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 Engineer 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

May 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 Engineer 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 Asheim.
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.
Thanks to Rosenborg Fotballklub for providing rewards to our test persons and their parents.

Contents

List of Figures

120figure.caption.392
120figure.caption.392

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 describe the purpose, motivation, research questions and the research method for the study.

1.1 Purpose

The goal of this project was to explore the use of mobile technology and tangible user interfaces in the treatment of asthmatic children. The project was 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, instruct, inform and reward children who suffer from asthma. Their main focus was on the development process of their developed prototypes, rather than researching the different solutions to help children with asthma. We intended to improve their versions of CAPP and GAPP (see Chapter 2), in addition to create a tangible user interface from scratch. The new and improved version of CAPP and GAPP was combined to one application, called *AsthmAPP*. The tangible user interface was named *AsthmaBuddy*.

In this project we focused solely on treatment 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 too much from the use of inhalers. The evaluation of our project was done through interviews 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 children find taking their medicine unpleasant, and they often do not understand what the medicine is good for. Children suffering from asthma may have to have several appointments with asthma specialists. This requires time and effort from the parents[1], and many parents have to take time off work.

We hoped to motivate children suffering from asthma to follow their treatment plan, since following their plan may lead to a more controlled form of asthma, where attacks occur less frequently[6]. Research done by Asheim showed that children suffering from HRS-virus [2] were easily distracted and motivated to finish treatments when shown a non-interactive flash-video during the treatment[7]. We have seen other projects where using gamification elements has provided positive results, such as Get Up and Move made by Penados et. al.[8][3]. By using mobile technology and tangible user interfaces we wanted to make the children more aware of their disease and thus make them better understand why they need to take their medicine on a daily basis. By using gamification elements we hoped to motivate the children to use the system regularly, and by making a dynamic and user-centered reward system, we hoped to make a system that the children will find interesting for a longer period of time.

1.3 Research Questions

The main goal for this study was to discover in ways technology can help and encourage children to take their medication. The objective was composed into following research questions:

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

RQ2: How can tangible user interfaces be used to help children with asthma?

[1]While not all child do not live with their parents, we chose to use the terms parents instead of guardian

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

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

1.4 Research Method

We started off by conducting a literature study, in order to gain knowledge about the state of the art, find arguments discussing gamification and tangible user interfaces and find development frameworks for building tangible user interfaces. We then developed a tangible user interface prototype, using a Raspberry Pi, which was placed inside a stuffed animal. Additionally, we continued development of Aaberg et. al.'s smartphone application prototypes; CAPP and GAPP.

In parallell with the development process, we conducted a series of semi-structured interviews, in order to retrieve information and feedback from a wide area of perspectives. Our interview subjects consisted of parents of two different children with asthma, a researcher with a PhD in psychology, two nurses with asthma as their field of expertise, a PhD candidate in industrial design, a senior advisor at NAAF and an industrial designer previously involved in the BLOPP project.

At the end of the project, we did a validation test of our prototypes on 3 children and 2 parents, by following the usability testing approach.

A more thorough explanation of the research methods employed can be found in Chapter 3.

1.5 Thesis Outline

Chapter 2 provides the reader with background information around Asthma, and some of the projects that have previously been developed by BLOPP, and introduces the latest developments in the use of mobile technology and tangible user interfaces for medical purposes. Chapter 3 gives an overview of the research methods we have employed. Chapter 4 will give the reader an introduction to gamification, with discussion around some of the principles that are being used. Chapter 5 dicusses the origins and use of tangible interfaces. Chapter 6 provides a product description of AsthmAPP, our prototype for gamifying children's experience with a smartphone, while Chapter 7 provides a description of AsthmaBuddy, our tangible interface. Chapter 8 provides the results we have discovered during our research. Chapter 9 provides the final conclusions of our thesis, with discussions around the results given in Chapter 8.

Chapter 2

Background

This chapter will give a brief introduction to the history behind the BLOPP project (Section 2.1). Section 2.2 will describe 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 of 2012. Section 2.4 will give an introduction to some of the recent research that has been performed on mobile technology in combination with children and health.

2.1 BLOPP Project

The goal of the BLOPP project was 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. BLOPP had previously worked with Asheim's "Concept for improved treatment of children affected by asthma/RS- virus"[7] and Høiseth's "Research-Derived Guidelines for Designing Toddlers' Healthcare Games" [9], in addition to several other projects.

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. Asthma may be difficult to diagnose, especially in children under the age of five.

An asthma attack may include coughing, chest tightness, wheezing and trouble breathing. The attack takes place in the lungs, the airways tighten letting less oxygen pass through. According to the Norwegian Ministry of Health and Care Services, acute asthma attacks were the most common reason for hospitalization of children in 2008[10]. In Norway, about 20 per cent of children are suffering from the disease, and because of this the condition may be said to have an effect on the economics of the society[1]. However, asthma can be controlled and asthma attacks avoided by taking medicine at regular intervals. Some of the medicines, such as Seretide and Flutide, are taken as a preventive measure to avoid asthma attacks. Ventoline is taken before exercise or when an asthma attack occurs, in order to stop/shorten the length of the attack. We will refer to this usage as “By Need” treatments.

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 breathing chamber, and the powder form of medication is taken straight from the disk. Before use, the container of the asthma medicine must be shaken in order to stir the particles. If a breathing chamber is used, the protection cap is removed and the container is mounted on the breathing chamber. The chamber is pressed towards the user’s face, covering the nose and mouth. The container is then pressed, to release the medicine into the breathing chamber, and the user breaths deeply for ten seconds[2].

2.2.1 Ways Asthma Affect the Family

Before sending children to school or kindergarten, remembering to give the child his/her medication may prove challenging for the parents. Often the child does not enjoy taking his/her medicine, and the child may start an argument, not wanting to finish the treatment. This may result in parents applying the medication incorrectly, applying the wrong treatment, or even forgetting to give the medicine, which in turn may 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

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

[2] There are different ways to conduct a treatment. Some specialists advice to take six breaths instead of breathing for 10 seconds

FIGURE 2.1: Mask used with inhaler

FIGURE 2.2: Ventoline in disk form

feels. In order to make these health zones understandable, a traffic light system is often used (see Appendix F). The green treatment plan tells what the user should do when all is normal. The yellow treatment plan indicates what to do when the user is feeling a bit ill, when there is a lot of pollen in the air or otherwise poor air quality or when the user is recovering from a cold. The red treatment plan indicates what to do when the user is feeling ill, or there is an extreme amount of pollen in the air or extremely poor air quality. If the red treatment plan is necessary, the child often has to consult a doctor.

