NTNU - NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Using Mobile Technology to Treat Asthmatic Children

by

Esben Aarseth and Aleksander Gisvold

Supervisor: Professor Pieter Jelle Toussaint

Co-Supervisors: Adjunct Associate Professor Ole Andreas Alsos and Terje Røsand

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

April 2014

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 our 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 ourselves.

Signed: ______________________________

Signed: ______________________________

Date: ______________________________

"Something funny someone said"

- A funny guy

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: Professor Pieter Jelle Toussaint
Co-Supervisors: Adjunct Associate Professor Ole Andreas Alsos and Terje Røsand

20 per cent of the Norwegian population has or has had asthma by the age of 10. Treating children for asthma is often a cumbersome task. Research has shown that tangible user interfaces and mobile applications have been useful in medical care in a number of different settings. The BLOPP project has previously proved that distraction during treatment has proved positive on the children's experience. Developed a tangible user interface, AsthmaBuddy, and AsthmAPP, an Android application, with the purpose of motivating children to take their asthma medicine.

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.

We would like to thank Terje Røsand for advice, ideas and expertise on digital prototyping.

Thanks to Elin H. Bergene, Marikken Høiseth and Jonas Åsheim.

Thanks to Andreas Ystmark for being the voice of AsthmaBuddy and AsthmAPP.

Thanks to Aaberg, Dahle and Svalestuen.

Thanks to Nanna Sønnichsen Kayed, for providing an insight into reward systems for children, and guiding us to excellent readings for Tangble Reward Systems.

Thanks to Norsk Institutt for Luftforskning (NILU) for giving us access to air quality readings.

Thanks to Norges Astma og Allergiforbund (NAAF) for providing access to pollen forecast readings.

Contents

List of Figures

List of Tables

Abbreviations

API	**A**pplication **P**rogramming **I**nterface
BLOPP	**B**arns **L**egemiddel**OPP**levelser
CAPP	**C**hild **APP**lication made by Aaberg et. al.
GAPP	**G**uardian **APP**lication made by Aaberg et. al.
GUI	**G**raphical **U**ser **I**nterface
KAPP	**K**arotz **APP**lication made by Aaberg et. al.
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 Comittee for Medical and Health Research Ethichs
RFID	**R**adio **F**requency **ID**entification
TUI	**T**angible **U**ser **I**nterface

To an important person

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 explore the use of mobile technology and tangible user interfaces in the treatment of asthmatic children. The project is based on a system made by Aaberg, Aarseth, Dale, Gisvold and Svalestuen in 2012[4]. During their project Aaberg et. al. made an Android application and a Karotz-program in order to motivate, inform and reward children suffering from asthma. Their main focus was to develop the applications, rather than do research. We intend to improve their versions of CAPP and GAPP (see Chapter 2) and in addition create a Tangible User Interface from scratch. The new and improved version of CAPP and GAPP will be combined to one application, called *AsthmAPP*. The tangible user interface will be called *AsthmaBuddy*. The planned functionality for the tangible user interface is to play sounds, blink with lights and sense interaction through RFID.

The evaluation of the project will be done through co-design sessions and usability tests of different versions of the system.

1.2 Motivation

1.2.1 Asthma Among Children

According to NAAF, 20% of the Norwegian population has or has had asthma by the age of 10, and 8% of the adult population suffers from asthma[5]. Many of the children find it unpleasant to use their medicine as they often do not understand why the medicine must be taken. Children suffering from asthma may have to attend numerous appointments with an asthma specialist. This requires time and effort from the parents, and some may have to take time off work. In this project we will solely focus on treatment done by the use of an inhaler (with or without the mask) and disk formed medication. We chose to exclude the use of the nebulizer, since the nebulizer treatments differs so much from the use of inhalers.

We hope to motivate children suffering from asthma, since following a treatment plan can lead to a more controlled form of asthma, where attacks occur less often[6]. 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[7]. We have seen other projects using gamification elements have positive results, such as Get Up and Move made by Penados et. al.[8][2]. By using mobile technology, tangible user interfaces and may make the children more aware of their disease and thus make them better understand why they must take their medicine on a daily basis. By using gamification elements we hope to motivate the children to use the system more often, and by making a dynamic and user-centered reward system, we hope to make a system that will be interesting for children for a longer period of time.

1.3 Research Questions

The main goal for this study is to figure out in which 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 can tangible user interfaces be used to help children with asthma?

[1] Center for Disease Control : HSRV - http://www.cdc.gov/rsv/

[2] A short summary of the relevance of Penados' research is given in Section 2.5.1

1.4 Research Method

We will expand on the Android application Aaberg et. al. with focus on gamification elements. We will also create a prototype for a tangible interface, called AsthmaBuddy. We will build these prototypes on information gained in the following steps:

1. We will start out by interviewing parents and domain experts to find out more about children's medication habits.
2. The prototypes will then be tested by potential users and parents of asthmatic children.
3. Based on feedback from the user tests, we will design new prototypes.
4. Step 2 and 3 will be repeated once.
5. The final prototype will be user tested by children with asthma.

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 gives us insight into the main problems in relation to taking medication. Having insight to the problems our users meet is a useful way to make sure the final product will be suited to meet the users needs. We also want to gather ideas for how the TUI should be designed in terms of functionality and look.

The mobile application was already built on the start of this project. The main focus for the mobile application will be to test the gamification elements of the mobile application.

We will build the TUI using a Raspberry Pi, with additional components in order to play sounds, display lights and different I/O. A detailed description of the TUI is given in Chapter 8.

Based on the feedback gathered in our first round of user testing and focus groups, we will make a second version of the prototype. This prototype will then again be brought back to our test persons and domain experts in order to receive feedback on the improved design.

The final prototype will undergo user testing by children in order to determine if the system is understood by the children and if the children enjoys using the system. We will not necessarily measure the usability in terms of a SUS-score[9], but rather by using the methods presented in Section 5.3, since we believe these methods to be more appropriate.

1.4.1 Theoretical Motivation Behind Interviews

When we interviewed domain experts and parents, we did it in a *semi structured* manner. By conducting semi structured interviews, we let our interviewees put more weight upon their own views and opinions around the subject, and we could explore more in depth on interesting answers, which could lead to findings we could not have obtained otherwise. It also allowed us to use some pre-determined questions, which provided uniformity among our subjects.

The purpose of conducting these interviews, was to ensure that the end product was not limited by our own imagination. We wanted feedback on the work we had done so far, in addition to exploring new functionality and elements we should keep in mind.

The problems of using this approach, is that it limits creativity of our subjects. For instance, people might be shocked over the research we're doing, and thus might not be in the correct mindset to give as good as possible feedback as far as creativity goes. We tried to minimize this threat by giving our subjects a brief understanding of our work beforehand, such that they could be able to explore their own opinions before meeting with us.

We collected data by having one interviewer, while the other was taking notes. We also recorded the interviews, in order to be able to play back these. The people we collected data from was

[TODO: Should we mention people by name?]

- Nanna Sønnichsen Kayed. PhD in psychology, with experiences in reward systems while raising children.
- A couple of parents with children suffering from asthma.
- X domain experts, including people working for the Blopp project and NAAF (The Norwegian Asthma and Allergy Association).
- X asthma nurses

1.5 Thesis Outline

Chapter 2 provides the reader with backround information around Asthma, and some of the projects that have previously been developed by Blopp, in addition to introduce the reader on the state of the art. Chapter 3 will give the reader an introduction to gamification, with discussion around some of the principles that are being used. Chapter 4 dicusses the origins and use of tangible interfaces. Chapter 5 gives an introduction to the principles behind usability. Though it is not a primary part of our thesis, we consider it important to keep in mind, especially when designing for children. Chapter 7 provides a product description of AsthmAPP, our prototype for gamifying children's experience with a smartphone, while Chapter 8 provides a description of AsthmaBuddy, our tangible interface. Chapter 9 provides the results we have found during our research. Chapter **??** provides an evaluation of our process, what could have been done better, etc. Chapter 10 provides the final conclusions for our thesis, with discussions around the results given in Chapter 9.

Chapter 2

Background

This chapter will give a brief introduction to the history behind the BLOPP project (Section 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

The BLOPP project aimed to explore how design and technology can motivate children with respiratory diseases to take prescribed medication and to promote positive interactions between children and caregivers, thereby increasing adherence to medical treatment. They have previously worked with Åsheim's "Concept for improved treatment of children affected by asthma/RS- virus"[10] and Høiseth's "Research-Derived Guidelines for Designing Toddlers' Healthcare Games" [11].

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 the age five.

An asthma attack may include coughing, chest tightness, wheezing and trouble breathing. The attack happens in the body's lungs, the airways tighten, letting less oxygen pass through. According to the Norwegian Minestry of Health and Care Services, acute asthma attacks was the most common reason for hospitalization of children in 2008[12]. About 20 per cent of children are suffering from the disease, which causes economical consequences for the society [1]. However, 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 before exercise or when an asthma attack occurs, in order to stop/shorten the length of the attack.

A treatment may be done in different ways. For young children a nebulizer is often used. The nebulizer is a device used to reduce liquid to an extremely fine cloud, in order to make it easier to inhale. Treatments using a nebulizer may last up to 10 or 15 minutes.

Older children use medication in spray or powder form see Figure 2.1 and Figure 2.2 respectively. The spray is often used with a mask, and the powder form of medication is taken straight from the disk. Before use the asthma medicine must be shaken, in order to stir the particles. If a breathing chamber is used, the medicine protection cap is removed and the medicine is mounted on the breathing chamber. The chamber is pressed towards the user's face, covering nose and mouth. The medicine is then pressed, to release the particles into the breathing chamber, and the user breaths calmly for ten seconds.

2.2.1 Ways asthma affect the parents

In an already hectic everyday life, remembering to give their children medication may be cumbersome for the parents. 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.

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 (see Appendix G). A green light tells what 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 be a lot of pollen in the air or otherwise poor air quality or that the user is recovering from a

[1]Costs of having parents at home instead of working, hospitalization costs, medicine costs, etc.

FIGURE 2.1: Mask used with inhaler

FIGURE 2.2: Ventoline in disk form

cold. A red light indicates 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 [2] . 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 at children. In this section, we elaborate on these applications, while a full report of their work is available at[4].

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

2.3.1 CAPP

CAPP is an Android application targeted at children[3]. It’s main purpose is to guide children through the medication process. Figure 2.5 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 access

[2] Course Description of TDT4290 - Customer Driven Project - http://www.idi.ntnu.no/emner/tdt4290/

[3] All applications have Norwegian as their main language

the medication process directly by pressing the Karotz showed in Figure 2.5, which is the way to start a by-need-treatment.

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 2.4

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. 2.6 -2.12 shows the information-part of this application.

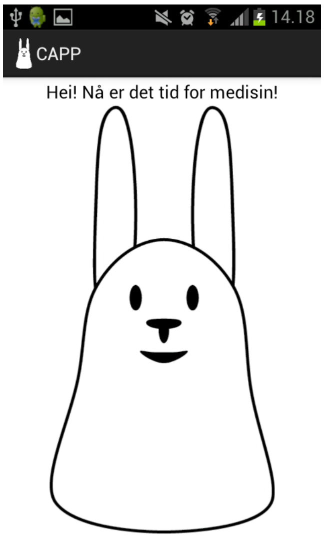


FIGURE 2.3: Starting a treatment

FIGURE 2.4: Inside the treasure chest

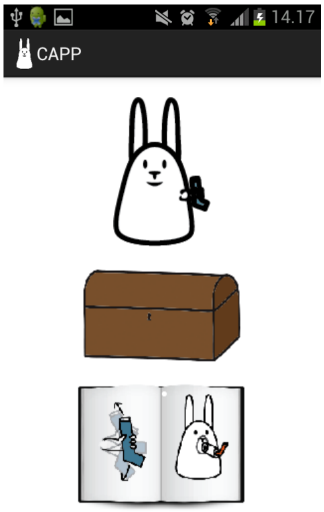


FIGURE 2.5: CAPP main menu

FIGURE 2.6: Instructions 1

FIGURE 2.7: Instructions 2

FIGURE 2.8: Instructions 3

FIGURE 2.9: Instructions 4

FIGURE 2.10: Instructions 5

FIGURE 2.11: Instructions 6

FIGURE 2.12: Instructions 7

2.3.2 KAPP

KAPP is the TUI-application targeted at children. The application runs on a Karotz [4], which is a small robot bunny (see Figure 2.13). 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 H.

FIGURE 2.13: Karotz. *Image source: http://karotz.com*

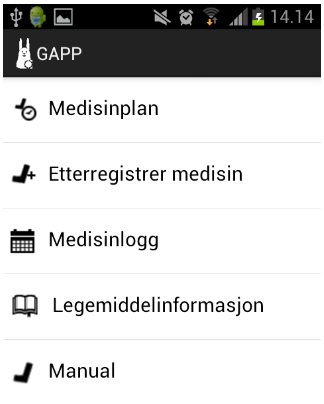


FIGURE 2.14: GAPP main menu

2.3.3 GAPP

GAPP is an Android application targeted at the guardians or parents of the children. Some parents have 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 child's disease.

Figure 2.14 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*.

[4] Karotz - www.karotz.com

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 G). 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 the 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 2.15 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 2.17 and 2.18 shows screenshots from this functionality.

Medicine Log *Medicine Log* shows how many times a child has taken his/her medicine the last couple of days. Figure 7.9 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 was taken on 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 Aaberg et. al created an artificial pollen distribution for demonstration purposes.

Manual The *Manual* is to help "newcomers" to medicate children. For instance, if a relative is 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 2.6 -2.12.

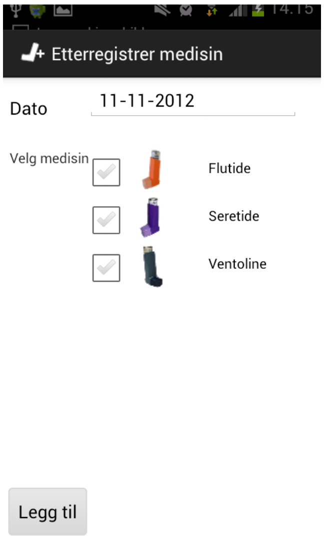


FIGURE 2.15: Register treatment

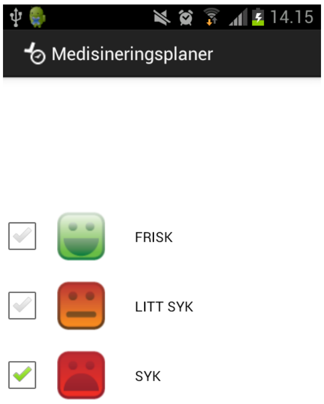


FIGURE 2.16: View plans

FIGURE 2.17: Information 1

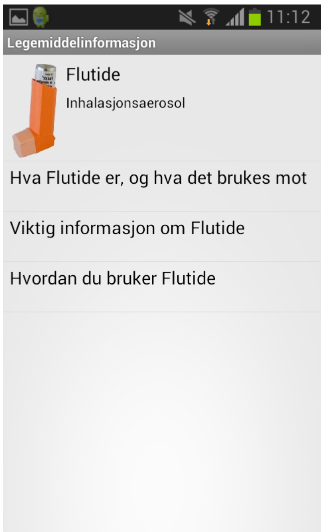


FIGURE 2.18: Information 2

FIGURE 2.19: 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 A (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

Research on self-management of monitoring your asthma condition has already been carried out. Much of this research was carried out by using SMS (Short Messaging System) technology. In 2009, Andhøj et. al.[13] did a feasability study to check how users would respond to a SMS-reminder. 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[14]. Thus our target group is likely to be familiar with the technology we plan to use.

