have not been implemented during the project. These requirements has either been requested early in the process of have been brought up during discussions and meetings with the stakeholders.

B.1 Improvements

The following sections describes the ideas we had for future improvements to the applications. It is parted into subsections for improvements in the fields of database records, the reward system, the distraction and the web application.

B.1.1 Rewardsystem

The children's application (CAPP) is all about changing the children's view of medication to something positive. It shall be a motivation for the children to take their medication. It is therefore an important task to entertain them and give them some form of reward when they take their medication. As for now, we have given stars to the child after completed medication. The stars are in a treasure chest where the child can see how many stars he or she has. This is a simple reward, but worked fairly well during the user tests. However, it may be boring over time.

The initial idea was to have a shop where the children could buy clothes and other items to their avatar. The stars earned from finishing treatments would serve as credits in the shop. This was not implemented due to time restrictions. It is also possible to take this to the real world, e.g. that the child gets a lollipop for every 10th star, but this would have to be supervised by the parents.

There is an endless line of opportunities for this reward system, and we chose the simplest implementation, so we would have something to test.

B.1.2 Distraction sequence for children

During our workshop, we came up with a lot of ideas for distractions for the children. These would range from simple animation sequences, like what we decided to implement, to more complex things like games that would not require a lot of movement and could therefore help during longer treatments.

The distraction sequence is one of the fields were we feel it has more or less never ending possibilities for improvement, and as more research into what children finds distracting, but not to the point where they can't take their medicine, this distraction sequence can be evolved.

B.1.3 User testing of the guardian application

GAPP has not yet been user tested on actual parents of asthmatic children. This has to be done to get an understanding of how they interact with the system, and to get knowledge about what they think of an application of this type. This is a system to make it easier for the guardians to give their children medications. While it is important that the children likes the system, it is also important that the parents feel it helps them give their children their medicines, without it being a big time waster.

B.1.4 Web application

There is a possibility of making this application as a web application, as a whole. By extracting the functionality and running it on a web service it would make it easier for people to use it across platforms. Done right, it may run on all devices with an internet connection. This may also give an easier integration with external information such as air pollution forecast, pollen forecast, temperatures, etc. Since our application is written in Java, using Android SDK, it will not run on an internet server as is. Making a web application will require an almost complete refactoring of the source code.

B.1.5 Support for more children

Currently, the application only use one child, but there are implemented support for using more children. Each child has its own id (childId), and support for more children can be implemented without much change of the existing code. There should also be concidered using accounts for the guardians connected to the children, in case of the guardians having more than one asthmatic child.

B.2 Ideas and minor improvements

Webinterface The doctors may prefer to set up the users medication plans through a web interface on their computers. This part may be integrated into existing systems.

Other devices The application are fitted for a phone running the Android operating system. For the future it should also be scalable to tablets. There may be more interesting for a child to work on a tablet than a phone. There will also be much more space for content. This extra space gives greater potential of the reward system. It should also be available on other operating systems than Android, e.g. iOS or Windows Phone. This will improve the availability for the users, not limiting them to Android phones.

Overall graphical design The priorities have been to make the major functionality work. We have used lots of time making the applications understandable and easy to use, but there is still a great potential in making the applications interaction design better.

Personalize the system The application may be more personalized. E.g. "It's time to take medication" could be "It's time to take medication, Eric". By involving the users name more in the system, they may feel more appreciated.

Integration of external elements The distraction part of the application may be integrated with a story or other external elements. I. eg. a story where the children will need to take medicine in order to get the next part of the story.

Appendix C

Questionnaire. Demographics

Vennligst besvar spørsmå lene under, før vi begynner testen.