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 [3] . 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 guardians of a child (GAPP) and the other for children (CAPP). Additionally, they created a Karotz application (KAPP) targeted at children. In this section, we describe these applications, while a full report of their work is available at[4].

Their prototype was the basis for our work in this project.

2.3.1 CAPP

CAPP is an Android application targeted at children. Its main purpose is to guide the child through the medication process. Figure 2.5 shows the main page of CAPP [4]. As

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

[4] All applications have Norwegian as their main language

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, and consequently 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 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 of CAPP was to introduce a gamification experience to the medication process. Accordingly, the child recieved a golden star in his/her treasure chest once the medicine has been taken. However, these stars cannot be used for anything, they are solely for display.

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 information as to how to take a medicine is ready available. 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.

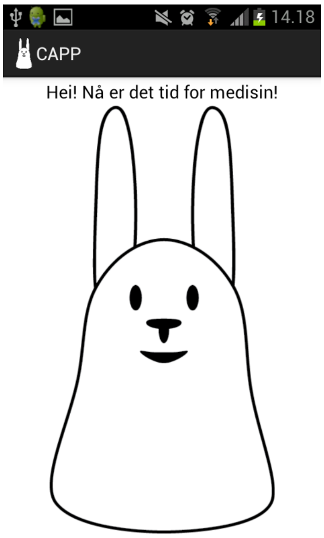


FIGURE 2.3: Starting a treatment

FIGURE 2.4: Inside the treasure chest

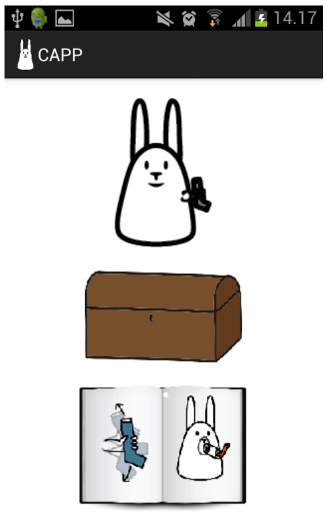


FIGURE 2.5: CAPP main menu

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 [5] , 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 the asthma medicine and give instructions during treatment. In order to interact with the Karotz, the child 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 E.

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

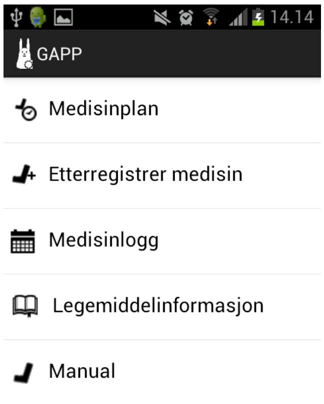


FIGURE 2.14: GAPP main menu

2.3.3 GAPP

GAPP is an Android application targeted at the guardians or parents of the child. Some parents have problems with remembering how often their child has taken his/her medication the last couple of days, when the child should take the medication and how the child's disease has evolved over 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*.

[5] 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 F). A child has three separate plans, to ensure 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 was carried out in case the child for some reason did not go through the process in CAPP or KAPP. This way, the child 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 of this functionality.

Medicine Log *Medicine Log* shows how many times a child has taken his/her medicine the last months. Figure 6.9 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 purpose of the *Manual* is to help "newcomers" to medicate their child. For instance, if a relative is watching a child with asthma, he/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.

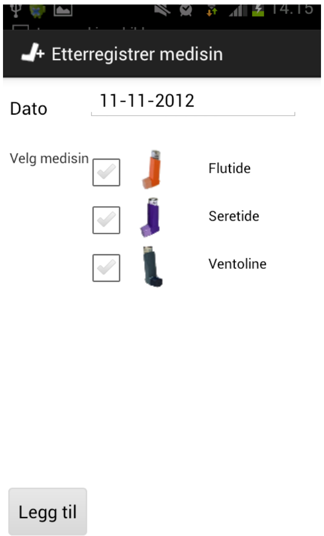


FIGURE 2.15: Register treatment

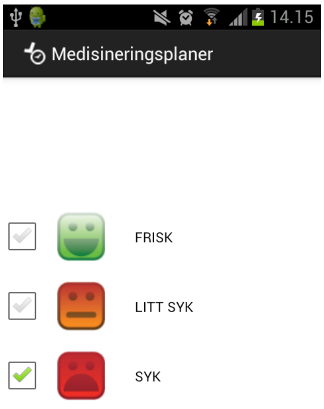


FIGURE 2.16: View plans

FIGURE 2.17: Information 1

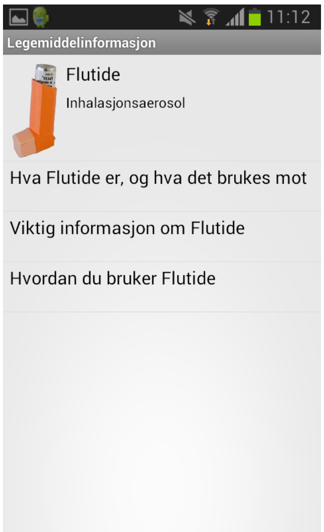


FIGURE 2.18: Information 2

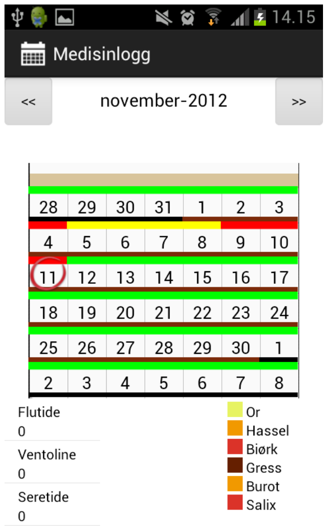


FIGURE 2.19: Medicine log

2.3.4 Known Areas For Improvement

As Aaberg et. al. 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 G (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 were used as a basis when we decided what to improve in this project.

2.4 Existing Research

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

2.4.1 Monitoring Asthma with Mobile Technology

Research on self-management of monitoring one's 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.[11] 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.

Andhøj et. al. concluded that SMS is a feasible solution for collecting asthma diary data, mainly because the SMS technology was an important part of the participants' everyday life. Although SMS is a great technology to be used for this purpose, few children in our target group are old enough to use this technology. 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[12]. Thus our target group is likely to be familiar with the technology we plan to use.