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[15]. 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 small child, they spend a considerable amount of their day playing with a smartphone. With this in mind, we aim to make an application that is used for a short period of time with each use. AsthmAPP and AsthmaBuddy is not a toy or a game. AsthmAPP and AsthmaBuddy will be tools for helping the children.

2.4.3 Children and Gestures

Abdul Aziz et. al.[16] 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 between the age of 2-12 years old, 3 children in each age group. 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 a cause for 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 AsthmAPP as child friendly as possible, it only uses "swiping" gestures and button presses for navigation.

2.4.4 Assessment of Existing Asthma Applications

In 2012, Huckvale et. al.[17] conducted an assesment on the existing asthma-related applications on both Google Play [5] and App Store [6] . 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"[17].

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

[5] Google Play - http://play.google.com
[6] Apple App Store - http://www.apple.com/itunes/features

areas in which mobile technology is being used with a combination of either gamification or tangible interfaces.

2.5.1 Get Up and Move (GUM)

Penados et. al.[8] created GUM an interactive toy to measure and stimulate physical activity. GUM is a small creature that needs to be taken care of by a child. The child's objective is to make his/her GUM healthier and happier by moving with it, feeding it and playing with it. GUM is healthy and happy when it has been through a minimal amount of daily physical activity, and since GUM can't move by itself, the child needs to do it. As GUM grows healthier, lighted stars will appear in its ears, until it reaches a maximum healthy state. To increase the number of stars, the child needs to progressively increase and later maintain its physical activity level. Penados et. al. argues that GUM had a positive effect on reducing sedentary behaviour and motivate physical activity with young children. The findings presented by Penados et. al.[8] gives us reason to believe that AsthmaBuddy will show positive results when tested on children with asthma.

2.5.2 Sisom

Sisom [7] 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 users can look around in the room and express how they feel when they are giving 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, and children participated more during the consultation[18].

2.5.3 Meassuring Blood Pressure

iHealth [8] , Withings [9] and other companies has created blood preassure monitors which are synchronized towards mobile applications. They allow easy monitoring over periods of time and make it possible to share meassurements to both friends, family and doctors.

[7] Sisom - http://www.communicaretools.org/sisom/
[8] iHealth - http://www.ihealthlabs.com/wireless-blood-pressure-monitor-feature_32.htm
[9] Withings - http://www.withings.com/en/bloodpressuremonitor/features

2.5.4 Controlling Your Diabetes

Cellnovo [10] 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 one to access the information. The interface helps users to check for trends and patterns in their blood sugar level, which motivates users to continue applying the correct treatment. It also allows users to send information to physicians, which helps them make decisions regarding how patients are managed.

2.5.5 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 developed an app called "'Røykeslutt" [11] . The application shows what the 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 money a user has saved at a particular time, which can be seen as "gamifying" the element of money in order to motivate users.

2.5.6 Wii Fit Plus

Nintendo Wii has gamified the way people train at home with Wii Fit and later Wii Fit Plus [12] . 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] Cellnovo - http://www.cellnovo.com/
[11] Røykeslutt - https://play.google.com/store/apps/details?id=no.lhl.roykeslutt
[12] Wii Fit - http://wiifit.com

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[19], but did not become a wide-spread term before 2010.

There are many different ways of describing gamification. Deterding, Dixon, Khaled and Nacke[20] define Gamification as:

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

Huotari and Hamari[21] 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 [1] . Apple developed a Game Center for iOS in 2010, giving every iPhone/iPod and iPad

[1] Foursquare - www.foursquare.com

user a hub for challenges, awards and other gamelike activities [2] , which made every iOS user a potential target for Gamification. Lately there has been many games built singularily around gamification, such as Cookie Clicker [3] or Farmville [4] . Even game consoles like Playstation 3 and Xbox contain gamification support per default, with their achievement/trophy systems [5] [6] . 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[7] 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.

[2] Apple Game Center - http://support.apple.com/kb/HT4314
[3] Cookieclicker - http://orteil.dashnet.org/cookieclicker/
[4] Farmville - www.farmville.com
[5] Xbox - http://xbox.com
[6] Playstation - http://playstation.com
[7] 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.

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 learns patterns and techniques from the players. By playing Foldit, researchers were able to solve the crystal structure of the M-PMV retroviral protease [8] [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.

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][9].

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[10]) 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. AsthmAPP 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. Since AsthmaBuddy is a computer supported learning system[36] it will be important for us to maintain focus on the learning and awareness created by our system, making gamification a tool and not the key feature.

[8] Mason Pfizer Monkey Virus - http://microbewiki.kenyon.edu/index.php/Mason_pfizer_monkey_virus
[9] While this is not a scientific publication, we found it interesting and relevant to the discussion
[10] Fiero is an italian term for personal triumph[30]

3.4 Game Elements

This section will take a brief look into the different classifications of players that exists, and will introduce the reader to game mechanisms commonly used to gamify users' experiences.

3.4.1 Bartle's Four Player Types

Richard Bartle defined four different player types [37]. These types are *Achievers*, *Explorers*, *Socialisers* and *Killers*. We'll take a brief look on each of these in this section.

3.4.1.1 Achievers

"Achievers regard points-gathering and rising in levels as their main goal, and all is ultimately subserviant to this" [37].

Most young children will fall under this category. Achievers mostly play games just for the fun of it, and don't necessarily need other incentives to the game than being able to clear it. Most children like to see progress in terms of points, clearing a lever, etc.

3.4.1.2 Explorers

"Explorers delight in having the game expose its internal machinations to them" [37].

Explorers are thus the players who easily enjoy a game more than once, and potentially want to find every secret embedded in the game. Children will in some cases fall under this category, but with our target group, it is hard to separate between achievers and explorers.

3.4.1.3 Socialisers

"Socialicers are interested in people, and what they have to say. The game is merely a backdrop, a common ground where things happen to players" [37].

This implies that socialisers play games in order to connect with new people or hang out with their friends. The youngest children in our target group probably won't fall under this category, as they won't understand whether John or Hanna is on the "other side of the screen".

3.4.1.4 Killers

"Killers get their kicks from imposing themselves on others" [37].

Killers thrives upon destroying other people's game experience. Hopefully, no children fall into this category, at least not in our target group. [Something about social skills not developed yet?]

3.4.2 Game Mechanisms Used to Achieve Gamification

There are some game mechanisms that are widely used for gamifying every day tasks. This section will explain some of them. We will use a stick figure to examplify each game mechanism.

3.4.2.1 Avatar Systems

Avatars are commonly used in children games. It gives a player a virtual character, which can be upgraded with different clothing and equipment when players reach certain points in the game. The equipment can usually be bought for either points awarded or through *In-app purchases*. Players can then show their avatar to other users, compare, and have fun with them. This approach could be seen as giving avatar a piece of their personality. For instance, some players would prefer that their avatar looked as ridiculous as possible, while others would prefer if they looked as cool as possible. Showing off "expensive" gear would also give some sort of accomplishment (*"I'm so good in this game, that I could afford this. Can you?"*).

Example: The stick figure will be a players avatar, which can be modified to have different pieces of clothing or equipment.

3.4.2.2 Acheivements and Badges

Achievements and badges are systems well incorporated into Microsoft's Xbox and Sony's Playstation. These achievements are typically given if the player achieves something in the game. For instance, on Foursquare, you get a badge called "Adventurer" if you check in at 10 different venues.

Example: If we combine this mechanism with avatar systems, we could give out a badge when the stick figure have obtained complete sets of clothes or a specific set (i.eg. buying all the green clothing).

3.4.2.3 Real-world Rewards

Often used with leaderboards, real-world awards could be given to some of the best players of the game. For instance, they could be rewarded with exclusive tickets to concerts. These real-world awards are often given during marketing campaigns, for instance "Invite your friends to use this system, and get one ticket in the lottery to win a brand new computer".

Example: Players could have a real stick figure, and could get rewarded with equipment sent to the player by mail. These rewards could be different clothing or equipment the player could apply to the figure.

3.4.2.4 Social networking

During the last couple of years, Facebook feeds has tended to get flooded by updates from third-party applications, like Runkeeper [11] , who updates everyone on your friend list that you have been working out. The idea here is to have a common platform, where users can brag of what they have achieved.

Example: Social networking could be used to upload images of a player's stick figure, and show it to his/her friends.

3.4.2.5 Mirroring User Behaviour

This is most commonly used for children, where an animation or a character shows how to go forward with a procedure. For instance, there are a lot of apps on App Store mirroring the process of brushing a child's teeth. A kid can then use this app as a reference that indicates how long the kid should brush on the same side.

Example: The stick figure could mirror the player's intended behavior.

3.4.2.6 Leaderboards

A leaderboard is a list of the players ordered by their collected points, completed activites or any other predefined system. Each user has a score defined by rules set before a competition is started. The score is compared and then players are ranked based on the scores. Leaderboards may be fully dynamic, changing when a player has scored points, or state based, where the new order is calculated after a certain period of time.

[11] Runkeeper - http://runkeeper.com/

Example: If the stick figure gathers enough experience points, it could find itself on a regional leaderboard, ranking players in your area (neighbourhood, town, country, etc).

3.4.2.7 Progress Bar

A progress bar is used to indicate how far a user has come towards a given goal. When the player completes task and/or activities, the progress bar is filled to indicate the progress of coming closer to a goal. How much the progress bar is moved is often determined by the severity of a task or by a system using points. The progress bar can often be combined with experience points, where the experience points collected determines the movement of the progress bar.

Example: The stick figure could be placed on a road. The figure's position on that road, would mirror the progress a player has made.

3.4.2.8 Experience Points

Experience points is an indicator of how much experience the player has gathered within a game or setting. These points may be awarded from completing tasks, exploring areas and features or other similar activities. Experience points are usually combined with a leveling system, where the player "climbs a ladder" using these experience points, for example by being awarded with a new level, new rewards or unlocking new features in a system. A player with many experience points is considered an experienced user, and is percieved as higher ranking than a player with less experience points. Experience points are also often combined with leaderboards.

Example: One experience point could be represented as a stick figure, and the goal is to gather as many stick figures as possible. Another example is that leveling up could be represented by the size or attributes of your stick figure.

3.4.2.9 Contests

Gamification can be done through having contests either with players in a duel-like head-to-head contest or a free-for-all contest with no limit on the capacity of players. A duel-like contest may be a knockout style of competition where players compete to get the most points within a given time period or a similar goal. A player may make progress in the tournament without being the player with the highest score, but being better than his/hers opponent. In a free-for-all contest, the winner is whoever fulfills a specific goal to the best degree. The goal which players try to achieve is set be a specific set of rules determined before the start of the contest.

Example: A player's stick figure could go into a voting contest, where votes are given on the best looking one, or similar.

3.4.3 Combining Game Mechanisms in AsthmAPP

Mechanism	**Included in AsthmAPP**	**Rationale**
Avatar Systems	No	We did not have time to implement this during our thesis, but we do believe this could be a good feature if it was implemented in a decent manner.
Achievements and badges	No	We believe our target group would not enjoy this feature as much as older children, like 12-16 years of age.
Real-World awards	Yes	Children enjoy the feeling of being rewarded with something real.
Mirroring User Behavior	Yes	Demonstration has a positive effect on children.
Leaderboards	No	There are no way to implement this in a realistic and legal way. Children would have to share their data, which consists of points based on medicine doses. Parents could be blamed if their child were at the bottom of the list. It would also be negative for small children's motivation if they have been really good at taking their medicine, and performs poorly on a leaderboard.
Social Networking	No	Much of the same reasons as why we did not choose leaderboards. We also believe that children in our target group would not understand this aspect.
Progress bar	No	In an ideal world, we could have shown how close the child was to becoming treated for asthma. However, identifying how close a patient is to becoming healthy, is virtually impossible. Another usage could be to match their progress for each week against their medicine plan. This would however, imply that by-need treatments would not be included, which would seem unfair for children. Additionally, their progress would be deleted every week, which would not have much motivational effect.
Experience Points	Yes	The stars will work as experience points, which can used to buy rewards from parents.
Contests	No	This would be a serious violation on different laws in Norway for instance privacy. It could also be used to pinpoint "bad" parents.

Table 3.1: Assessment of different game mechanisms

[This table should probably go somewhere else]

3.5 Summary

Stapleton argues that:

"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."[38]

Stapleton's argument is a central argument for why we believe in our the use of tangible user interfaces and applications as a method of treating children with asthma. Children are easily distracted, and we believe that making the treatment into a serious game will distract the children enough to forget what they are doing and instead look on the treatment process as a fun game.

In AsthmAPP 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. This stands to reason with the arguments of Nicholson[34] regarding how to design gamification.

As McGonigal's studies show, the effect of gamification tend to wither down after a longer period of time[31]. We aim to solve this problem by letting the user choose their own rewards. While putting the responsibility for the reward system in the hands of the user will lead to more work for the user, we believe that the positive effect of the reward system will make it worthwhile.

The children are rewarded with stars based on their health state. The rationale behind this is that the children may have to take more medicine when they have a cold or there is a lot of 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 a sufficient number of stars. This way the parents and their children create their own gamification environment. Examples of possible rewards could be to give their child an extra 10 NOK in allowance, taking them to soccer matches or even 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 on a "milestone" basis. We do not want children to feel they lose something if they buy a reward, which some might experience 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 the user 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 receive 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" [39]. They established the term "Tangible User Interface" (TUI) as a way to move beyond the dominant model of Graphical User Interfaces (GUI). While GUIs show information (bits) in the form of pixels mapped to a display, Ishii meant for TUIs to represent the bits in form of physical objects. The objective of TUI was explained to *augment the real physical world by coupling digital information to everyday physical objects and environments*[39].

Urp[40] is an example of an first-generation TUI. Urp is a workbench architects used to determine shadow patterns for models of buildings. By moving a "clock tool" the lighting on the workbench would move according to what time of day was choosen. Instead of interacting with the lights directly, the TUI factor of the workbench was the clock tool. What makes this a first-generation TUI is the fairly simple and state-determined operations.

Sandscape[41] is an example of a second-generation TUI. Sandscape uses clay, sand, cameras, digital software and lighting to give an overview of a Geographical Information System(GIS). The users could interact with the clay, forming dunes or dig holes and the software would calculate landscape analysis based on the interaction. Sandscape is dynamical user interface since it may change to several different non-predefined states, also named a "Continuous TUI".

In 2008, Xie et. al. performed a study on how children reacted using different interfaces in order to solve a jigsaw puzzle[42]. 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 equally. 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.

4.2 Examples of Use

Using TUIs instead of GUIs has 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[43]. Children could then rotate the cube in order to get the correct answer pointing upwards, like a dice. They concluded that the TUI gave children a different set of affordances that prompted a great initial engagement[43].

Information Sharing Hinckley et. al. created a tangible user interface for neurosurgical vizualisation[44]. Their tool proved helpful for neurosurgeons to provide physical familiar tools that could display information digitally. Their tool showed possibilities for creating and view cutting planes and planning neurosurgery. Their tool made it easier for them to display it to other persons with less knowledge of neurosurgery.