Kjønn
Alder
Utdanning
Yrke

Appendix D

Interview conducted before usability testing

Experience with computers
Access to internet
Time spent online per day
Has a smartphone
SMS Usage
Has facebook account
Uses electronic reminders (calendar, to-do list etc)

Appendix E

Scenario and tasks

Du er verge til et barn på 4 år. Dere har nylig vært hos en lege med spesialkompetanse på barnesykdommer. Barnet har fått diagnostisert astma. For å enklere holde orden på at medisinene blir tatt til riktig tid, på riktig måte, har du lastet ned applikasjonen [SETT INN APPNAVN]. Systemet har ikke behov for at du registrerer navn eller lignende, for du ønsker ikke at slik informasjon kommer på avveie. For at du best mulig skal kunne benytte deg av [APPNAVN], er det nødvendig at du gjennomfører noen oppgaver.

Oppgave 1: Du skal sette opp en medisineringsplan i henhold til anbefaling fra legen. For enkelhets skyld skal du kun endre medisineringsplanen for barnet når det er helt friskt. Legg til en varsel for "Flutide" kl 13:37 og en varsel for "Seretide" kl 18:30. Velg deretter å følge denne medisineringsplanen.

Oppgave 2: Barnet ditt tok allerede en dose med medisin da dere var hos legen. Du ønsker å starte loggføringen med en gang. Etterrigstrer bruk av Seretide kl 12:51 i dag.

Oppgave 3: Du ønsker å motivere barnet ditt til å ta medisinene sine uten at det skal bli en krangel hver gang. Lag en premie barnet ditt kan få dersom hun/han har fulgt medisineringsplanen sin. Som premiebilde kan du ta et bilde med kameraet pe̍lefonen, og premietekst og antall stjerner velger du selv.

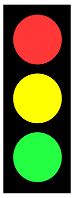
Oppgave 4: Se hvordan barnet ditt ligger an i forhold til målet du satte i forrige oppgave?

Oppgave 5: Det er nå gått to uker, og du ønsker å se hvordan du og ditt barn har fulgt medisineringsplanen. Let gjennom loggen for å se om dere har gjort jobben på en god nok måte.

Du har nå gjennomført testen. Vennligst fyll inn skjemaene for å forklare hvordan du oppfattet bruken av applikasjonen.

Appendix F

Asthma Traffic Light System



Emergency Department
KAPI'OLANI MEDICAL CENTER FOR WOMEN & CHILDREN
An Affiliate of Hawai'i Pacific Health

Triggers: Respiratory infections

Other:________________

Need info: Call ER at 983-8637

Your ASTHMA ACTION PLAN

Your appointment is at 10:00 am tomorrow or the next day that your doctor's office is open. Please call your doctor's office to confirm or call to change your appointment time.

Want to take an Asthma Class: Call 983-6336

GREEN ZONE: DOING WELL

- Breathing is good
- No cough or wheeze
- Can work and play
- Sleeping through the night
- Healthy, no cold symptoms

Use these medicines EVERY DAY even when well

MEDICINE	HOW MUCH	HOW OFTEN / WHEN
Pulmicort OR	1 ampule	1 or 2 times daily
Flovent	1 to 2 puffs	Daily

There are several other possible medicines such as Advair and Singulair. Discuss this with your doctor. These are preventive medicines to prevent bad cough and wheezing.

For asthma with exercise: Use albuterol as needed

YELLOW ZONE: CAUTION

- First sign of a cold
- Exposure to known trigger
- Cough or wheeze
- Tight chest
- Coughing at night
- Problems working or playing
- Some trouble breathing

Continue Green Zone control medications and add:

MEDICINE	HOW MUCH	HOW OFTEN / WHEN
Albuterol Xopenex OR	1 ampule	Now and repeat in 20 minutes, plus every 3 to 4 hours
Albuterol or Xopenex inhaler	2 to 4 puffs	
Prednisolone or prednisone	Call your doctor now for dose and how often to give it	

Move to the RED ZONE if no improvement

RED ZONE: DANGER

- Cannot work or play
- Getting worse instead of better
- Medicine is not working
- Breathing is hard and fast
- Nose open wide
- Ribs showing
- Trouble talking