2.4.2 Children and Mobile Devices

Accoring to the Norwegian Media Authority's [6] latest report on "Young Children and Media", children between the age of one and twelve years old spend an average of 43 minutes each day at playing video games and mobile games combined[13]. Additionally, they spend 20 minutes at a mobile phone each day. By introducing them to AsthmAPP, we do not intend to increase this statistic. We aim to make an application that is used for a short period of time with each use. AsthmAPP and AsthmaBuddy will be tools for helping the children, and should not be considered as a game.

[6] Norwegian Media Authority - http://www.medietilsynet.no/

2.4.3 Children and Gestures

Abdul Aziz et. al.[14] performed a study on which gestures children are able to comprehend when playing with an iPad. They tested children's ability to gesticulate on a variety of applications suited for children. The children were between the age of 2 - 12, three children in each age group. The study showed the following restrictions:

- 2 year olds 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 olds have difficulties with drag and drop until they are told to do so, in addition to having problems with pinch and spread.
- 4 year olds have difficulties with drag and drop.

In order to make AsthmAPP as child friendly as possible, it only uses "swiping" gestures and button presses for navigation. [INSERT MORE CONCLUSIONS??]

2.4.4 Assessment of Existing Asthma Applications

In 2012, Huckvale et. al.[15] conducted an assesment on the existing asthma-related applications on both Google Play [7] and App Store [8] . 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"[15].

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 challenge for research. This section covers the state of the technological development of some of the areas in which mobile technology is being used with a combination of either gamification or tangible interfaces.

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

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 not 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 the GUM's physical activity level. Penados et. al. argues that GUM had a positive effect on reducing sedentary behaviour and motivate physical activity with young children.

2.5.2 Sisom

Sisom [9] 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. The user can look around in the hospital and express how he/she feels when giving a blood sample. The results showed that when a child played the game before a consultation with his/her physician, the child was better prepared, the communcication had a better quality, and the child participated more during the consultation[16].

2.5.3 Meassuring Blood Pressure

iHealth [10] , Withings [11] and other companies has created blood pressure monitors which are synchronized with mobile applications. By using a wrist monitor, heartbeat, blood pressure level and pulse wave is meassured and stored in the application. The application visually presents graphs of the user's historic blood pressure levels and tracks progress. The application also allows for sharing meassurements with friends, family and doctors. By sharing detailed information with a doctor, a more accurate treatment plan may be laid out.

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

2.5.4 Controlling Your Diabetes

Cellnovo [12] has created a system that helps to control diabetes. It consists of a handheld device for meassuring blood sugar levels, 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 again motivates users to continue applying the correct treatment. It also allows users to send information to physicians, which helps them make decisions regarding patient care.

2.5.5 Quit Smoking

There are lots of mobile applications that help people to quit smoking. For instance, *The Norwegian Heart and Lung Patient Organization* has developed an app called "'Røykeslutt" [13] . The application shows what the body is going through after a specific amount of days after the user has stopped smoking, which according to the reviews of the application, is a huge motivational factor. Additionally, they show how much money a user has saved at any given time, which can be seen as "gamifying" the element of money in order to motivate users.

2.5.6 TUIs and Multimodal Interfaces for Safety-Critical Applications

Cohen et. al. proposed the use of TUIs and Multimodal Interfaces(MMUI) for safety-critical applications [17]. He presents and example with making strategic military planning of a battlefield. By combining special pens with cameras, CPUs and communication units, the lines drawn on a physical map would easily translate to a digital one. These tools made it easier to collaborate on making strategies and sharing them between officers. Cohen argues that the combination of TUIs and MMUIs may make a suitable improvement for traditionally paper-heavy work.

2.5.7 Wii Fit Plus

Nintendo Wii has gamified the way people train at home with Wii Fit and later Wii Fit Plus [14] . It gives a user the ability to choose his/her own training programme, including Yoga, Strength and Aerobics. The user can easily track his/her progress over several months. Additionally, it contributes to keeping children healthy, by having games that

[12] Cellnovo - http://www.cellnovo.com/
[13] Røykeslutt - https://play.google.com/store/apps/details?id=no.lhl.roykeslutt
[14] Wii Fit - http://wiifit.com

depend on the child's movement. For instance, if a child flaps his/her arms up and down, a bird on the screen is able to fly.

Chapter 3

Research Method

3.1 Finding Relevant Information

We conducted a literature study early in the project, in order to get an overview of the research that is fundemental for our project. In order to find reliable research, we used Google Scholar [1] and the IEEE Xplore Digital Library [2] .

Initially, we found two key search phrases; “Gamification” and “Tangible User Interfaces”, which were used to build a foundation of relevant material. Later, we used those terms in a combination with other relevant terms, eg. “Health”, “Asthma”, “Development”, etc. We also twisted words to find related research fields, eg. replacing “Gamification” with “Game Elements”.

In order to determine if an article was relevant to our project, we read through the papers’ abstract and its’ discussion and conclusions, before eventually reading the paper in detail. We then searched through the papers’ references and skimmed their abstracts to potentially find new sources of information.

To assess an article’s validity, we used our judgement, based on a combination of whether an article had been quoted and a check for critiques or comments on the respective article. If the critiques were mainly negative, or pointed out serious deficiencies in the research performed, we decided not to put more effort into the article. In order to create a balanced viewpoint when discussing a specific theme, we tried to find contradicting arguments on the specific topic.

Searches for information regarding tangible user interfaces were also performed in standard search engines (i.e. Google) in addition to Google Scholar. The reason behind this

[1] Google Scholar - scholar.google.com
[2] IEEE Xplore Digital Library - http://ieeexplore.ieee.org/

is that there exists few commercially available tangible user interfaces, which has been subject for a research article. Thus, it became hard to assess whether the project was a success on a larger scale.

3.2 Semi structured Interviews

Semi structured interviews is a data collection method that allows interview subjects to put more weight upon their opinions, and what they perceive is important in a certain topic. As opposed to structured interviews, the interviewers can explore interesting answers more in depth by asking follow-up questions, instead of sticking to a fixed schedule. The interviewer comes up with a plan beforehand, with the main topics that should be covered during the interview, and some of the key questions that should be answered. If the interview stagnates within a specific topic, the interviewer can change the subject according to the plan.