Moran et. al. designed a physical wall for sharing information about people in an office[45]. The system, named Collaborage showed a people locator and different types of project information. Collaborage showed how the use of traditional use of walls and sticky notes translated into a digital software in a positive manner.

Collaborative Learning Scarlatos et. al. created a system called TICLE (Tangible Interface in Collaborative Learning), which are used to help children solve a Tangram[46].

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[47]. Stanton et. al. created a “Magic Carpet”, giving children possiblity to influence a story in the classroom[48].

Social Context Marble Answering Machine is an invention by Durrell Bishop, dating back to 1992[49]. The interface allows users to drop marbles into a play-back indent on the system, which plays a recorded message.

4.3 TUIs Used in Health Care

In 2003, Wada et. al. conducted a study on how the introduction of robotics affected the elderly[50]. 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 removed. In addition, nurses burnout rate decreased during the experiment, which implied that the subjects had easier days when Paro was there. The study showed that their quality of life improved after Paro was introduced.

Farr et. al. did a study on children with Autisitic Spectrum Condition (ACS), when playing with a TUI called Topobo [1] [51]. The study compared the level of social interaction when playing with Topobo, compared to playing with LEGO. Their findings showed that ACS children were playing more cooperatively with the TUI than LEGO. Additionally, children with traditional development were able to play more cooperative, solitary and parallell when using a TUI, suggesting that

“(. . .) programmable digital technology may support more pathways to social interaction.”

4.4 Paradigms in Tangible Interfaces

Ullmer states that a tangible user interface should embody the following four properties[52]:

[1] Topobo - http://www.topobo.com/

1. Physically Embodied
2. Physically Representational
3. Physically Manipulable
4. Spatially Reconfigurable

Ullmer further states that these four properties describe physical artifacts as representations and controls for digital information.

Ullmer proposes three different paradigms of tangible interfaces; *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[52].

4.4.1 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 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 comparing shapes and forms. It may help human manipulation since interpretive constraints provide an increased sense of kinesthetic feedback from the manipulation of tokens.

4.4.2 Interactive Surfaces

In this paradigm, users manipulate physical objects upon an augmented planar surface [52]. These objects are then tracked, interpreted and graphically mediated through the surface. A popular usage of interactive surfaces is to create interactive workbenches, where objects are configured upon a horizontal workbench. For instance, metaDESK with the Tangible Geospace application, had a large map of a city as it's workbench [53]. Combined with magnifying glass, it allowed users to look at 3D models of particular places in a town.

4.4.3 Constructive Assemblies

One major approach for tangible interfaces draws inspiration from buildings blocks and LEGO^{TM}. Such “constructive assemblies” of modular, interconnecting elements have been used for modeling real life buildings [54], and geometric modeling of all kind of shapes[55]. Constructive assemblies give an easy-to-use and highly tangible representation of digital information.

While there are possibilities for how to use constructive assemblies for developing a tangible user interface to help children with asthma, we decided to not use this paradigm in the construction of AsthmaBuddy. The use of small parts that can easily be lost was not a solution we saw fit for our age group of 3-7 year-olds.

4.5 Developing Tangible Interfaces

4.5.1 Champoux’s Development Framework

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, this 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?	**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 artefact without any electromechanical and phyical ergonomic properties, i.e. moving arms, waving ears, etc. As far as questions **FC7** and **FC8** goes, we consider these irrelevant. These questions assumes that the tangible interface developed is performing a task for the user, which is not a part of our system. The remaining questions are considered relevant, and will be discussed in Section **??**.

4.5.2 Development Challenges

Working with GUI's is quite 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.[3] 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, 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 a TUI[3]

4.6 Summary

Tangible interfaces is about giving digital information to physical objects. There are a lot of examples on Tangible Interfaces, and we have taken a brief look into some of them (see 4.2). There seems to be a lot of activity going on in this research field. However, few are commercially available.

Champoux proposed a design mechanism to create tangible interfaces. The design mechanism is somewhat abstract, and misses out on obvious points like how to actually display information to a user, which Bellotti et. al. (see 4.5.2) exposes as a challenge when creating ubiquitous systems and TUI's. We will use Champoux' approach to a certain extent, and keep Bellotti's challenges in mind when designing AsthmaBuddy.

When developing AsthmaBuddy, we will continually look for ways AsthmaBuddy can be of use for the asthmatic children. Our main focus will be on helping children to remember and apply the treatment correctly. Additionally, we will research the motivational effects of using TUI's and the reward system. Additionally, we will continue to look for other ways AsthmaBuddy may be of help for the children or their parents throughout the project.

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 at 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[56]:

"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 well the system performs and the user's feedback defines how the design scores on usability.

Schneiderman stated eight golden rules in order to achieve a good usability of computer systems[57]. 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.

Today usability is extremely important in order to achieve success for a system. The users expect a functional and easy-to-use system. From the user's point of view, working with a product which is easily understood, leads to increased productivity, which again may lead to increased sales/usage[58]. Proper usability engineering may also lead to lower costs for the developers and higher chances for projects being finished on time[59].

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[60], 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[61], 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 poorly designed	Abras[61] says it should be at the end of the project while others[62] 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[63].

The usability testing can be performed in different ways[62]. 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

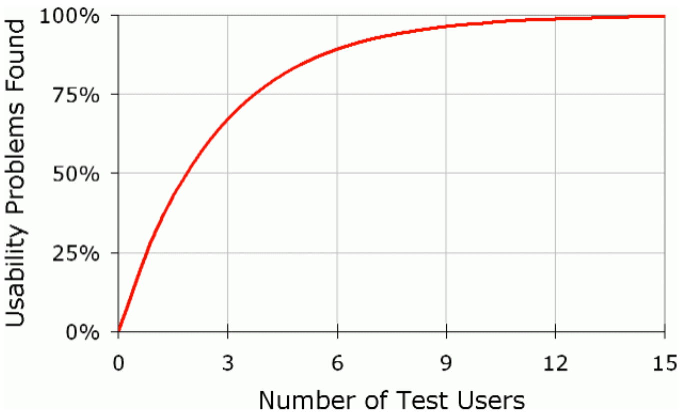


FIGURE 5.1: Number of users needed to find percentage of errors according to J. Nielsen[1]

tasks to provide real data. Observing and recording each usability test may help the developers to analyze their system, and correct the flaws[63].

Before starting the usability tests, the developers should plan goals for what they want to know about the system[64]. 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 not to 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[65] states that six test persons is the ultimate number. Faulkner[66] 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 **??**, 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 tests 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, 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"[67]. The test leader should answer questions from the participants, 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 obtain answers to all the questions that may remain unanswered. A system usability scale(SUS)[68] 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.[69] 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 **??**), 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.[70] 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[15], this may not be great of a concern.

Since our application is targeted at 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 changes 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[71] 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.

Zaman et. al. proposes a way to measure the likeability of tangible interaction with preschoolers[72]. They based their research on work done by Read, MacFarlane and Casey[73], who found that traditional measures for likeability, for instance a smileyometer, proved to give false results. In fact, Read et. al. found that more than 80% of the children being tested gave a “Brilliant” score. Zaman et. al. implies that children are actually lying when giving these scores, which is understandable from a questionnaire perspective. Instead of using scales as a measure of what is likeable or not, they propose a model where they compare different interaction systems against eachother. They call it the “This or that” method. For instance, the interviewer asks the child which system the child prefers, followed by “this or that” while pointing to the different systems. We will use a similar approach to understand which forms of interaction children like most.

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, compared to when walking on the street[74].

Schusterich et. al.[75] 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.

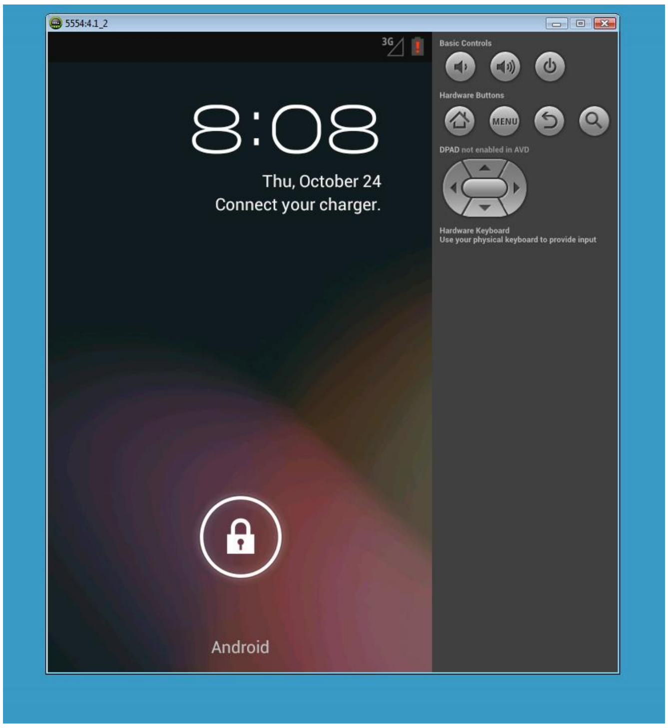


FIGURE 5.2: The Android Emulator running an emulation of Android 4.1

5.4.1 Emulator vs. 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 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 a number of screen recorders for Android devices exist, these require that the device is rooted [1] , which is

[1] Android Rooting - http://en.wikipedia.org/wiki/Android_rooting

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[76] 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.

5.5 Summary

The ISO-standards for usability and context of use[56] are well known and often mentioned, as they are in fact standards. We aim to achieve a usability as high as possible, through user-centered design and usability testing.

While we aim to follow Shneidermann's eight golden rules[57] when designing AsthmAPP, we focus more on the rules of consistency, informative feedback, reducing short-term memory load and designing dialog to yield closure, rather enabling shortcuts for frequent users (see Chapter 7.2 for an explanation).

Based on the research we read and the fact that NTNU has an excellent usability test lab at NSEP [2] we decided to do usability testing in doors, with smartphone devices.

[2] NSEP Usability lab - http://www.ntnu.no/nsep/brukbarhetslaboratorium

Chapter 6

Usability Tests

6.1 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.

6.2 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 B and C.

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 D. 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[63].

- 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”.

6.2.1 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, 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/her 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 7

AsthmAPP

This chapter will give a description of AsthmAPP, through textual description and screenshots. Please note that the main language of the application is Norwegian. We have translated the text where it seemed appropriate.

7.1 Basic System Architecture

Figure 7.1 shows an overview of the architecture we intend to use for our solution. We reused some of the components Aaberg et. al. created during Customer Driven Project[4].

We have access to a MySQL-server hosted at NTNU, which we will access by a PHP-server hosted at NTNU. The main reason we have to access the database through a server layer, is that it is quite cumbersome to connect to the database if a device is not connected at NTNU's network. In addition, by having a webservice do some of the work for us, it becomes easier to parse results from the database through JSON. By making this choice, system scalability is reduced, but we consider this as outside the scope of our thesis.

7.2 How Usability Research has Affected our Design

While designing AsthmAPP, we strive for a easy-to-use design with a good overview. In chapter 5 we described usability and general terms a designer should consider. We have especially taken Shneidermann's eight golden rules into consideration when designing[57] in addition to the Android Design Principles[77]. We have tried to lighten the short-term memory load by using a combination of sounds, pictures and text to tell the user

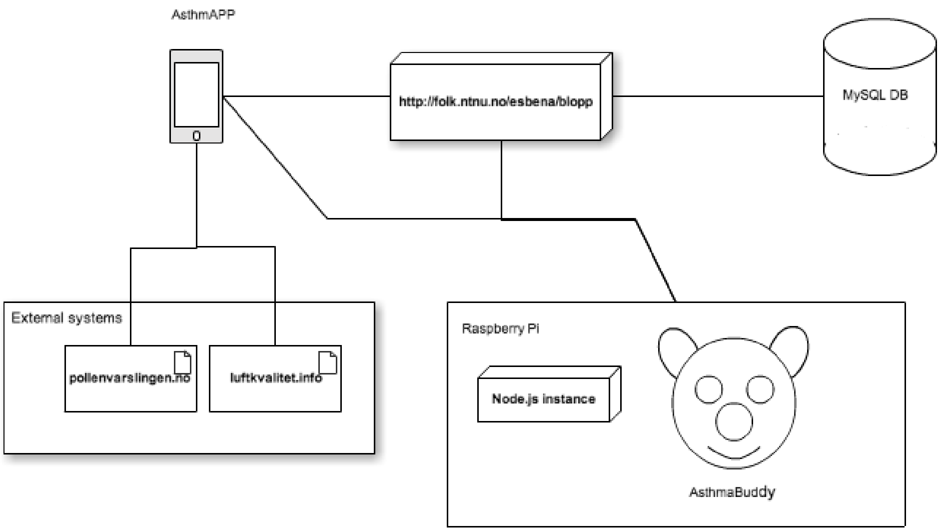


FIGURE 7.1: System Architecture

what options are available or what is expected from the user. During a treatment the user is prompted to take active action in order to continue through the process, giving the user a locus of control. The layout for both partitions of AsthmAPP give a general overview, and has few shortcuts between the different elements. To navigate from one element to another the user will have to go via the main menu. While this breaks with Shneidermann's rules and the Android design principles, we believe that the solution we have found is the best solution.

7.3 Child partition

The child partition of our application consists mainly out of four parts. When Aaberg et. al. created the original application, they wanted a conceptual look and feel throughout the applications. They used images of Karotz in the application in order to introduce a sense of completeness, i.e. the Karotz bound CAPP, GAPP and KAPP together. [TODO: Vi burde bytte ut Karotz-bilder med eget produkt imo].

7.3.1 Treatment

Figure 2.3 shows a screenshot for the application when the child starts their treatment. Starting this sequence can come from one out of two events: (i) *The child reacts to an alarm set in the parent partition*, and (ii) *The child needs to take their medicine by need*. If (ii) is the case, the child is instructed to pick the medicine from a list shown by the application. If (i) is the case, the medicine is chosen beforehand. When a child has started their treatment, they are taken through an animated sequence, which reacts when a child interacts with the device. In addition, they are being told what to do through the comforting voice of Andreas Ystmark.

7.3.2 Showing rewards

Figure 2.4 shows a screenshot for the application when the child wants to review how many stars he/she has received, based on the amount of treatments completed. We have made two design decisions for our reward system. First, we never want stars to be removed. We dont́ want children to feel that credits are being removed from them. Second, we cant́ assume children are able to read, and thus we have made it countable, and hopefully they can comprehend how many stars they've actually got. In addition, we provide some help to those who are able to read numbers, by showing the amount of stars a child has on the top. The downside here comes when a child has been completed a huge number of treatments, as this will obscure the view.

7.3.3 Shop

In the shop, children are allowed to buy rewards from parents. Figure 7.3 and 7.4 shows an inside-view of our shop. Children can buy a reward by pressing the selected reward in the menu. Due to time constraints and lack of good software solutions, we have not been able to implement voice over, so the children might need help with reading the name of the rewards. The possibility of adding pictures to represent the reward should make it easier for children to understand.