Take these medications and CALL YOUR DOCTOR NOW

MEDICINE	HOW MUCH	HOW OFTEN / WHEN
Albuterol or Xopenex OR	1 ampule	Give treatment every 20 minutes, up to 3 times in a row on your way to the ER or doctor's office
Albuterol or Xopenex inhaler	3 to 5 puffs	
Prednisolone or prednisone	Dosing will be done by ER or your doctor's office	

KMCWC ED Ver. Nov 4, 2009

GET HELP FROM A DOCTOR NOW! THIS IS AN EMEREGNCY. IF YOU CANNOT CONTACT YOUR DOCTOR, GO DIRECTLY TO THE NEAREST E.R. OR CALL 911.

Appendix G

Manuscript

During a medication process, CAPP and KAPP speaks to a child. The following is a breakdown on the manuscript the applications follow.

1. Hei, jeg heter Blipp. Nå er det på tide å ta pustemedisin. Trykk på hodet mitt, så forteller jeg deg mer. *Hi, my name is Blipp. It's time to take the breathing medicine. Press my head, and I'll tell you more.*

2. Hent den C medisinen og masken du puster i, og trykk på hodet mitt når du har hentet dem. *Get the C medicine and the mask you breath in, then press my head when you have fetched them.*

3. Rist den C medisinen. Trykk på hodet når du er klar. *Shake the blue medicine. Press my head when you are ready*

4. Av den C medisinen skal du ta 1 puff. Sett på deg masken og gjør deg klar. Trykk på hodet mitt, så teller jeg mens du puster inn og ut. *You are going to take 1 spray of the C medicine. Put on your mask and get ready. Press my head, and I'll count when you breathe in and out.*

5. Når jeg sier i fra, skal du trykke 1 gang. Trykk på hodet mitt, så begynner jeg å telle. *Upon signal, press the medicine one time. Press my head, and I'll start counting.*

6. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

7. Nå var du flink. *You did great*

8. Som belønning får du N stjerner i skattekista di. *As a reward, you'll get S stars in your treasure chest.*

The above script has the following properties:

C $\in \{Blue, Orange, Purple\}$

S $\in \{1, 3, 5\}$

Appendix H

Constraints

By law, we have some constraints in order to proceed start usability testing. This Appenix cover these.

H.1 The Health Register Act

Norway has specific laws for storing of medical information. The most significant law is "The Health Register Act[1]"[73]. This law regulates who is allowed to store health records and how they store the records.

The most significant consequences is that the information has to be stored on servers on Norwegian soil. This eliminates the option of using cloud-based services such as Amazon EC2, Windows Azure or Google App Engine.

In addition, we need permission from *REK* [2] n order to store medical records in the application. If the application were ever to be deployed to Google Play, we would need permission from *The Data Protection Authority*, but it not required if the application is just for research purposes. Our permission from REK is included in Appendix [INSERT REFERENCE ONCE FOUND].

H.2 Measures for Anonymization

Pursuant to section 16 of the Health Register Act [73] all information that may identify a person, must be encrypted, i.e. it should be impossible to find which person a specific record corresponds to by looking at a database dump.

[1] Lov om helseregistre og behandling av helseopplysninger

[2] https://helseforskning.etikkom.no/

Bibliography

[1] J. Nielsen. Why you only need to test with 5 users. 2000. URL http:///www.useit.com/alertbox/20000319.html.

[2] Sriram Subramanian and Bernard Champoux. A design approach for tangible user interfaces.

[3] Dale Gisvold Svalestuen Aaberg, Aarseth. Blopp - development of a prototype for treatment of asthmatic children, using android and karotz. 2012.

[4] Norges astma- og allergiforbund. URL http://www.naaf.no/.

[5] Jonas Asheim. Konsept for forbedret behandling av barn rammet av astma/rs-virus, 2012.

[6] Karotz - your smart rabbit. URL http://store.karotz.com/en_GB/.