The negative effects of this method is that it limits the creativity to our subjects. For instance, if people are initimidated or surprised by the research performed, getting the best possible feedback could become challenging. It is therefore encouraged to give a brief summary of the research field beforehand, so that the interview subjects are able to make up their own opinions about a topic before meeting for the interview.

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 interview subjects consisted of the following:

Nanna Sønnichsen Kayed, PhD/Researcher in Psychology.

Rose Lyngra, Senior Advisor at NAAF.

Marikken Høiseth, PhD candidate in Industrial Design at NTNU.

Two nurses with asthma within their field of expertise.

Two parents of children suffering from asthma.

3.3 Prototyping

A part of our research involves developing prototypes; one Android application and a tangible user interface. There are several reasons as for why we chose to include prototyping in our research; Firstly, it would be great if we were able to develop tools that help children get rid of their disease. This aspect provided a lot of motivation during the project. Secondly, we wanted to validate whether some of the literature we had studied were suitable for such a tool. Thirdly, we are creative people, who thrive when we do creative work. If we did not develop anything useful, we would easily have been burned out. Additionally, it is generally considered a good idea to develop prototypes in order to test concepts with potential users *INSERT REFERENCE* .

3.4 Usability testing

3.4.1 Introduction to Usability

There are many ways to describe the term usability.

The International Organization for Standardization(ISO) uses the following definition[18]:

"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?

Schneiderman stated eight golden rules in order to achieve a good usability of computer systems[19]. 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[20]. Proper usability engineering may also lead to lower costs for the developers and higher chances for projects being finished on time[21].

3.4.2 Purpose

Usability tests are usually performed in order to detect errors in a system. We wanted to perform usability tests in a slightly different manner. In addition to discover errors, we observed how children take their medicine in combination with technology. We used the results of the usability tests to find potential for improvements and design ideas for the product, in addition to validate whether or not our solution worked in a satisfactory manner.

The tasks given to the participants were created with routine use of the application in mind. Usability tests were performed with the help of participants with no prior knowledge of the application. These participants were chosen in order to receive 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 resembled everyday life of the users.

As one of the systems we tested was an Android application, the question of whether we should test it on an emulator installed on a computer, or by the use of a smartphone was raised. While the emulator allows for easier screen and input capturing, it suffers from the drawbacks that interaction is performed through a mouse and a keyboard, in addition to running far slower than an Android device. Using an Andriod device would lead to a more realistic interaction pattern, but it suffers from the drawback that screen capturing is not possible unless the device is rooted [3] . We chose to test the system on an Android device, as we figured it would seem more natural for a child and the NSEP laboratory has capabilities to record the user interaction through cameras.

3.4.3 Test Method

The usability tests were performed at the NSEP Usability Lab [4] , which provided measures for recording the sessions.

[3] Android rooting - http://en.wikipedia.org/wiki/Android_rooting
[4] NSEP Usability Lab - www.ntnu.no/nsep

Before each test, we performed a pilot test in order to discover last minute critical errors that could make an impact on the result.

The test was divided into two stages. In the first stage, the parent were to use AsthmAPP for a couple of basic tasks. In the second stage, the child was to perform a set of tasks (the tasks can be found in Appendix C). We wanted children to observe while their parent performed the tasks, in order for them to understand that the process was harmless. Additionally, we let their parents sit next to them and explain the tasks for them, such that the children were not told to perform some seemingly random task by a stranger.

The participants were given an Android mobile device to perform their tasks on. The different tasks were given one by one. The participants were introduced to the "think-aloud"-method[22], and was told to ask questions during the process, even though the test leader was not allowed to answer questions during the test. The main reason for gathering questions was for the discussion afterwards and facilitate for the "think-aloud"-method.

The test leader finished the test by asking questions regarding what the participants thought of the system and by answering the questions that were asked during the test. We also asked parents how they felt that the medication process went, so that they could compare it to their daily situation at home, and if they got the impression that the product could be helpful.

The results were later analyzed in order to discover any improvements needed to the system. The errors were rated after level of severity[23].

- Critical (Level 1) - Prevents the participant from completing the task.
- Significant (Level 2) - Generates significant problems when trying to complete the task.
- Minor (Level 3) - Has 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".

An often used approach to measure the usability of a system, is to use the System Usability Scale (SUS)[24], together with the observations made during the test. These scores may give an indication of the usability of a system[25]. As we were dealing with children, we had to use a different approach in order to get feedback from the children.

Zaman et. al. proposes a way to measure the likeability of tangible interaction with preschoolers[26]. They based their research on work done by Read, MacFarlane and Casey[27], 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 used a similar approach to understand which forms of interaction children like most, and which system they liked to interact with the most, AsthmAPP or AsthmaBuddy.

3.4.4 Scenario and Tasks Given to the Users

Since the application has Norwegian as it’s main language, the scenario and tasks were given in Norwegian. A translation of the scenario and tasks handed to the participants can be found in Appendix C, but for convenience the next paragraph gives a brief summary.

The scenario explained that the user was a parent of a 4-year-old child with asthma. They have recently seen a 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 the use of medicines.

Chapter 4

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.

4.1 What is Gamification?

“Gamification” as a term was first mentioned by Currier in 2008[28], but did not become a wide-spread term until 2010.

Huotari and Hamari[29] define gamification as:

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

There are many different ways of describing gamification. Deterding, Dixon, Khaled and Nacke[30] define Gamification as:

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

Deterding, Dixon, Khaled and Nacke’s definition is often commonly referred to, because of its simplicity and understandability for people who have little or no connection to traditional video 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 have 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 criticised for using gamification to lure players into playing.

4.2 What are Serious Games?

The term “serious game” became a concept with the emergence of the Serious Game Initiative in 2002[31]. 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 criticised for being too narrow, and for 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 have later grown to become a multi-billion industry. Pilots are being trained in simulators, lecturers make lecture quizzes for students[32], Swedish firefighters have used serious games for training[33] and persons suffering from diabetes can use 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 solving bigger problems than the game itself[34]. Foldit is a massive multiplayer online game (MMO). The objective for the player is to fold protein by following a set of rules. The system

[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.

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] [35].

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.

4.3 Discussion about Gamification

Gamification is a much discussed theme, and no agreement seems to have been reached as to whether gamification is useful or not. Antin and Churchill argues that gamification may be used for goal setting or instruction[36]. Goal setting challenges the users to meet the mark that is set for them, and is known to be an effective motivator[37].