7.3.4 Treatment instructions

The treatment instructions is a book-styled instruction set which shows generically how to take a medicine. The following steps are included in instructions:

1. Shake the inhaler to loosen the particles.
2. Take the cap of the inhaler
3. Attach the inhaler to the inhaling chamber
4. Cover nose and mouth with the inhaling chamber
5. Press the inhaler until you hear a sound
6. Let the child breathe calmly 10 times in and out
7. Let the child wash his/her mouth

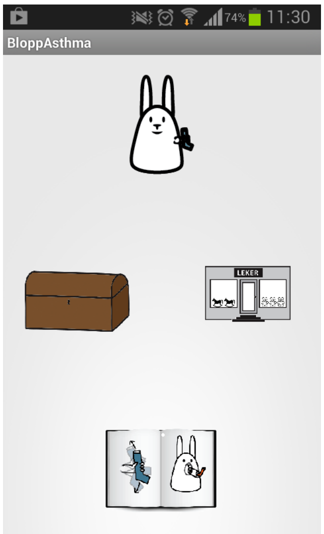


FIGURE 7.2: Main menu of child partition

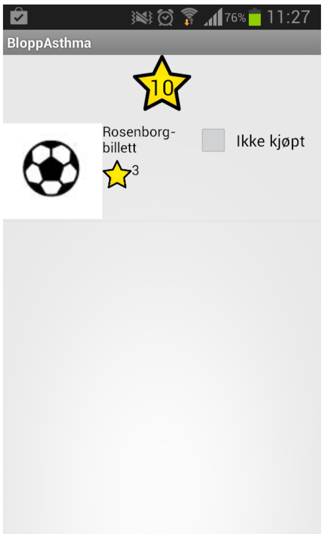


FIGURE 7.3: Possible rewards a child can choose from

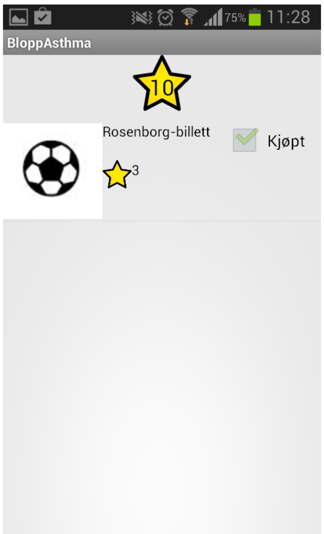


FIGURE 7.4: A child has bought the reward

7.4 Parent Partition

7.4.1 Menu

Figure 7.5 shows the main menu of the parent partition. It has six options (Norwegian translation in paranthesis):

1. Medicine Plan (*Medisinplan*)
2. Register Medicine Afterwards (*Etterregistrer medisin*)
3. Medicine Log (*Medisinlogg*)
4. Rewards (*Premier*)
5. Manual (*Manual*)

In order to access the parent partition, the user is prompted with a PIN challenge. This was an effort to anonymize children's medical data if a phone is lost or stolen.

7.4.2 Medicine plan

Creating a medicine plan for asthma treatment is highly connected to the Traffic Light System explained in Appendix G. Users can have three different plans, depending on which health state they are currently in. As we are targeting children, we can not assume that they are aware of which category they are currently in, and as a result, we

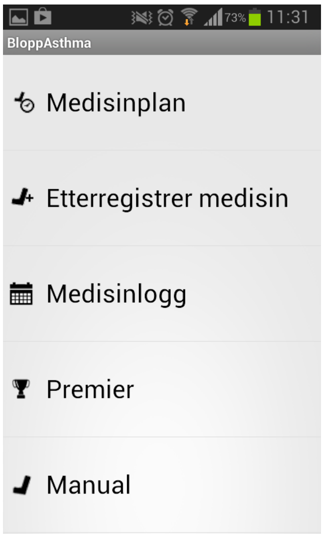


Figure 7.5: Main menu of partent partition

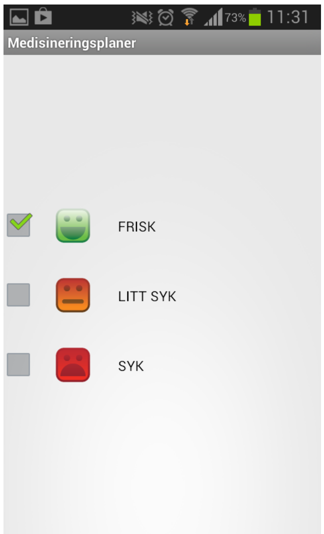


Figure 7.6: Available medicine plans

Figure 7.7: Adding a medicine to a plan

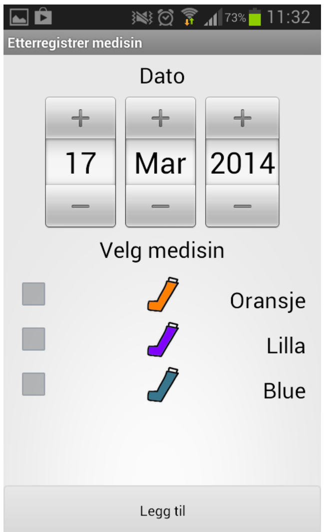


Figure 7.8: Register a medicine that was taken without the help of AsthmaBuddy or AsthmAPP

Figure 7.9: Medicine log

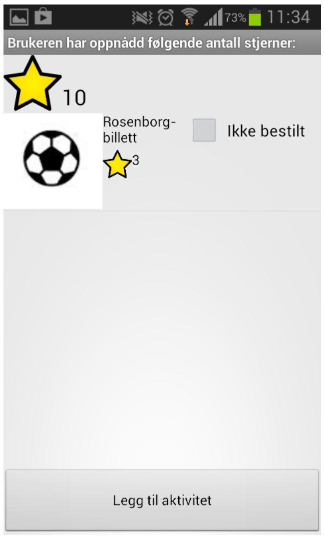


Figure 7.10: Overview of rewards a child can get

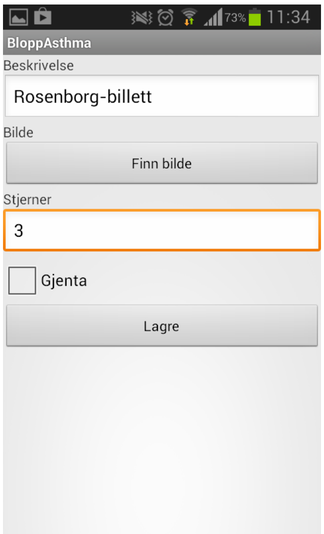


FIGURE 7.11: Creating a reward. Parents can either choose a reward from our standard image set, or they can take one from their gallery

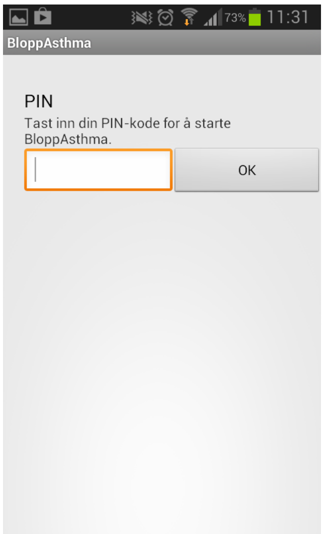


FIGURE 7.12: In order to access the parent partition, users have to complete a PIN-challenge

let their parents control it. Figure 2.16 and 7.7 shows the view in which one may the change medicine plan their child are currently on, in addition to setting alarms where appropriate. For instance, one might set an alarm at 07:00, which makes the user aware before it is time to leave for school. Changing medicine plan is done by selecting the checkbox at the left side of the panel.

7.4.3 Register Treatment

What happens if a child need their medicine, but the application or our TUI is not nearby? They would probably be disappointed because they did not get their star, and did not get any rewards. Fortunately, it is possible to register a medicine that has been taken afterwards, which entitle the child the amount of stars they should have gotten. *Register Treatment* allows parents to register the medicine, at any given day prior to current time (See Figure 7.8).

7.4.4 Medicine log

The *Medicine log* can be used by parents to show how many times a child has taken their medicine. One of the main reasons that children does not take their medicine is lack of communication between parents. Having an option to show medicine log, give parents the ability to check and see whether they have taken the necessary amount at a given day.

Figure 7.9 shows the calendar view of the application. The view is a bit complicated. The cells show any given day of a month. In addition, there is a top bar in the view. The top bar indicates which health state (or health plan) the child was in at the day represented below. At the bottom of the screen, there are three panels. The left one shows which medicine that has been taken at a selected day. The topbar indicates which day is shown. The middle one shows the air quality in Trondheim [1] . The right shows the pollen distribution of the 6 most common pollen types [2] . The idea behind this is that asthma symptoms can often be the same as allergy symptoms, and if parents are able to recongize a pattern between health state and pollen distribution, they might want to take their child to a hospital.

7.4.5 Manual

The manual contains excactly the same information as shown in Section 7.3.4. The manual is added to both the parent partition and the child partition of the application. This is done because it is important for both the children and the parents to know how to use the medicine correctly.

7.4.6 Reward

Figure 7.10 shows the list of possible rewards a child might receive. They are added by parents through *Add reward*. The idea of having parents set their children's rewards is to specify rewards according to children's interest (see Section 3.5). Figure 7.11 shows how one may add a reward. Users inserts a description, then either take a photo or select one out of our standard images. It is possible to set a reward on *Repeat*, which will make the reward appear multiple times, each time with an increased cost. When the user press *Save* (Lagre), the reward is added and children have the possibility to buy it.

[1] Measured by NILU - http://luftkvalitet.info/
[2] Measured by NAAF - http://www.pollenvarslingen.no/

7.5 Evaluation

Chapter 3 gave an introduction to the term gamification, and how it should be used. We have developed a reward system that is highly based on parent's opinions, and thus, have some flaws that we'll discuss further here.

First of all, children might become bored of the rewards if the rewards are not increased in difficulty to achieve, and their apparent value. For instance, if a child is rewarded with a ticket to a football match for achieving 10 stars, and then gets a piece of gum if they achieve 20 stars, they will easily lose interest and important motivation in order to do their treatment.

Second, the amount of stars is rewarded depending upon their inferred health state (green state yields 1 star, orange state yields 3 stars and red state yields 5). This could be easy for a "sneaky" child to social engineer. In the long run, a child could fake being sicker than he or she actually is, just in order to achieve a reward more easily. This is a grayzone flaw that *could* occur, but we did not have the possibility to observe this pattern over time.

Third, the gamification during their treatment, i.e. the animation on the phone, could become boring over time. The interactions are not variated, and it takes approximately 2 minutes to go through with a treatment. For expert users, who have had asthma for several years, it will become boring. Thus it should be noted that this is an application that probably would work best for children in the early stage of their disease.

In order to get some expert opinion on our reward system, we asked a children psychologist, Nanna Sønnichsen Kayed, who has expertise in reward systems for behavioral patterns among children, about the gamification parts of our system. She told us that letting parents choose when and what children should receive as rewards was good, but it has a downside. If the parents don't have an understanding of how fast a child needs his/her reward, the child could easily loose interest. The amount of time necessary between each reward is higly individual. Preschoolers would need rewards almost every day, while a little older children could manage with a reward twice a week. The part that is somewhat hard to understand here from a parent perspective, is that children needs to know they are rewarded for a treatment well done, and not necessarily something completely different. She proposed that if an application like this should be launched to an app store, a parental guide should follow along, as parents often don't understand this principle.

Additionally there has to be a balance between the rewards a child receives, and the work they are actually doing. For instance, a child can't get a bike after completing three treatments. Parents also have a materialistic mindset, i.e. rewards has to be something material. Kayed implies otherwise. Letting children choose a dinner, which TV program to watch at nighttime, or even eating their breakfast under the table could be just as effective and fun as giving them tangible rewards. In order to equalize rewards across families, she concluded that parents already do this in other “domains”, like allowance.

Chapter 8

AsthmaBuddy

8.1 Background

In 2012, we did a similar project using Karotz [1] as our platform[4]. The thought behind Karotz is great. It is an open source robot which allows people to build applications and launch it to the Karotz store. However, in our subjective opinion, it is not ideal to work with. The Karotz starters kit costs $200, not including customs, thus it is a pretty large investment for a family wanting to buy the product to use with our application. The API is only documented in French, which makes it a hassle, in addition to the fact that it is pretty cumbersome to configure for a "non-technological" family.

8.2 Technology

We have looked around for other options than Karotz to create our tangible user interface, i.e. Arduino and Raspberry Pi. Arduino is an open source electronics prototyping platform[78], which allows for many different combinations of configurations, while Raspberry Pi is a cheap computer on the size of a credit card. Arduino shields comes in many shapes and sizes and is built for modularity and extendability. A wide-range of components are available if you want to add technical functionality to an Arduino system, such as Bluetooth, WiFi or small motors. While Arduino allows complex hardware configurations, Raspberry Pi makes larger abstractions, which seemed like the better choice for us as developers. Arduino programs are normally written in C[79], and while there exists many tutorials and manuals for how to write Arduino code, we found the thought of writing in a programming language we had little prior knowledge of too challenging. Arduinos generally have low-powered CPUs, in order to keep them cheap. These

[1] Karotz - www.karotz.com

low-powered CPUs tend to have problems with decoding MP3-files, which would lay constraints on our system. Due to these facts, we choose to develop the system on a Raspberry Pi.

8.2.1 Raspberry Pi - Specifications Overview

The Raspberry Pi was initially intended to teach british school children about computer programming[80]. Since its release, it took an unexpected turn when lots of computer enthusiasts bought the product to do their own mini projects for a cheap price.

The specification of a Raspberry Pi (Model B) is included in Table 8.1. Figure 8.1 shows an overview of the Raspberry Pi.

Property	**Specification**
CPU	700 MHz ARM1176JZF-S core
Memory	512 MB
USB 2.0 ports	2
Video Output	HDMI
Audio Output	3.5 mm jack, in addition to ability to play sound through HDMI
Low-level Peripherals	8 x GPIO (General Purpose Input/Output)
Power Source	5 volt MicroUSB
Storage	SD card (available with preinstalled OS)
Network	10/100 Mbps Ethernet.

TABLE 8.1: Raspberry Pi specifications

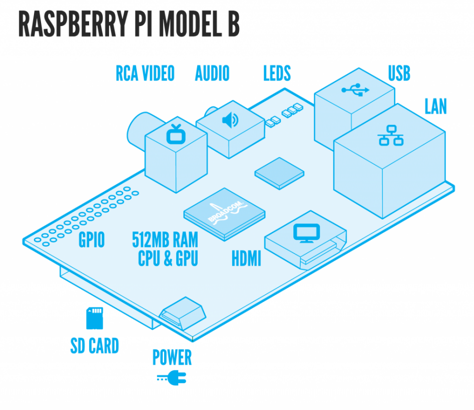


FIGURE 8.1: Raspberry Pi Model B architecture. *Image source: http://raspberrypi.org/faqs*

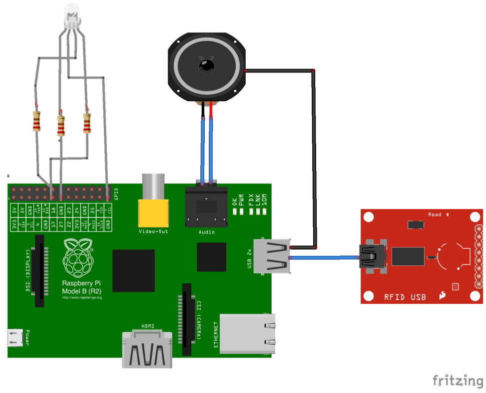


FIGURE 8.2: Digital schematic over Raspberry Pi

8.2.2 Additional Components

In addition to the Raspberry Pi we needed some components that children are able to interact through. These components and their functionality are summarized in this section.