[7] Jacob Anhøj and Claus Møldrup. Feasibility of collecting diary data from asthma patients through mobile phones and sms (short message service): response rate analysis and focus group evaluation from a pilot study. *Journal of Medical Internet Research*, 6(4), 2004.

[8] Toddlers use tablets often, 2011. URL http://www.nrk.no/nyheter/norge/1.7921036.

[9] Babies using smartphones. URL http://www.babies.co.uk/blog/babies-using-smartphones/.

[10] Nor Azah Abdul Aziz. Childrens interaction with tablet applications: Gestures and interface design. *Children*, 2(03), 2013.

[11] Kit Huckvale, Mate Car, Cecily Morrison, and Josip Car. Apps for asthma self-management: a systematic assessment of content and tools. *BMC medicine*, 10(1): 144, 2012.

[12] Communication of illness related experiences of chronically ill children and the effect of sisom, a computerized symptom assessment tool. URL http://www.communicaretools.org/sisom/research/the-effect-of-sisom.aspx.

[13] James Currier. Gamification: Game mechanics is the new marketing, 2008. URL http://blog.oogalabs.com/2008/11/05/gamification-game-mechanics-is-the-new-marketing/.

[14] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: defining "gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, MindTrek '11, pages 9–15, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0816-8. doi: 10.1145/2181037.2181040. URL http://doi.acm.org/10.1145/2181037.2181040.

[15] Kai Huotari and Juho Hamari. Defining gamification: a service marketing perspective. In *Proceeding of the 16th International Academic MindTrek Conference*, pages 17–22. ACM, 2012.

[16] Foursquare, 2013. URL http://foursquare.com.

[17] Apple. How to use game center, 2011. URL http://support.apple.com/kb/HT4314.

[18] Orteil. Cookie clicker, 2013. URL http://orteil.dashnet.org/cookieclicker/.

[19] Zynga. Farmville, 2013. URL http://www.farmville.com.

[20] Xbox, 2013. URL http://xbox.com.

[21] Playstation, 2013. URL http://playstation.com.

[22] Serious games initative, 2013. URL http://http://www.seriousgames.org/.

[23] Alf Inge Wang, OK Mørch-Storstein, and T Øfsdahl. Lecture quiz-a mobile game concept for lectures. In *Proceedings of the 11th IASTED International Conference on Software Engineering and Application (SEA07)*, pages 305–310, 2007.

[24] Mikael Lebram, Per Backlund, Henrik Engström, and Mikael Johannesson. Design and architecture of sidh–a cave based firefighter training game. In *Design and Use of Serious Games*, pages 19–31. Springer, 2009.

[25] Seth Cooper, Firas Khatib, Adrien Treuille, Janos Barbero, Jeehyung Lee, Michael Beenen, Andrew Leaver-Fay, David Baker, Zoran Popović, et al. Predicting protein structures with a multiplayer online game. *Nature*, 466(7307):756–760, 2010.

[26] Firas Khatib, Frank DiMaio, Seth Cooper, Maciej Kazmierczyk, Miroslaw Gilski, Szymon Krzywda, Helena Zabranska, Iva Pichova, James Thompson, Zoran Popović, et al. Crystal structure of a monomeric retroviral protease solved by protein folding game players. *Nature structural & molecular biology*, 18(10):1175–1177, 2011.

[27] Judd Antin and Elizabeth F Churchill. Badges in social media: A social psychological perspective. In *CHI 2011 Gamification Workshop Proceedings (Vancouver, BC, Canada, 2011)*, 2011.

[28] Kimberly Ling, Gerard Beenen, Pamela Ludford, Xiaoqing Wang, Klarissa Chang, Xin Li, Dan Cosley, Dan Frankowski, Loren Terveen, Al Mamunur Rashid, et al. Using social psychology to motivate contributions to online communities. *Journal of Computer-Mediated Communication*, 10(4):00–00, 2005.