Bogost goes as far as naming gamification as “marketing bullshit”, used as a way of moneytizing bad business[38][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.”[40]

Steinung argues that gamification is not powerful enough to make a task interesting[41]. Simply adding points, badges, a leveling system or similiar, will not 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[41]. Zichermann makes a similar statement, saying gamification needs to take ethical precautions[42].

While McGonigal's research focuses on how rewards are percieved when playing over a longer consecutive time, our intent was to make the user spend only small amounts of time using the application. AsthmAPP is a tool, not a pastime.

In order to achieve a meaningful use of gamification Nicholson[43] suggests using a user-centered design approach[44] when developing systems with elements of gamification. Since AsthmaBuddy is a computer supported learning system[45] it was important for us to maintain our 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[39]

4.4 Game Elements

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

4.4.1 Bartle's Four Player Types

People have different preferences when it comes to playing a game. Richard Bartle proposes a classication of four different player types[46]. These types are *Achievers*, *Explorers*, *Socialisers* and *Killers*. We'll take a brief look on each of these in this section.

4.4.1.1 Achievers

"Achievers regard points-gathering and rising in levels as their main goal, and all is ultimately subserviant to this"[46].

Most young children will fall under this category. Achievers mostly play games just for the fun of it, and do not necessarily need other incentives to the game than being able to finish the challenge imposed by the game. Most children like to see progress in terms of points, clearing a level or a similar sense of progression.

4.4.1.2 Explorers

"Explorers delight in having the game expose its internal machinations to them"[46].

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. [Children play the game for the fun of playing, not necessarily to find discover secrets][Find something that supports this claim]

4.4.1.3 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"[46].

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 will probably noy fall under this category, as they will not comprehend that there is someone "on the other side of the screen".

4.4.1.4 Killers

"Killers get their kicks from imposing themselves on others"[46].

"Killers" thrive 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?]

4.4.2 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.

4.4.2.1 Avatar Systems

Avatars are commonly used in children's 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. Such 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 may be seen as giving the avatar a piece of the player's personality. For instance, some players would want their avatar to look as ridiculous as possible, while others would prefer that it looked as cool as possible. Showing off "expensive" gear may also give the player a feeling of accomplishment (*"I'm so good at this game that I could afford this golden armour. Have you managed to get it yet?"*).

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

4.4.2.2 Achievements and Badges

Achievements and badges are systems well incorporated into Microsoft's Xbox [11] and Sony's Playstation [12] . Such achievements and badges are typically given if the player

[11] Xbox - www.xbox.com
[12] Playstation - www.playstation.com

reaches a certain point or level in the game. For instance, on Foursquare, the players gets a badge called "Adventurer" if he/she checks in at 10 different venues.

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

4.4.2.3 Real-world Rewards

Used together with leaderboards, real-world awards may 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 recieve one ticket in the lottery to win a brand new computer".

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

4.4.2.4 Social networking

During the last few years, Facebook feeds has a tendency to be flooded by updates from third-party applications, like Runkeeper [13] , who updates everyone on your friend list that you have been working out. The idea here is to have a common platform, where users may brag about their accomplishments.

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

4.4.2.5 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 child may use this app as a reference that indicates how long he/she should brush on the same side.

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

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

4.4.2.6 Experience Points

Experience points is an indicator of how much experience the player has gaines 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 unlocking new levels, new rewards or new features. 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 may be represented as a stick figure, and the goal is to gather as many stick figures as possible. Another example is that leveling up, based on experience points, may be represented by the size or attributes of your stick figure.

4.4.2.7 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 started. The score is compared and the 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 determined after a certain period of time.

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

4.4.2.8 Progress Bar

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

Example: The stick figure is placed on a road. The figure's position on that road, mirrors the progress a player has made. When completing a task, the figure will be moved closer to its goal.

4.4.2.9 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 highest amount of points within a given time period or a similar type of a 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 may enter a voting contest, where votes are given to the best looking one.

4.4.3 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 right manner.
Achievements and badges	No	We believe our target group would not enjoy this feature as much as older children, those of 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 on 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 perform 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 fully treated for asthma. However, identifying how close a patient is to becoming healthy, is virtually impossible. Another usage may be to match the child's progress for each week against his/her medicine plan. This would however, imply that by-need treatments would not be included, which may seem unfair for the child. 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 may used to cash in rewards from the parents.
Contests	No	Using medical history to participate in contests would be a violation of Norwegian privacy laws. It may also be used to pinpoint "bad" parents.

Table 4.1: Assessment of different game mechanisms

4.5 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."[47]

Stapleton's argument is one the reasons for why we believe in the use of tangible user interfaces and applications as a method for 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 aimed 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 may decide what works best for them. This stands to reason with the arguments of Nicholson regarding how to design gamification[43].

As McGonigal's studies show, the effect of gamification tends to wither down after a longer period of time[40]. We aimed to solve this problem by letting the user, together with his/her parents, choose his/her 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 the children create their own gamification environment. Examples of possible rewards could be to give the child an extra 10 NOK in weekly allowance, taking him/her 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 wish to invest in it.

The rewards will appear on a "milestone" basis. We do not want children to feel they lose something if they spend stars on a reward, which some may feel as 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 give. The use of the reward system is 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. This had some implications on the complexity of our gamification system.

Chapter 5

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. In addition the chapter will describe how we intend to make our tangible user interface.

5.1 About Tangible User Interfaces

In 1997, Ishii et. al. presented an article called “Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms” [48]. 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 that TUIs would represent the bits in form of physical objects. The objective of TUI was explained as to *augment the real physical world by coupling digital information to everyday physical objects and environments*[48].

“Urp”[49] 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 made this a first-generation TUI are the fairly simple and state-determined operations.

“Sandscape”[50] 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[51]. The different interfaces were a physical interface (i.e. a standard jigsaw puzzle), a TUI and a GUI. Their main finding was 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 the children are 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, the children did not get the same sharing experience as with the other interfaces.

5.2 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[52]. 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[52].

Information Sharing Hinckley et. al. created a tangible user interface for neurosurgical vizualisation[53]. 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 the surgical cutting planes to other persons with less knowledge in neurosurgery, or to other surgeons.

Moran et. al. designed a physical wall for sharing information on people in an office[54]. The system, named “Collaborage” showed a person 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 were used to help children solve a Tangram[55]. Their system consisted of the tangram pieces and a surface to place them on. The tangram pieces had a tracker on them, which was used to guide children when placed a piece in the wrong place. Once the solution had been found, the children were able to explain the underlying geometric principles behind their solution.