RFID Reader A child needs to be able to interact with AsthmaBuddy. We identified two approaches; using a button and/or using RFID technology to do it. We figured that having a big button on the top of a teddy bear would seem somewhat unnatural for a child. Additionally, this could cause problems with the wires inside the teddybear, as a child pushing a button could imply that AsthmaBuddy would be moved around. This could have been avoided by using a battery pack for the Raspberry Pi, but their capacity does not seem to exceed 24 hours when the Raspberry Pi is in idle mode. The conclusion was to use RFID technology to proceed in the medication process.

The RFID reader we used was a Sparkfun ID-12LA [2] . One of the requirements of the USB reader was that it should be able to connect through an USB-port.

USB speakers In order to play sounds to children, we decided to integrate speakers inside AsthmaBuddy. Since we did not want to pull too many wires out of the bear, we decided to use USB-powered speakers.

[2]Sparkfun ID-12LA documentation - http://tiny.cc/sparkfundoc

LED lights We used LED lights connected to a breadboard in order to play around with the first prototype. The LED lights emits light in different colors to correspond to what action(s) is expected from the user during a treatment (see more in 8.5).

Pi4j Pi4j [3] is a Java framework that allows development for Raspberry Pi in Java, without having to write anything in C.

Figure 8.2 shows a digital overview of AsthmaBuddy. The green figure to the left is our Raspberry Pi. While it is also connected to a power supply and an internet cable, we chose not to include these in our figure. The red figure to the right is the RFID reader. It is connected to the Raspberry Pi through an USB cable. The black figure on top is the speaker, connected to the Raspberry Pi through the audio port. The grey lines and the lamp represents our LED light. It is connected to three of the GPIO (General Purpose I/O) ports on the Raspberry Pi, through a resistor. The last leg of the LED light is connected to ground on the Raspberry Pi, without a resistor.

8.3 Design Rationale

8.3.1 Why a Teddy Bear?

When designing AsthmaBuddy we choose to use a teddy bear as an avator for our system. There are several reasons as to why we think this is an appropriate avatar. Teddy bears are well known toys, and has been loved for a long time. They are considered gender-neutral[81][82] and in our subjective opinion it is a toy that could be discretely placed in a children's room. With the look of a teddy bear, AsthmaBuddy can easily be placed among other toys and not be too visible. It was also important for us to choose a teddy bear of some size. A too thin bear could lead to problems with fitting the system inside the bear, and could in order lead to scepticism from the children. AsthmaBuddy will have similarities to Tamagotchi[83] and Furby[84], but AsthmaBuddy's purpose is to motivate, instruct and learn children about asthma, not being a toy meant purely for play.

While designing our system we also wanted to make sure our system did not have robot-like features or robotic similarities. While children tend to find technology very interesting, we want to make AsthmaBuddy seem as natural as possible, making a stuffed animal buddy, rather than a technological toy. We believe that these design choices serves our purpose of making children more aware of their asthma, while not being a constant reminder and a stress element.

[3] Pi4j - http://pi4j.com

Norwegian fire fighters have used a teddy bear in order to calm down children who find themselves in dramatic situations [4]. The fire fighters state that the children respond positively to the teddy bear. While we were not able to find scientific research done on the use of teddy bears in dramatic situations, we found this news article interesting and a relevant mention to our research.

[Pictures of the bear we chose?]

8.3.2 Interaction design

When we started developing the interaction design of AsthmaBuddy, we had a brainstorming session with the intentions of coming up with reasonable interaction patterns. By "reasonable", we imply that the underlying functionality should be relatively cheap to implement. The interactions should also be fun for the children to perform, in addition to being efficient.

[4] NRK: Firefighters use teddy bears to calm down children - http://www.nrk.no/trondelag/bamser-i-utrykningsbilene-1.11548966

Interaction Process	**Rationale**	**Possible implementation**
Give AsthmaBuddy a "High five"	Demonstrates to children that AsthmaBuddy is friendly. It is intended that a child should keep AsthmaBuddy's arm up, and high five AsthmaBuddy with the other arm	A gyroscope and a preassure sensor combined could verify that a high five has been received.
Hold AsthmaBuddy's hand	Demonstrates to children that AsthmaBuddy is friendly.	Preassure sensor within the hand of AsthmaBuddy could solve this.
Hold smartphone close to AsthmaBuddy's belly	Could demonstrate the "smartness" of AsthmaBuddy, i.e. it can communicate with other things.	Could be solved by Bluetooth.
Press AsthmaBuddy's nose.	Demonstrates to children that AsthmaBuddy is friendly.	Preassure sensor within the nose of AsthmaBuddy could solve this.
Press AsthmaBuddy's belly.	Same as above	Same as above
Hold medicine close to AsthmaBuddy's mouth	Demonstrates that AsthmaBuddy also needs his medicine.	An RFID-tag attached to the medicine, and an RFID-reader inside the nose of AsthmaBuddy could be used here to control the flow.
Hold RFID-tag close to AsthmaBuddy's mouth	Is a relatively easy way to proceed with the process.	A loose RFID-tag could be used together with an integrated RFID-reader, in order to proceed.
Hold RFID-tag close to AsthmaBuddy's belly	Same as above	Same as above
Clap your hands	Should be a fun way of interacting with systems, considering the age of our target group	Sound recognition could be used here.

TABLE 8.2: Rationale behind AsthmaBuddy's interaction design

8.3.3 Answering to Champoux's Development Framework

In Section 4.5.1 we described the development framework presented by Champoux et. al.. When developing AsthmaBuddy, we tried to answer the proposed questions that we considered relevant.

BO1: What should the user experience? The user should experience an interactive guide to applying an asthma treatment correctly. AsthmaBuddy should give correct information in an understandable manner.

BO2: What are the human tasks?

- Fetch an adult
- Fetch inhaler and mask
- Shake medicine
- Attach the inhaler to the mask
- Put the mask around your mouth

BO3: What should the artefact represent and control? AsthmaBuddy represents a caregiver, who supervises children during their treatment. The artefact controls that children take their medicine at the correct time, and in a correct manner.

BO4: What are the conventions? Children have their inhaler and mask stored within a short distance of AsthmaBuddy. Their RFID-tags are attached on their inhalers.

OC5a: What is the nature of the interaction for each sub task (Continuous vs Discrete vs Assembly)? The subtasks performed when taking a medicine is the following:

1. Fetch parents
2. Fetch inhaler
3. Fetch mask
4. Prepare medicine
   (a) Shake the inhaler
   (b) Attach inhaler to the mask
5. Inhale dosage
   (a) Hold medicine towards mouth
   (b) Press the inhaler
   (c) Breathe heavily for 10 seconds

6. Optional, depending on the medicine: Rinse mouth

Step 4 is an assembly task, 5(c) is a continuous task for a short period of time, while the remaining tasks are all discrete.

OC6: Does the sub-task need any relational interaction? None of the sub-tasks needs relational interaction. [Pieter: Vil RFID-tag og RFID-leser her telle som en form for relational interaction?]

8.3.4 Dealing with Bellotti's challenges

Section 4.5.2 introduced some of the challenges that are exposed when designing tangible interfaces. Here, we'll discuss how we intend to handle the challenges presented, by answering his questions that we found relevant.

Address: How do I address one of many possible devices? One of the challenges mentioned here is "How to not address the system". This is an interesting challenge when the system is intended for children, as they like to pick things up and carry them around. AsthmaBuddy will only start a treatment in two ways, either by an alarm firing or an RFID-tag attached to an inhaler is read. The RFID-reader is only capable of reading within a distance of 3-5 cm. Thus, as long as no alarms is fired, and an inhaler with attached RFID-tag is not withing the reach of the RFID-reader, the system should not respond.

Attention: How do I know the system is ready and attending to my actions? AsthmaBuddy will as mentioned previously have a LED-light on it's nose. When this light is green, the user can expect that the system is running.

Action: How do I effect a meaningful action, control its extent and possibly specify a target or targets for my action? The part that regards specifying a target or several targets is considered irrelevant. The interesting part is how the user can effect a meaningful action and control its extent. This will be taken care of by interactions between the user and AsthmaBuddy. AsthmaBuddy will never run several instructions at once. It will always give short and clear instructions, and wait for feedback from the user in order to proceed.

Alignment: How do I know the system is doing the right thing? By listening when AsthmaBuddy speaks, the user should be aware of what is going on. There is not a lot of room for human errors here. By following the normal sequence of operation, the worst thing that can happen is a system crash. This will be handled by shutting down the lights, and AsthmaBuddy will not be running.

Accident: How do I avoid mistakes? Again, as long as the user is paying attention to what AsthmaBuddy says, and does the intended interaction. A part of the challenge here is to recover from mistakes that has happened. For instance, if the user goes further proceeds further than was actually intended, and missed out on an instruction they needed, AsthmaBuddy should have a way to go back to missed instruction. This was handled by having a separate "back"-interaction method. [TODO: Finn en interaksjon som kaller Back].

8.4 System Overview

8.4.1 Use Cases

Figure 8.3 shows a general overview of the use cases we have included in our prototype. A medication process can be started in one out of two ways. A parent can register an alarm by using AsthmAPP. This alarm is then triggered by AsthmaBuddy, giving the child a notification that it is time to take their medicine.

The alternative is if children need to take their medicine by need. If they need to take a medicine by need, they simply register their RFID-tag before children are taken through a quicker process (see Manuscript H).

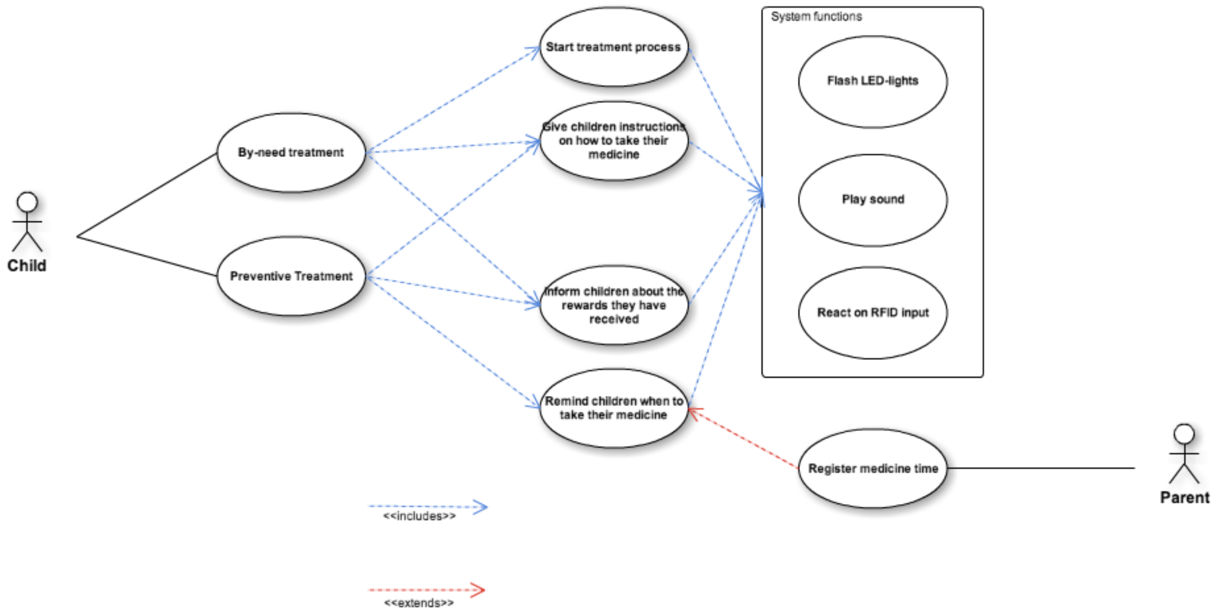


FIGURE 8.3: AsthmaBuddy Use Cases

8.4.2 Textual Use Cases

Title	By need treatment
Preconditions	-
Scenario	1. User triggers treatment by holding a specific RFID-tag close to AsthmaBuddy 2. System flashes LED-lights to notify user that the system is ready for use 3. System plays sound to instruct the user to shake the medicine 4. System plays sound to instruct user to mount the medicine on the mask and place the mask on his/her face 5. User starts a treatment by interacting with AsthmaBuddy (by pressing it's hand or similar interaction) 6. System plays sound to count during treatment (1-2-3-4-5-6-7-8-9-10), while flashing lights for each count 7. System plays sound to tell user he/she has done a good job 8. System calculates reward based on health state 9. System plays sound to award user with the calculated amount of stars 10. System plays sound to tell the user how many stars he/she has collected totally
Extensions	x.a User aborts treatment by not continuing the sequence

TABLE 8.3: Textual use case: By need treatment

Title	Planned treatment
Preconditions	The current time corresponds with the time for a planned treatment
Scenario	1. The system recognizes the time for a planned treatment 2. The system starts blinking with LED-lights and playing sound to notify user 3. Child registers interacts with AsthmaBuddy, to notify that he/she is ready for the treatment 4. Start instructions by playing sound, telling the user to find a grown-up that can keep watch 5. System waits for interaction to make sure the user is ready 6. System tells the user to mount the medicine on the mask and put the medicine towards AsthmaBuddy's face 7. System plays sound to simulate breathing 8. System plays sound to tell the user how easy it was to take medicines and that it is the user's turn 9. System plays sound to instruct user, telling the user to shake the medicine 10. System waits for interaction to make sure the user is ready 11. System plays sound to instruct user to put the mask on his/her face 12. System plays sound counting to 10. 13. System plays sound to tell the user he/she has done a good job 14. System calculates reward based on health state 15. System plays sound to award user with the calculated amount of stars 16. System makes a HTTPGet call to the server to find the total amount of stars collected 17. System plays sound to inform the user about how many stars the user has collected totally
Extensions	x.a Child does not interact with AsthmaBuddy when prompted

TABLE 8.4: Textual use case: By need treatment

8.4.3 State Diagram

When the Raspberry Pi boots, it retrieves the latest version of the source code from Git, compiles it, and starts running it. If a child approaches AsthmaBuddy and registers a RFID-tag, a medication sequence is started.

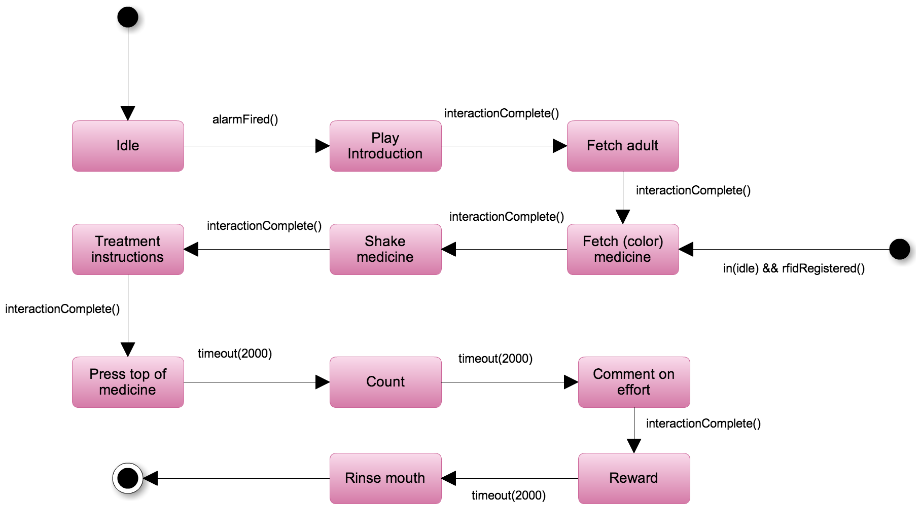


FIGURE 8.4: AsthmaBuddy State Diagram.