[29] Ian Bogost. Gamification is bullshit, 2011. URL http://www.bogost.com/blog/gamification_is_bullshit.shtml.

[30] Paul Ekman. *Emotions revealed: Recognizing faces and feelings to improve communication and emotional life.* Macmillan, 2007.

[31] McGonigal Jane. Reality is broken, why games make us better and how they can change the world, 2011.

[32] Truls Steinung. Interessante utfordringer: En studie av gamification og belønningsstrukturer i et spillperspektiv. 2012.

[33] Gabe Zichermann and Christopher Cunningham. *Gamification by Design: Implementing game mechanics in web and mobile apps.* O'Reilly Media, Inc., 2011.

[34] Scott Nicholson. A user-centered theoretical framework for meaningful gamification. *Proceedings GLS*, 8, 2012.

[35] Theodore W Frick Michael D. Corry and Lisa Hansen. User-centered design and usability testing of a web site: An illustrative case study. *Educational Technology Research and Development*, 45:65–76, 1997. URL http://www.jstor.org/stable/30221343.

[36] Andrew J Stapleton. Serious games: Serious opportunities. In *Australian Game Developers Conference, Academic Summit, Melbourne*, 2004.

[37] Hiroshi Ishii and Brygg Ullmer. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, pages 234–241. ACM, 1997.

[38] Zhiying Zhou, Adrian David Cheok, JiunHorng Pan, and Yu Li. Magic story cube: an interactive tangible interface for storytelling. In *Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology*, pages 364–365. ACM, 2004.

[39] Lucia Terrenghi, Matthias Kranz, Paul Holleis, and Albrecht Schmidt. A cube to learn: a tangible user interface for the design of a learning appliance. *Personal and Ubiquitous Computing*, 10(2-3):153–158, 2006.

[40] Lori L Scarlatos, Yuliya Dushkina, and Shalva Landy. Ticle: a tangible interface for collaborative learning environments. In *CHI'99 Extended Abstracts on Human Factors in Computing Systems*, pages 260–261. ACM, 1999.

[41] Danae Stanton, Victor Bayon, Helen Neale, Ahmed Ghali, Steve Benford, Sue Cobb, Rob Ingram, Claire O'Malley, John Wilson, and Tony Pridmore. Classroom collaboration in the design of tangible interfaces for storytelling. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 482–489. ACM, 2001.

[42] Gillian Crampton Smith. The hand that rocks the cradle. *ID magazine*, pages 60–65, 1995.

[43] Kazuyoshi Wada, Takanori Shibata, Tomoko Saito, and Kazuo Tanie. Effects of robot-assisted activity for elderly people and nurses at a day service center. *Proceedings of the IEEE*, 92(11):1780–1788, 2004.

[44] Lesley Xie, Alissa N Antle, and Nima Motamedi. Are tangibles more fun?: comparing children's enjoyment and engagement using physical, graphical and tangible user interfaces. In *Proceedings of the 2nd international conference on Tangible and embedded interaction*, pages 191–198. ACM, 2008.

[45] Brygg Anders Ullmer. *Tangible interfaces for manipulating aggregates of digital information*. PhD thesis, Massachusetts Institute of Technology, 2002.

[46] Elizabeth B-N Sanders and Pieter Jan Stappers. Co-creation and the new landscapes of design. *Co-design*, 4(1):5–18, 2008.

[47] Lars Albinsson, Mikael Lind, and Olov Forsgren. Co-design: an approach to border crossing, network innovation. *Expanding the knowledge economy: issues, applications, case studies*, 4(Part 2):977–983, 2007.

[48] Donald A Norman and Stephen W Draper. *User centered system design; new perspectives on human-computer interaction*. L. Erlbaum Associates Inc., 1986.