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[56]. Stanton et. al. created a "magic carpet", giving children possiblity to influence a story in the classroom[57].

Social Context The "Marble Answering Machine" is an invention by Durrell Bishop, dating back to 1992[58]. The interface allows users to drop marbles into a play-back indent on the system, which plays a recorded message. Similarly, Karotz were read your Twitter feed if the Twitter application for Karotz had been installed [1] .

5.3 TUIs Used in Health Care

In 2003, Wada et. al. conducted a study on how the introduction of robotics affected the elderly[59]. They carried out their research 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 the elderly were in a better mood 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 they had easier days when Paro was there. The study showed that the elderly's 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 [2] [60]. 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.

[1] Twitter applciation for Karotz - http://tiny.cc/karotztwitter
[2] Topobo - http://www.topobo.com/

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."

5.4 Paradigms in Tangible Interfaces

Ullmer states that a tangible user interface should embody the following four properties[61]:

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; *Token and Constraints*, *Interactive Surfaces*, and *Constructive Assemblies*. These classes are partly based on varying degree of support for continuous and discrete forms of interaction[61].

5.4.1 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.

For instance, a system that is capable of reading RFID-tags is a Token + Constraint system. The RFID-tag is considered a token, while the area the RFID scanner can read from is considered as a constraint.

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.

5.4.2 Interactive Surfaces

In this paradigm, users manipulate physical objects upon an augmented planar surface [61]. 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 [62]. Combined with magnifying glass, it allowed users to look at 3D models of particular places in a town.

5.4.3 Constructive Assemblies

One major approach for tangible interfaces draws inspiration from buildings blocks and LEGO™. Such "constructive assemblies" of modular, interconnecting elements have been used for modeling real life buildings [63], and geometric modeling of all kind of shapes[64]. Constructive assemblies give an easy-to-use and highly tangible representation of digital information.

While there were 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.

5.5 Developing Tangible Interfaces

5.5.1 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

Answering the questions in Table 5.1, will make the development phase easier.

Defining the Boundaries	Orienting the Concepts	Fitting the Components
BO1: What should the user experience? **BO2**: What are the human tasks? **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 5.1: The eight questions stated by Champoux[2]

We considered Question **OC5b** as irrelevant for our purposes, as we will have a stationary artefact without any electromechanical and phyical ergonomic properties, i.e. no moving arms, waving ears, etc. As far as questions **FC7** and **FC8** go, we considered these irrelevant. These questions assume that the tangible interface performs a task for the user, which is not a part of our system. The remaining questions were considered relevant, and will be discussed in Section 7.3.3.

5.5.2 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 formulated as questions, which exposed several challenges regarding each issue. Some of the challenges they found considered ubiquitous computing, assuming there are several possible target systems at the same location. Table 5.2 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 5.2: The challenges of interacting with a TUI[3]

5.6 Summary

Tangible interfaces are about inserting digital information into physical objects. There are a lot of examples on tangible interfaces, and we have taken a brief look into some of them (see 5.2). There seems to be a lot of activity going on in this field of research. However, only a few are commercially available.

Champoux proposed a design mechanism to create tangible interfaces. The design mechanism is somewhat abstract, and lacks obvious issues such as how to actually display information to a user, which Bellotti et. al. (see 5.5.2) expose as a challenge with creating ubiquitous systems and TUI's. We used Champoux' approach to a certain extent, and kept Bellotti's challenges in mind when designing AsthmaBuddy.

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

Chapter 6

AsthmAPP

This chapter gives 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.

6.1 Architecture and Technology

6.1.1 System Architecture

Figure 6.1 shows an overview of the architecture we used for our products (AsthmaBuddy included). We reused some of the components Aaberg et. al. created during Customer Driven Project[4].

Data is stored at a MySQL database hosted by NTNU. AsthmAPP and AsthmaBuddy accessed the database through a PHP-server, which is also hosted by NTNU. The reason for accessing the database through a PHP-server is twofold. First, it is difficult to access the database when a device is not located on the local network at NTNU. It would be required that a user had VPN installed to access the NTNU network at their smartphones, which is not ideal from a performance point-of-view.

Second, by having a webservice that interprets the results given by the database, it becomes easier for the client to deserialize these results, as they are given as JSON-objects[1].

When one of the applications want to store data to the database, they do a HTTP POST, with the data as POST parameters, to a predefined route on the webservice.

[1] JavaScript Object Notation

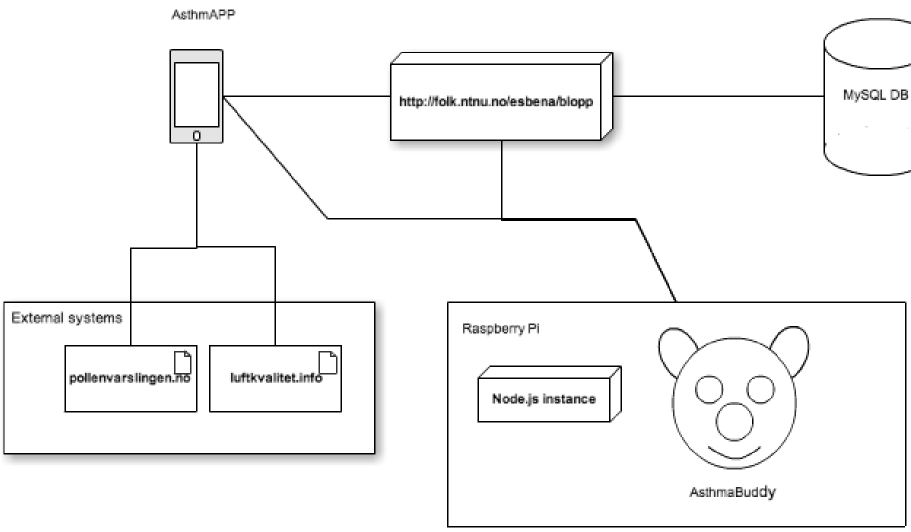


FIGURE 6.1: System Architecture

When the application wants to retrieve data from the database, it does a HTTP GET to the webservice, which extracts the data requested from the database, formats it to JSON, and returns the data to the application.

By having a webservice layer between the applications and the database, the system scalability suffers, but modifiability is increased, which we considered as a good trade-off at the current state of our project.