8.4.4 Sequence Diagram

Figures 8.5 - 8.8 shows sequence diagrams of how the system works internally. Some abstractions have been made, in order to reduce the cluster of arrows.

By Need Treatment We were not able to find a reasonable easy way to let the AsthmaBuddy automatically be aware of the medicine that was to be taken at the start of a treatment. As a result, we used ssh into the Raspberry Pi, and provided the color of the medicine and the sequence number for the interaction that was to be tested.

After inserting these parameters, the LogicHandler retrieves a LinkedList of Interactions that is to be played. After this sequence is ended, the system jumps to 8.7.

Planned Treatment If AsthmaBuddy is started without any parameters, it starts looking through alarm files (see Section 8.4.5) every 60 seconds. If no alarm is returned from UserDataManager, it waits. Once an alarm is found, it AsthmaBuddy is notified through onNotificationFired, which starts the treatment process.

Playing Instructions Playing instructions is mainly a loop of running a playing a sound, and turning on and off the LED-lights.

Finishing a Treatment When a treatment is finished, i.e. we are out of the while loop in Figure 8.7, we register the treatment in the database. This ensures that children are able to see the rewards in AsthmAPP.

8.4.5 Node Server

In addition to the Java application running on the Raspberry Pi, we developed a Node.js server [5] . This backend system was developed in order to easily visualize the rewards given to a child after a treatment using AsthmaBuddy. The initial problem is that AsthmAPP stores data to a MySQL database, with childId as the primary key for most tables. Initially, AsthmaBuddy has no way of knowing which childId to use in order to store the rewards. The current solution to our problem was to develop a Node.js server on AsthmaBuddy, which run as a background process. Whenever we want to switch users, AsthmAPP does an HTTP POST to this server, including the childId as a parameter. The server then retrives JSON-formatted data from our webservice, which includes the rewards a child has been given until now (for instance, by use of the smartphone), and the alarms set for this user. When AsthmaBuddy starts running, it checks for alarms to be fired every 60 seconds. When a child has finished a treatment, AsthmaBuddy updates the database, with the childId previously retrieved, and the amount of stars a child gathered during his or her treatment. Additionally, with the data retrieved from the database, AsthmaBuddy has the capability to tell the user how many stars a child has gathered[6]. This process is shown in Figure 8.9.

8.5 Prototype version 1

Our first prototype was a "dumb" version with the purpose of testing out different methods of interaction. We wanted to get as many different experiences as possible, in order to find what kids are thinking as ideal. Even though some of the interaction methods are infeasible to implement during the thesis, we wanted to know what children think of as fun interaction. We also found it important that children were motivated to give us honest results, so we wanted to give them freedom to be innovative and let their imagination play a part. [TODO: Change to something useful, and actual...]

[5] Node.js - http://nodejs.org/

[6] Since this is a prototype, this functionality only works until a child has gathered 20 stars. It became cumbersome to handle rewards totalling more than 20 stars