[49] Victoria Bellotti, Maribeth Back, W Keith Edwards, Rebecca E Grinter, Austin Henderson, and Cristina Lopes. Making sense of sensing systems: five questions for designers and researchers. In *Proceedings of the SIGCHI conference on Human factors in computing systems: Changing our world, changing ourselves*, pages 415–422. ACM, 2002.

[50] International Organization for Standardization (ISO). Ergonomics of human system interaction-part 210: Human-centred design for interactive systems (formerly known as 13407). *9241-210*, 2010. URL http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52075.

[51] Ben Shneiderman and Shneiderman Ben. *Designing The User Interface: Strategies for Effective Human-Computer Interaction, 4/e (New Edition)*. Pearson Education India, 2003.

[52] Eelke Folmer and Jan Bosch. Architecting for usability: a survey. *Journal of systems and software*, 70(1):61–78, 2004.

[53] Jakob Nielsen. *Usability engineering*. Access Online via Elsevier, 1994.

[54] Jeffrey Rubin and Dana Chisnell. *Handbook of usability testing: howto plan, design, and conduct effective tests*. Wiley. com, 2008.

[55] Maloney-Krichmar D. Preece J Abras, C. User-centered design. *Encyclopedia of Human-Computer Interaction*, 2004.

[56] Plaisant-C. Cohen M. Jacobs S. Schneiderman, B. Designing the user interface: Strategies for effective human-computer interaction - 5th edition. 2009.

[57] Joseph S Dumas, Janice C Redish, and KA Schriver. A practical guide to usability testing. *IEEE Transactions on Professional Communications*, 38(1):45–45, 1995.

[58] International Organization for Standardization (ISO). Iso/iec 25062:2006 software engineering – software product quality requirements and evaluation (square) – common industry format (cif) for usability test reports. *25062*, 2006. URL http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=43046.

[59] Rolf Molich and Henrik Larsen. *Usable web design*. Nyt Teknisk Forlag, 2008.

[60] Laura Faulkner. Beyond the five-user assumption: Benefits of increased sample sizes in usability testing. *Behavior Research Methods, Instruments, & Computers*, 35(3):379–383, 2003.

[61] Clayton Lewis. *Using the" thinking-aloud" method in cognitive interface design.* IBM TJ Watson Research Center, 1982.

[62] J. Brooke. Sus- a quick and dirty usability scale. pages 189–194, 1996.

[63] Kortum P. Bangor, A. and J. Miller. Determining what individual sus scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, 4:114–123, May 2009.

[64] Risden Hanna and Alexander. Guidelines for usability testing with children. pages 9–14, September + October 1997.

[65] A Donker and P Markopoulos. A comparison of think-aloud, questionnaires and interviews for testing usability with children. *People and Computers XVI-Memorable Yet Invisible, Proceedings of HCI*, pages 305–316, 2002.

[66] Elena T Beck, Morten K Christiansen, Jesper Kjeldskov, Nikolaj Kolbe, and Jan Stage. Experimental evaluation of techniques for usability testing of mobile systems in a laboratory setting. In *proceedings of Ozchi*, pages 106–115, 2003.

[67] Rudy Schusteritsch, Carolyn Y Wei, and Mark LaRosa. Towards the perfect infrastructure for usability testing on mobile devices. In *CHI'07 extended abstracts on Human factors in computing systems*, pages 1839–1844. ACM, 2007.

[68] Adriana Holtz Betiol and Walter de Abreu Cybis. Usability testing of mobile devices: A comparison of three approaches. In *Human-Computer Interaction-INTERACT 2005*, pages 470–481. Springer, 2005.

[69] Arduino. URL http://www.arduino.cc/.

[70] Rasperry pi foundation, 2013. URL http://www.raspberrypi.org/.

[71] About the rasperry pi foundation. URL http://rasperrypi.org/about.

[72] 500 000 pis in wales, 2013. URL http://www.raspberrypi.org/archives/3686.

[73] Lov om heleseregistre og behandling av helseopplysninger, May 2001. LOV-2001-05-18-24.