6.1.2 Technology and Frameworks Used in AsthmAPP

AsthmAPP is developed in native Android code, which implies using Java as the programming language and the Android Application Framework [2] . Additionally, we used the following frameworks to ease the development:

Gson As mentioned in previously, our webservice gives out JSON-formatted objects of data stored in our database. We used Google's Gson-library [3] to deserialize these objects into Java objects.

JodaTime Java's default implementation of time is cumbersome to work with, with a lot of it's functionality deprecated. JodaTime [4] is an open source project that seeks to handle time in a proper manner on the Java platform.

[2] Android Application Framework - http://developer.android.com/develop/index.html
[3] Google Gson - https://code.google.com/p/google-gson/
[4] JodaTime - http://www.joda.org/joda-time/

6.2 How Usability Research has Affected our Design

While designing AsthmAPP, we strived for an easy-to-use design with a good overview, in addition to the Android Design Principles[65]. We have also taken Shneidermann's eight golden rules into consideration when designing AsthmAPP[19]. We tried to lighten the short-term memory load by using a combination of sounds, pictures and text to tell the user the options that are available or what is expected from the user. During a treatment the user is prompted to take action in order to continue through the process, giving the user a locus of control. The layout for both partitions of AsthmAPP gives 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 believed that the solution we found is the preferrable one.

6.3 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.

6.3.1 Treatment

Figure 2.3 shows a screenshot for the application when the child starts his/her treatment. This sequence may be started by on of two events: (i) *The child reacts to an alarm set in the parent partition*, or (ii) *The child needs to take his/her 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 his/her treatment, he/she is taken through an animated sequence, which reacts when a child interacts with the device. In addition, the child is being told what to do by the comforting voice of Andreas Ystmark[5].

6.3.2 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

[5] A classmate of ours at NTNU

made two design decisions for our reward system. Firstly, we do not want stars to be removed. We do not want the child to feel that credits are being removed from him/her. Secondly, we cannot assume that children are able to read, and thus we have made the stars countable, and hopefully the child is able to comprehend how many stars he/she actually has. In addition, we provide some help to those who are able to read numbers, by showing the number of stars a child has on the top of the screen.

6.3.3 Shop

In the shop, children are allowed to select rewards given by their parent(s). Figure 6.3 and 6.4 show 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 a voice over, so the children may need help with reading the names of the rewards. The possibility of adding pictures to represent the reward should make it easier for the children.

6.3.4 Treatment instructions

The treatment instructions is a book-styled instruction set which shows generically how to take the medicine. The following steps are included in the 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 in and out 10 times.
7. Let the child wash his/her mouth.

6.4 Parent Partition

6.4.1 Menu

Figure 6.5 shows the main menu of the parent partition. It has five options (Norwegian translation in paranthesis):

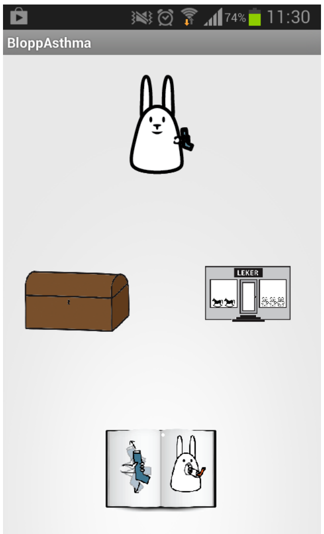


FIGURE 6.2: Main menu of child partition

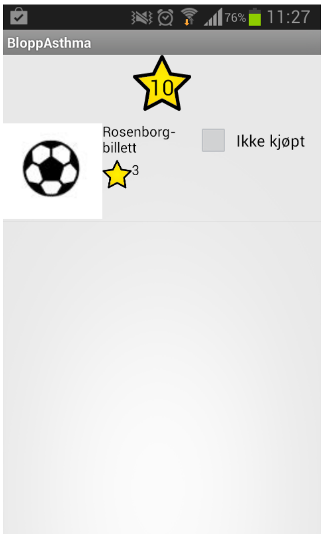


FIGURE 6.3: Possible rewards a child can choose from

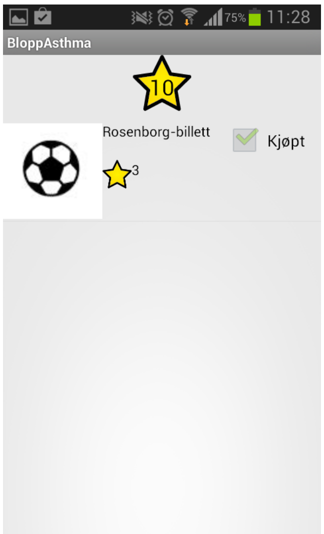


FIGURE 6.4: A child has bought the reward

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 done in order to protect the child's medical data if a smart phone is lost or stolen.

6.4.2 Medicine plan

Creating a medicine plan for asthma treatment is highly connected to the Traffic Light System explained in Appendix F. 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 let their parents control it. Figure 6.6 and 6.7 shows the view in which one may change the medicine plan their child are currently on, in addition to setting alarms where appropriate. For instance, one may set an alarm at 07:00 AM, so that it reminds the user before it is time to leave for school. Changing the medicine plan is done by selecting the checkbox at the left side of the panel.

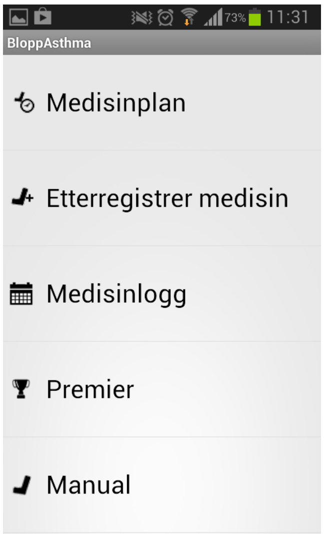


FIGURE 6.5: Main menu of partent partition

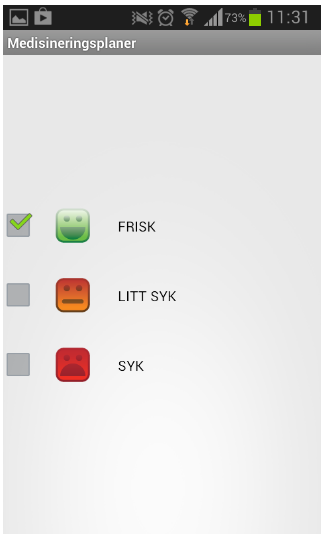


FIGURE 6.6: Available medicine plans

FIGURE 6.7: Adding a medicine to a plan

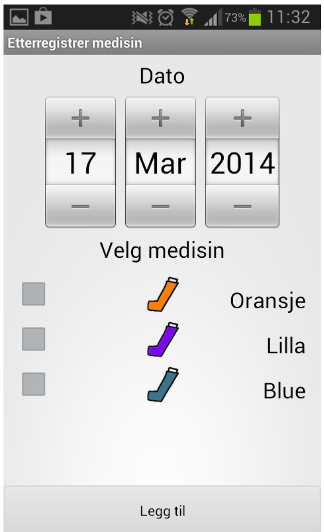


FIGURE 6.8: Register a medicine that was taken without the help of AsthmaBuddy or AsthmAPP