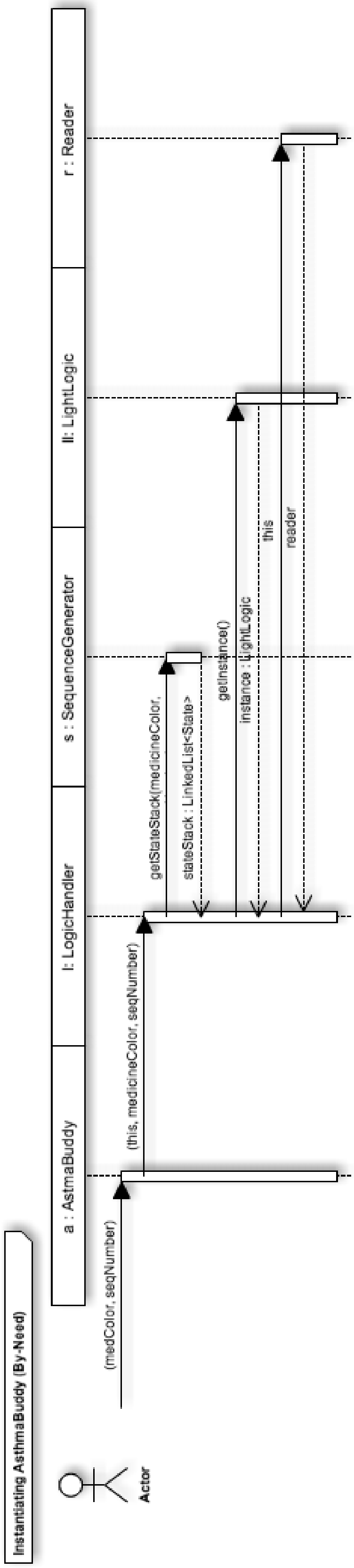


FIGURE 8.5: By Need Treatment - Sequence Diagram

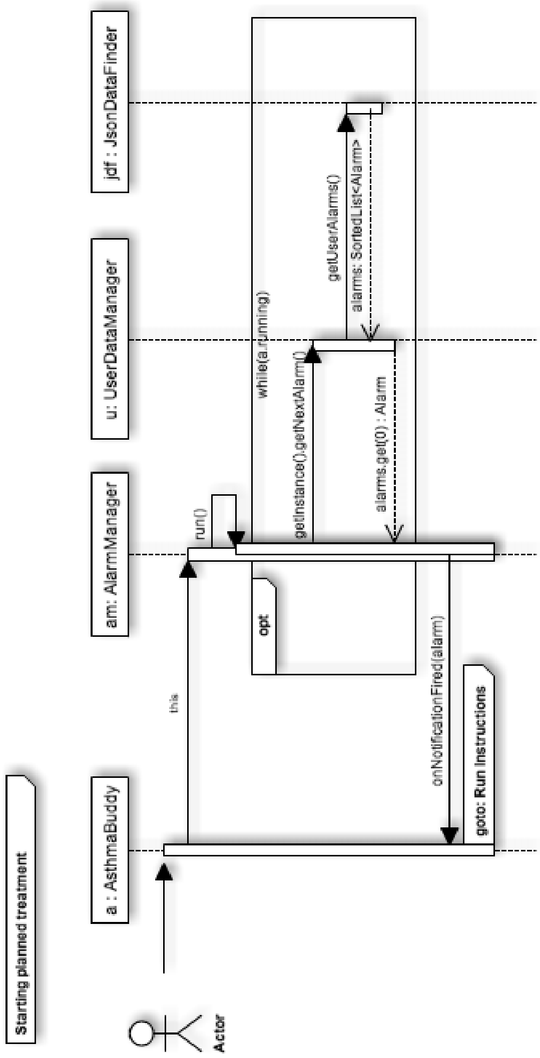


Figure 8.6: Planned Treatment - Sequence Diagram

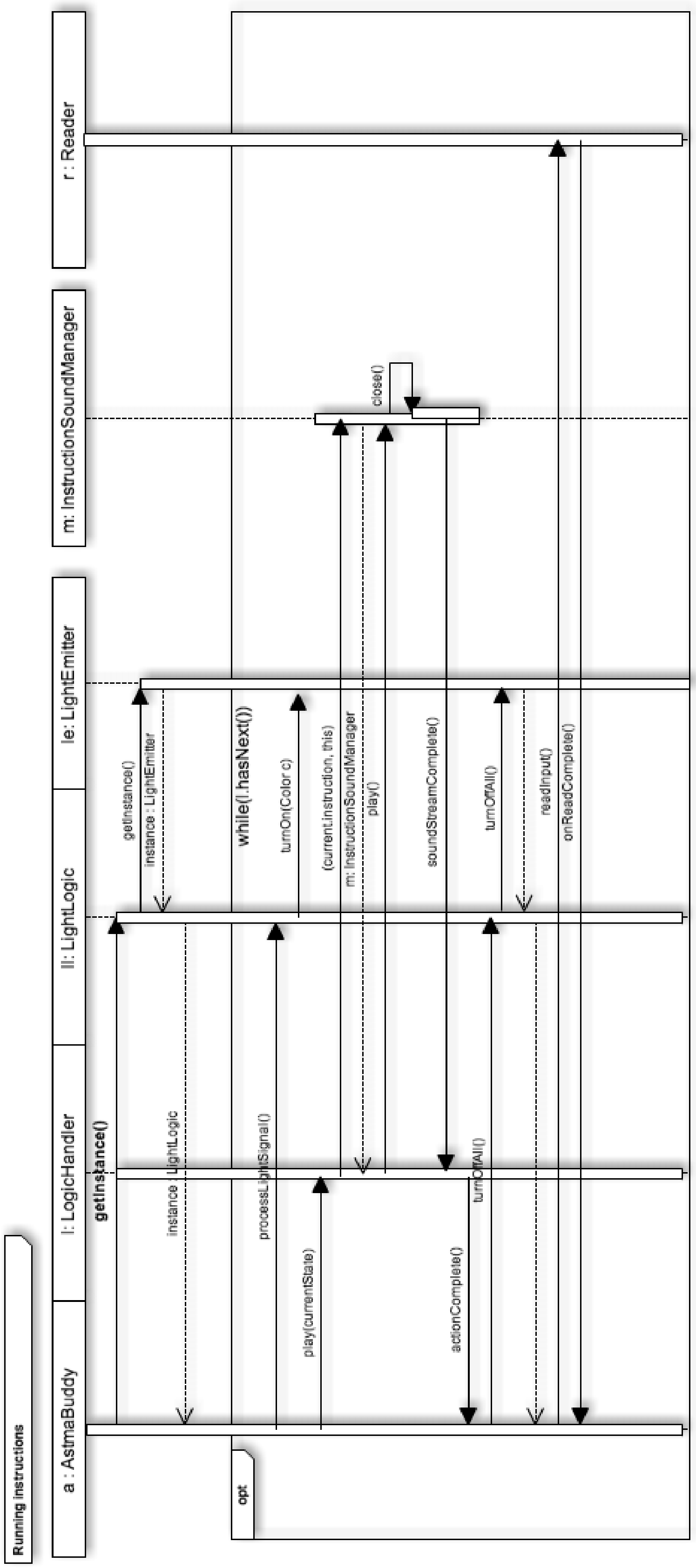


Figure 8.7: Playing Instructions - Sequence Diagram

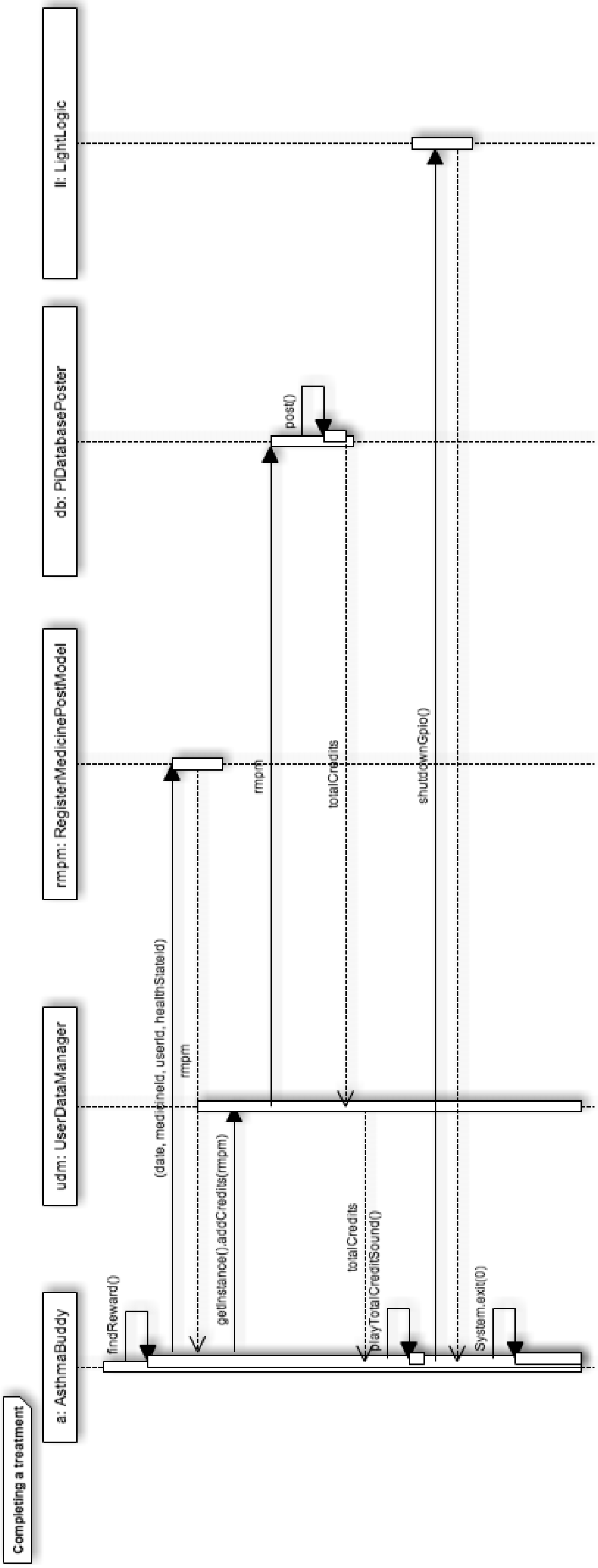


FIGURE 8.8: Finishing a treatment - Sequence Diagram

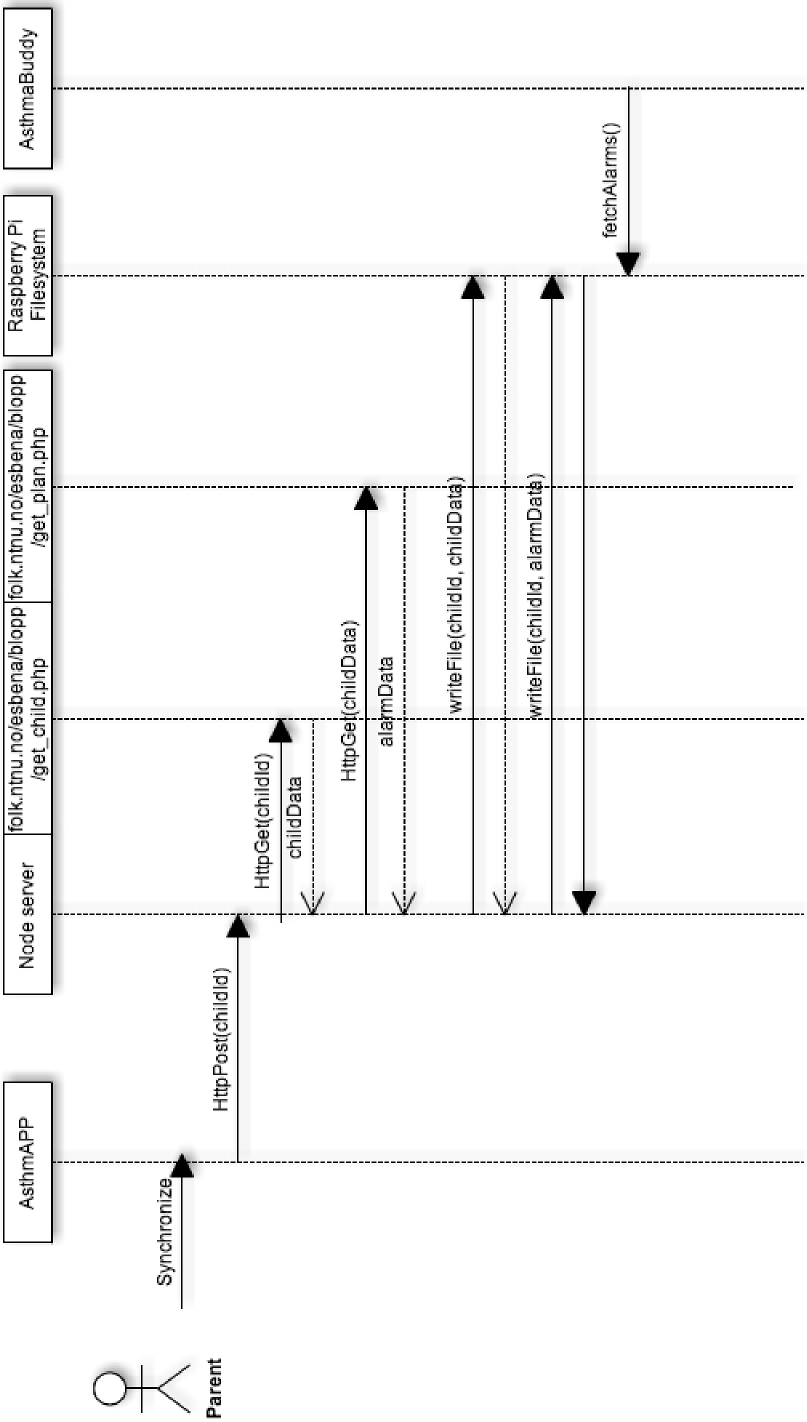


Figure 8.9: Synchronizing - Sequence Diagram

As a result, the first prototype was a simple state machine. The usability test was performed on NSEP's usability lab. Terje Røsand sat in the backroom filming the sequence, while having a computer with ssh-connection to AsthmaBuddy. Whenever he observed that the children performed the method of interaction, he pressed enter in order for AsthmaBuddy to progress it's medication sequence.

For the first prototype we tried out the following types of interaction with AsthmaBuddy:

1. Give AsthmaBuddy a "High Five"
2. Hold AsthmaBuddy's hand
3. Hold smartphone close to AsthmaBuddy's belly
4. Press AsthmaBuddy's nose
5. Press AsthmaBuddy's belly
6. Hold medicine close to AsthmaBuddy's mouth
7. Hold RFID-tag close to AsthmaBuddy's nose
8. Hold RFID-tag close to AsthmaBuddy's belly
9. Clap your hands
10. A variation of the above interactions

The prototype was not connected to the database. In order to show children their rewards, we simply added some stickers to a sheet of paper.

8.5.1 Information Gathering

During the development phase we interviewed a couple of domain experts and parents in order to gather information about how they perform asthma treatments.

8.5.2 Evaluation of prototype version 1

Interaction Method	Comments	Will it be in version 2?
Give AsthmaBuddy a “High Five”		
Hold AsthmaBuddy’s hand		
Hold smartphone close to AsthmaBuddy’s belly		
Press AsthmaBuddy’s nose		
Press AsthmaBuddy’s belly		
Hold medicine close to AsthmaBuddy’s mouth		
Hold RFID-chip close to AsthmaBuddy’s nose	The thickness of AsthmaBuddy’s nose made it difficult for the RFID tag to communicate with our reader, this caused problems for the user.	No
Hold RFID-chip close to AsthmaBuddy’s belly		
Clap your hands		
A variation of the above interactions		

Table 8.5: Evaluation of interaction methods for AsthmaBuddy

Evaluation of interaction methods

Operating time The longest time for taking a planned treatment was about 2 minutes for an experienced user, and about 2.5 minutes for an inexperienced user. This treatment included the part where AsthmaBuddy completes the treatment before the child. [SETT INN HVOR LANG TID DET TAR TIL VANLIG]. [SETT INN SAMMENLIGNING]. [VURDER OG KONKLUDER].

A By Need treatment was registered to take about a minute for an experienced user. Usually, it takes approximately [XX] minutes to do a By Need treatment [7]. [SETT INN SAMMENLIGNING]. [VURDER OG KONKLUDER].

Feedback

[7] Information gathered from parents

8.6 Prototype version 2

8.7 Evaluation

8.8 Further improvements

Chapter 9

Results

9.1 Gamification

9.1.1 Bartle's Four Player Types

[HOW TO MOTIVATE DIFFERENT PLAYERS eller noe]

9.2 Tangible Interfaces

9.2.1 Learning

9.2.2 Motivation

9.2.3 Distraction

9.2.4 Information

Pollution levels, pollen forecast and indoor air quality

Reminders

9.3 Other Aspects

9.3.1 Helping Kindergartens, Schools and Caregivers

During our interviews, we discovered a potential problem when children are in the kindergarten or at pre-school. It may occur that the caregivers don't know how to handle an asthma attack properly. According to one of our interview subjects:

"The biggest problem is that the teachers/kindergarten teacher may not have knowledge of what to do when an asthma attack occurs. An application with instructions may be of help to them."

A solution to this problem was provided by a kindergarten teacher we interviewed, who said that it was hard to keep track of which child was supposed to take his/her medicine at the correct time. They sometimes had this information stored on their own phone, or had a note in their pocket. In some cases, no such tool were used, which relies heavily on the teachers' memory. If the teacher forgets it, there is a possibility that the child don't take their medicine properly at the given day. The kindergarten teacher proposed an application that allowed parents to register a medicine that was to be taken, and sent push notifications to the teachers, that could remind them of their child's need for a treatment. We concluded that this functionality is out of the scope in this thesis, but we found the idea interesting.

From our viewpoint, having a shared AsthmaBuddy in a kindergarten could lead to complexity and problems. First, AsthmaBuddy would have to learn the names of the children in order to keep track of children whose turn it is. Second, there could be no overlapping of treatments, which might become inefficient (depending on the teachers). Third, having a shared AsthmaBuddy in a kindergarten could easily be destroyed. If placed in a kindergarten, AsthmaBuddy in it's current state would probably cause more problems rather than helping the kindergarten teachers. With changes and modifications, we still see the use for tangible interfaces in kindergartens and preschools, as a useful tool to help teachers and children.

9.3.2 Tangible Interfaces to Help Parents Help Children

When children suffers from asthma, they often have to rely on their parents in order to maintain control of their disease. Parents have to maintain a clean house and they have to keep an eye on pollen, as pollen and asthma often are related. One of the features AsthmaBuddy could have in order to help parents is a morning cast, informing parents about the weather, pollen distributions and air quality.

In the future, AsthmaBuddy could communicate with dust sensors, that could indicate whether or not parents actually needed to clean the house. Additionally, AsthmaBuddy could communicate with a Roomba [1] , which in turn could start cleaning. AsthmaBuddy could also indicate the air humidity at the child room, starting up the air condition.

[Pieter: Visjonshistorie?]

9.3.3 Do's and Don'ts when Using a TUI

Mobility When developing a TUI for children it is important that the TUI is mobile. Children become attached to their toys and like to take them with them. To make the most out of a tool such as AsthmaBuddy it is important that the children may take it with them. The problem of power usage may be solved by a battery. The problem of recharging can be solved by charging at nights.

LED lights With AsthmaBuddy we tried the use of LED lights to make AsthmaBuddy more interesting than a normal teddy bear. During a treatment the LED light would indicate which medicine was supposed to be taken, by beaming lights in the same color, blink to count the seconds when breathing and using red light to indicate the seriousness of having to find an adult to overview the process.

[Paavirket det pustingen til barn?] [Ble barna forvirret?]

One of our interview subjects, a PhD candidate of product design stated in an interview: *"People's perception of and preference for sensory stimuli differs. The use of lights and sound may affect the children in different ways, but that will have to be explored in user studies."*

We believe this is a complete field of research on it's own. There already exists some research, such as Mæhlum's *INSERT REFERENCE* , and we have not done enough research to draw conclusions on the use of LED lights.

Interaction Methods AsthmaBuddy in it's prototype form was not able to sense interaction, and was operated by using a "Wizard-of-Oz technique"[85]. AsthmaBuddy was not able to give feedback that the user did interaction correctly. The only form of confirmation was that the next sound clip would start playing. This may lead to confusion and uncertainties among users as to whether they interact correctly. *INSERT REFERENCE*

[1] iRobot Roomba - http://www.irobot.com/us/

[NOE OM INTERAKSJONSMETODER? HAR DET VERDI?]

9.4 Feedback from Parents

[SKAL SKRIVES OM VED FLERE RESULTATER]

We spoke to a mother of a child who have a "weak" form of asthma, i.e. he did not have severe attacks very often. This section will summarize some of the findings:

Boy, about 5 years old

- She did not have to "fight" with him very often
- It was hard to stay on the medicine plan correctly
- She missed an application that could easily structure when and how much medicine had been taken.
- She found it difficult to meet up at doctor appointments, and remember when she had switched medicine plans.
- In order to calm her child, she would sing or count while he was breathing
- As far as rewards go, she had experimented with using bumperstickers on a sheet of paper while giving him toilet training. In her opinion, this was rewarding enough. She did not that our reward system could be useful for other kids though. 3-7 years old is a very large span in terms of cognitive development, and we should have this in mind.
- Alarms were, in her opinion, the most important feature.
- Demonstration worked pretty good, as it calmed the child down.
- She was positive to having a bear at home that could help children take their medicine. However, she would not let him take medicine by himself.
- Sidenote: She is a kindergarten teacher, which implies that she gives asthma medicine to several children. An application that could help kindergarten teachers remind when a specific child was to take their medicine would be much appreciated.
- She did not see that it was need for By Need treatments via an application or a teddybear, as it would slow the process down. Children were often stressed out when they had an asthma attack, so having a teddybear *could* help during the process to calm him down.
- Teaching children about their disease could be given more of an effort. However, this was outside the scope of our project.
- Having a shared mobile application across caregivers could be benefitiary, as she often had to explain to give a medicine to others.

9.5 Effects of Gamification in The Treatment Process

Our solution to gamification is highly coupled with parents' initiative. In order for our reward system to have any motivational effect, parents has to be highly involved. They need to understand how often their child needs a reward, in addition to understanding what defines a "good" reward for their children.

Webster-Stratton and Herbert claims that

Preschool children aged between the ages of three and four may be rewarded by the special sticker or token itself without needing a back-up reinforcer. Youngsters aged four to six should be able to trade in stickers for something each day if they like. Children of seven and eight can wait a few days before getting a reward. [86]

9.6 How can tangible user interfaces be used to help children with asthma?

When we first started this project we aimed to look into how tangible user interfaces may be of use for children with asthma. This section presents our findings.

Information spreading and educating asthmatic children and their parents
[Reasons we believe in this]

"Preschool children aged between the ages of three and four may be rewarded by the special sticker or token itself without needing a back-up reinforcer. Youngsters aged four to six should be able to trade in stickers for something each day if they like. Children of seven and eight can wait a few days before getting a reward." [86]

In order for our AsthmAPP and AsthmaBuddy to be a motivational success, parents have to be aware over their children's maturity. They need to understand the above statement, and use this for their own children.

Learning *"Children below your target group (i.e. younger than 3 years old) can be even harder, as children in the group 3-5 years old has an understanding as to why they need to take their medicine."* Children in the age of 3-5 years old understands that they get better from taking their medicine. However, few parents actually tells them specifically what is wrong with them [Sitat?]. AsthmaBuddy could have been used to inform children about what happens with their lungs before and after they take their medicine. [TODO: Write more.]

Chapter 10

Conclusion

This chapter completes the discussion chapter by representing the research questions, providing answers where possible, and evaluates the process of obtaining these answers.

10.1 Discussion

[Pieter: Slik vil vi legge opp denne seksjonen]

10.1.1 General Discussion

10.1.2 Process Evaluation

As with all other software development projects, the development of AsthmAPP and AsthmaBuddy has hit some bumps in the road. This chapter will look into possible improvements of the developments process. Second it will evaluate the experiment design and point out different elements which could have been done differently.

10.2 Conclusions

The research questions presented in Chapter 1.3 provides a basis for summarization of results discussed in Chapter 9 Results and Chapter **??**.

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

RQ2: How can Tangible Interfaces be used for motivating children to take their asthma medicine?

10.2.1 Difficulty finding children

[NOE OM HVOR VANSKELIG DET VAR AA FINNE BARN MED ASTMA, RIKTIG ALDERSGRUPPE, OG FORELDRE SOM KAN STILLE].

Chapter 11

Further Work

AsthmAPP and AsthmaBuddy are early prototypes, and need further work and changes before finalization. This chapter presents different solutions to previously mentioned evaluation and other changes based on user feedback.

As stated in Section 3.3, the motivational effect of gamification withers over time. We have not been able to test our prototypes over a longer period of time, and there is an existing risk that AsthmaBuddy and AsthmAPP will become less interesting over time.

[Oversettbarhet til andre medikamenter?]

Appendix A

Further Work

This appendix is reprinted from the final report of 'BLOPP - Development of a prototype for treatment of asthmatic children, using Android and Karotz'[1] [4]

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 **??** [2] 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.

A.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.

A.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

[1] Reprinted with permission from Aaberg, Aarseth, Dale, Gisvold and Svalestuen

[2] This section is not included in the thesis, and will therefore on purpose result in '??'

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.

A.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.

A.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.

A.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.

A.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.

A.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 B

Questionnaire. Demographics

Vennligst besvar spørsmålene under, før vi begynner testen.

Kjønn
Alder
Utdanning
Yrke

Appendix C

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 D

Draft for Interview Conducted after Usability Test

Nå som du har gjennomført testen ønsker vi å vite hva du synes om applikasjonen.

Hvordan synes du gjennomføringen av oppgavene gikk?	
Var det noe du opplevde som vanskelig?	
Hvorfor var det vanskelig?	
Har du brukt noe(n) lignende applikasjon(er) tidligere?	

Appendix E

Scenario and tasks

Slett AsthmAPP's brukerdata på forhånd.

Forklar hvorfor vi ikke har kalt medisinene Flutide, Seretide og Ventoline, men at vi har kalt de etter fargekoder.

E.1 Foreldre

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 AsthmAPP. 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 AsthmAPP, er det nødvendig at du gjennomfører noen oppgaver.

Oppgave 0: Gå inn på voksendelen av applikasjonen. Du vil bli bedt om å lage en PIN-kode. Sett denne til “1111”.

Oppgave 1: Du skal sette opp en medisineringsplan i henhold til anbefaling fra legen. I første omgang skal du kun sette opp medisineringsplanen som gjelder når barnet er frisk. Legg til en varsel for “Oransje” kl 13:37 og en varsel for “Lilla” 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 en dose av “Lilla” for dagens dato.

Oppgave 3: Du ønsker å motivere barnet ditt til å ta medisinene ved hjelp av en belønning. Lag en premie barnet ditt kan få dersom hun/han har fulgt medisineringsplanen sin. Som premiebilde kan du velge en fotball fra "Standardbilder". Premietekst kan du sette til "Fotballbillett" og sett antall stjerner til 3. Premien skal ikke gjentas.

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

Oppgave 5: Du ønsker å sjekke hvordan luftkvaliteten er i dag, før barnet skal på fotballtrening. Se i loggen om du bør ta hensyn til luftkvaliteten før du sender barnet av gårde.

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

E.2 Barn

Oppgave 0: Dette er Blipp. Han har fått astma han også , akkurat som deg. Du kan hilse på han og spørre om han er klar for å leke litt.

Oppgave 1: Kan du sjekke hva du kan tjene på å ta medisinen din i fremtiden. Se i lekebutikken om du finner noen premier. Hvor mange stjerner trenger du for å kjøpe deg premien?

Oppgave 2: Nå er det på tide å hjelpe Blipp med å ta pustemedisinen hans. Dersom du er klar, kan du klappe han på hodet. For å hjelpe han, må du gjøre akkurat som han forteller deg.

[Kjør til Blipp har tatt medisinen sin]

Oppgave 3: Nå er det din tur til å ta pustemedisin. Følg instruksene til Blipp videre. Det kan hende at du vinner noen stjerner som du kan kjøpe premie med!

Demonter medisin fra masken

Oppgave 4: Nå ringte det en alarm på mobilen som sier at du må ta en medisin til. Kan du gjøre dette igjen, og gjøre som kaninen på telefonen sier til deg? Telefonen vil også gi deg stjerner når du har gjort det.

Oppgave 5: Nå har du samlet mange stjerner. Sjekk i butikken om du kan kjøpe deg en premie, og kjøp den hvis du har råd.

- Synes du dette var mer moro enn når du gjør det til vanlig?
- Hvilken likte du best? Bjørnen eller kaninen?
- Kunne du tenkt deg å leke med bjørnen en annen gang?

E.3 Nødplaner

Vi tar med oss følgende utstyr som kan roe ned barna Tegnesaker, spill på mobilen.

Hva gjør vi dersom barnet ikke har lyst til å leke med bjørnen? Spør foreldre om de kan kjøre en gjennomgang for å demonstrere for barnet at det ikke er noe farlig. Dersom foreldre ikke vil, prøver vi selv å kjøre en gjennomgang for å demonstrere at det ikke er noe farlig.

Dersom strøm/internett-ledninger gå r ut "Blipp er dessverre ikke noen superhelt, så han er avhengig av strøm for å fungere, akkurat som en TV eller lampe. Han har det helt fint, vi må bare koble han opp igjen. Det er ikke noe farlig. I mellomtiden kan du tegne litt på papirene dine"

Dersom barna ikke gjennomfører testen, og vi må avbryte: Gi de et "gavekort" på 3 stjerner, som kan cashes inn.

Hva gjør vi dersom barna er helt ville? Spørre foreldre om de kan roe de ned? I verste fall, spørre om de vil vente på siderommet og tegne litt.

E.4 Bakromsoppgaver

Ha to terminalvinduer oppe (T1 og T2)

T1 Kjør følgende kommandoer:

- $ ser
- $ node index.js

La serveren kjøre gjennom hele brukertesten.

T2

- $ blopp
- $ ./v2.sh CN

C er her fargen på medisinen som barnet har, N er sekvensnummer som skal kjøres. N = 0-9

Dette vil kjøre Blipp-scriptet, og vil terminere når et barn er ferdig. ./v2.sh CN må kjøres på nytt når et nytt barn ankommer.

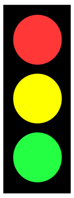
Appendix F

AsthmaBuddy Manual

The following Appendix works as a user manual for AsthmaBuddy.

Appendix G

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

Want to take an Asthma Class: Call 983-6336

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.

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	

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.

KMCWC ED Ver. Nov 4, 2009

Appendix H

AsthmAPP Manuscript

AsthmaBuddy and AsthmaBuddy has a prerecorded manuscript, which is included below.

C is the color of the medicine, i.e. C $\in \{Blue, Orange, Purple\}$.

N is the number of stars a child gets, i.e. C $\in \{1, 3, 5\}$, depending on the current health state of the child.

H.1 AsthmaBuddy

AsthmaBuddy's manuscript is twofold, depending on the interaction we want to run with.

H.1.1 Instructions

The following are the instructions a child receives, and where the manuscript reads "(Interaction)", one of the interactions in H.1.2 are insterted. The norwegian manuscript is used in the applications, while the english manuscript is included for the reader's convenience.

1. Hei! Jeg heter Blipp, og nå er det tid for å ta pustemedisinen din.(Interaction). *Hi! My name is Blipp. It's time to take your breathing medicine. Press my head, and I'll tell you more (Interaction)*
2. Hent en voksen som kan se på, og (Interaction). *Fetch an adult who can supervise, and (Interaction)*

3. Hent den **C** medisinen din, og masken du puster i. (Interaction). *Fetch your **C** medicine, and the mask you're breathing in. (Interaction)*
4. Rist den **C** medisinen din (ristelyd), og fest den på masken din. (Interaction). *Shake your **C** medicine, and attach it to your mask. (Interaction)*
5. Sett masken mot munnen min, og tell til 10 mens jeg puster inn og ut. *Put the mask towards my mouth, and count to ten while I breathe in and out.*
6. (Pustelyd i 10 sekunder). *(Breathing sound for ten seconds)*
7. Så du hvor lett det var? Nå er det din tur. *Did you see how easy that was? Now it's your turn.*
8. Av den **C** medisinen skal du ta 1 puff. Sett på deg masken, og (Interaction). *You are going to take one spray of the **C** medicine. Put on your mask, and (Interaction).*
9. Når jeg sier i fra skal du trykke på sprayen. Jeg skal telle til 10 mens du puster inn og ut. Klar, ferdig, TRYKK! *When I tell you, you are going to press the spray. I'm going to count to 10 while you breathe in and out. Ready, set, PRESS!*
10. En, To, Tre, Fire, Fem, Seks, Syv, åtte, Ni, Ti. *One, Two, Three, Four, Five, Six, Seven, Eight, Nine, Ten!*
11. Flott innsats! Som belnning får du **N** stjerner i skattekista di. *Well done. As a reward, I'll put **N** stars into your treasure chest*
12. Da er vi ferdige for nå. Nå må du huske å skylle munnen din, så sees vi neste gang *We are done for now. Remember to rinse your mouth. We'll see each other next time.*

H.1.2 Interactions

1. Hold meg i hånda når du er klar. *Hold my hand when you are ready*
2. Hold mobiltelefonen din foran magen min for å gå videre. *Hold your mobile phone in front of my belly in order to proceed*
3. Trykk på nesen min når du er klar. *Press my nose when you're ready*
4. Gi meg en high five for å gå videre. *Give me a high five in order to proceed*
5. Hold medisinen foran munnen min for å gå videre. *Hold your medicine in front of my mouth in order to proceed*
6. Trykk på magen min for å gå videre. *Press my belly in order to proceed*

7. Hold kortet ditt foran magen min for å gå videre. *Hold your card in front of my belly in order to proceed*

8. Hold kortet ditt foran nesen min. *Hold your card in front of my nose*

9. Klapp hendene dine for å gå videre. *Clap your hands in order to proceed.*

H.2 AsthmAPP

1. Hei! Jeg heter Blipp, og nå er det tid for å ta pustemedisinen din. Trykk på hodet mitt, så setter vi i gang. *Hi. My name is Blipp. It's time to take your breathing medicine. Press my head, and I'll tell you more*

2. Hent en voksen som kan følge med, og trykk på hodet mitt når dere er klare. *Fetch an adult who can supervise. Press my head to proceed*

3. Hent den **C** medisinen din, og masken du puster i. Trykk på hodet mitt når du er klar. *Get the **C** medicine and the mask you're breathing in. Press my head to proceed*

4. Rist den **C** medisinen (ristelyd), og fest den på masken din. Trykk på hodet mitt for å gå videre. *Shake the **C** medicine, and attach it to your mask. Press my head to proceed*

5. Av den **C** medisinen skal du ta ett puff. Sett på deg masken, og trykk på hodet mitt når du er klar. *You are going to take 1 spray of the **C** medicine. Put on your mask and press my head when you're ready*

6. Når jeg sier i fra skal du trykke på sprayen. Jeg skal telle til 10 mens du puster inn og ut. Klar, ferdig, TRYKK! *When I tell you, you are going to press the spray. I'm going to count to 10 while you breathe in and out. Ready, set, PRESS!*

7. En, To, Tre, Fire, Fem, Seks, Syv, åtte, Ni, Ti. *One, Two, Three, Four, Five, Six, Seven, Eight, Nine, Ten!*

8. Flott innsats! Som belønning får du **N** stjerner i skattekista di. *Well done. As a reward, I'll put **N** stars into your treasure chest*

9. Da er vi ferdige for nå. Nå må du huske å skylle munnen din, så sees vi neste gang *We are done for now. Remember to rinse your mouth. We'll see each other next time.*

Appendix I

Constraints

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

I.1 The Health Register Act

Norway has specific laws for storing of medical information. The most significant law is "The Health Register Act[1]"[87]. 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] in order to store medical records in the application. This document is attached as Appendix [INSERT REFERENCE]. If the mobile application were ever to be deployed to Google Play, or AsthmaBuddy commercialized, we would need permission from *The Data Protection Authority*, but it is not required if the application is just for research purposes.

I.2 Measures for Anonymization

Pursuant to section 16 of the Health Register Act [87] 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] Regional Committees for Medical and Health Research Ethics - 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] Bernard Champoux and Sriram Subramanian. A design approach for tangible user interfaces. *Australasian Journal of Information Systems*, 11(2), 2007.

[3] 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.

[4] Dale Gisvold Svalestuen Aaberg, Aarseth. Blopp - development of a prototype for treatment of asthmatic children, using android and karotz. 2012. URL http://folk.ntnu.no/esbena/kpro/FinalReport_main.pdf.

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

[6] Global Initiative for Asthma. Pocket guide for asthma management and prevention. URL http://www.ginasthma.org/local/uploads/files/GINA_Pocket2013_May15.pdf.

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

[8] Andrea Leal Penados, Mathieu Gielen, Pieter-Jan Stappers, and Tinus Jongert. Get up and move: An interactive toy that measures (in) activity and stimulates physical activity.

[9] John Brooke. Sus-a quick and dirty usability scale. *Usability evaluation in industry*, 189:194, 1996.

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

[11] Marikken Høiseth, Michail N Giannakos, and Letizia Jaccheri. Research-derived guidelines for designing toddlers' healthcare games. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems*, pages 451–456. ACM, 2013.

[12] Nasjonal strategi for forebygging og behandling av astma- og allergisykdommer. URL http://www.regjeringen.no/upload/hoD/Dokumenter%20fha/astmastrategi.pdf.

[13] 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.

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

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

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

[17] 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.

[18] 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.

[19] 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/.

[20] 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.

[21] 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.

[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] Gerry Stahl, Timothy Koschmann, and Dan Suthers. Computer-supported collaborative learning: An historical perspective. *Cambridge handbook of the learning sciences*, 2006, 2006.

[37] Hearts, clubs, diamonds, spades: Players who suit muds. URL http://mud.co.uk/richard/hcds.htm.

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

[39] 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.

[40] John Underkoffler and Hiroshi Ishii. Urp: a luminous-tangible workbench for urban planning and design. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, pages 386–393. ACM, 1999.

[41] Hiroshi Ishii, Carlo Ratti, Ben Piper, Yao Wang, Assaf Biderman, and E Ben-Joseph. Bringing clay and sand into digital designcontinuous tangible user interfaces. *BT technology journal*, 22(4):287–299, 2004.

[42] 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.

[43] 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.

[44] Ken Hinckley, Randy Pausch, John C Goble, and Neal F Kassell. Passive real-world interface props for neurosurgical visualization. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 452–458. ACM, 1994.

[45] Thomas P Moran, Eric Saund, William Van Melle, Anuj U Gujar, Kenneth P Fishkin, and Beverly L Harrison. Design and technology for collaborage: collaborative collages of information on physical walls. In *Proceedings of the 12th annual ACM symposium on User interface software and technology*, pages 197–206. ACM, 1999.

[46] 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.

[47] 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.

[48] 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.

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

[50] 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.

[51] William Farr, Nicola Yuill, and Hayes Raffle. Social benefits of a tangible user interface for children with autistic spectrum conditions. *Autism*, 14(3):237–252, 2010.

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

[53] Brygg Ullmer and Hiroshi Ishii. The metadesk: models and prototypes for tangible user interfaces. In *Proceedings of the 10th annual ACM symposium on User interface software and technology*, pages 223–232. ACM, 1997.

[54] Robert Aish and Peter Noakes. Architecture without numberscaad based on a 3d modelling system. *Computer-Aided Design*, 16(6):321–328, 1984.

[55] David Anderson, James L Frankel, Joe Marks, Aseem Agarwala, Paul Beardsley, Jessica Hodgins, Darren Leigh, Kathy Ryall, Eddie Sullivan, and Jonathan S

Yedidia. Tangible interaction+ graphical interpretation: a new approach to 3d modeling. In *Proceedings of the 27th annual conference on Computer graphics and interactive techniques*, pages 393–402. ACM Press/Addison-Wesley Publishing Co., 2000.

[56] 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.

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

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

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

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

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

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

[63] 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.

[64] 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.

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

[66] 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.

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

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

[69] 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.

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

[71] 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.

[72] Bieke Zaman and VV Abeele. How to measure the likeability of tangible interaction with preschoolers. *Proc. CHI Nederland*, 5, 2007.

[73] JC Read, SJ MacFarlane, and Chris Casey. Endurability, engagement and expectations: Measuring children's fun. In *Interaction Design and Children*, volume 2, pages 1–23. Shaker Publishing Eindhoven, 2002.

[74] 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.

[75] 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.

[76] 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.

[77] Android design principles. URL https://developer.android.com/design/get-started/principles.html.

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

[79] Brian D Strahl and C David Allis. The language of covalent histone modifications. *Nature*, 403(6765):41–45, 2000.

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

[81] Karen Stagnitti, Sylvia Rodger, and John Clarke. Determining gender-neutral toys for assessment of preschool children's imaginative play. *Australian Occupational Therapy Journal*, 44(3):119–131, 1997.

[82] Isabelle D Cherney and Kamala London. Gender-linked differences in the toys, television shows, computer games, and outdoor activities of 5-to 13-year-old children. *Sex Roles*, 54(9-10):717–726, 2006.

[83] Tamagotchi. URL http://www.tamagotchi.com.

[84] Electronic furby - the furbsters guide to all things furbish. URL http://www.mimitchi.com/html/furby.htm.

[85] James Wilson and Daniel Rosenberg. Rapid prototyping for user interface design. 1988.

[86] Carolyn Webster-Stratton and Martin Herbert. *Troubled familiesproblem children: Working with parents: A collaborative process.* John Wiley & Sons, 1994.

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