FIGURE 6.9: Medicine log

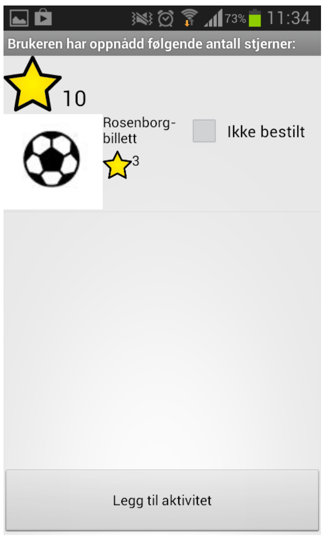


FIGURE 6.10: Overview of rewards a child can get

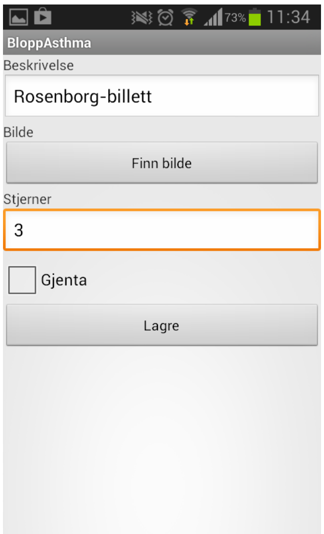


FIGURE 6.11: Creating a reward. Parents can either choose a reward from our standard image set, or they can take one from their gallery

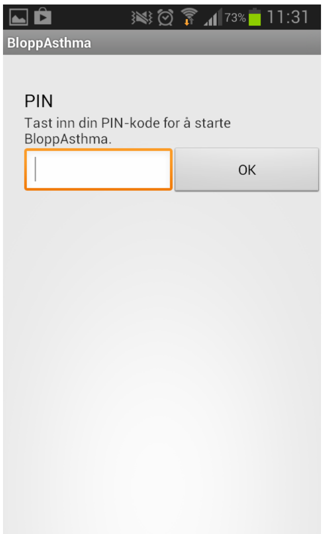


FIGURE 6.12: In order to access the parent partition users have to complete a PIN-challenge

6.4.3 Register Treatment

If a child need to take their medicine, but do not have the possibilty to do the treatment with AsthmaBuddy or AsthmAPP nearby, they can take their medicine and register the treatment later. This ensures that children are able to collect their stars even though they did not do their treatment with AsthmaBuddy or AsthmAPP as their companion. Figure 6.8 shows how this is solved in AsthmAPP.

6.4.4 Medicine log

The *Medicine log* can be used by parents to show how many times a child has taken his/her medicine. We assume that one of the main reasons for a child not taking his/her medicine is lack of communication between parents. A medicine log gives parents the ability to check and see whether the child has taken the necessary dose on any given day.

Figure 6.9 shows the calendar view of the application, which we will explain into details. The calendar module used is an open source component developed by Chris Goo, which we modified for our purposes. The cells show any given day of a month. In addition, there is a top bar which shows the health state (or health plan) of the child on the day selected below. At the bottom of the screen, there are three panels. The left panel shows which medicine has been taken on the selected day. The topbar of this panel indicates which day is selected. The middle panel shows the air quality in Trondheim [6] . The right panel shows the pollen distribution of the 6 most common pollen types [7] . The idea behind this is that asthma symptoms are often the same as allergy symptoms, and if parents are able to recognize a pattern between health state and pollen distribution, they may wish to take special precautions, such as no outdoor activity on a day with extreme amounts of pollen.

6.4.5 Manual

The manual contains the same information as shown in Section 6.3.4. 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.

6.4.6 Reward

Figure 6.10 shows the list of possible rewards a child may 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 4.5). Figure 6.11 shows how one may add a reward. The user inserts a description, then either adds a photo or selects 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 the child has the possibility to select it.

6.5 Evaluation

Chapter 4 gave an introduction to the term gamification, and how gamification should be used. We have developed a reward system that is highly based on parents' opinions, and thus, have some flaws that we will discuss further in the followin.

First of all, children may become bored of the rewards if the rewards are not increasingly difficult to achieve, and have not increased in value. For instance, if a child is rewarded with a ticket to a football match for achieving 10 stars, and then receives a piece of gum if he/she achieves 20 stars, the child may lose interest and important motivation in order to complete his/her treatment.

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

Secondly, the number of stars rewarded depends on the child's inferred health state (green state yields 1 star, orange state yields 3 stars and red state yields 5). This calculation of rewards leaves a possible exploit where children may pretend to be sicker than they are. In the long run, a child could fake being sicker than he/she actually is, just to achieve a reward more easily. This is a situation that *could* occur, but we did not have the resources necessary to observe this pattern over time.

Thirdly, the gamification during the treatment, i.e. the animation on the phone, could become boring over time. The interactions are not varied, and it takes approximately 2 minutes to go complete 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 young children in the early stage of their disease.

In order to receive 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 do not have an understanding as to 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 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 do not understand this principle.

Furthermore, there has to be a balance between the rewards a child receives, and the work they are actually doing. For instance, a child cannot receive a bike after completing three treatments. Parents also have a materialistic mindset, i.e. rewards have to be something material. Kayed implies otherwise. Letting children choose a dinner, which TV program to watch at nighttime, or even being allowed to eat 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 7

AsthmaBuddy

7.1 Background

As mentioned in Chapter 2; in 2012, we did a similar project using Karotz [1] as the platform for the tangible user interface[4]. This project left us with mixed feelings towards Karotz as a platform. 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 use our application. The API is only documented in French, which limits the number of developers who are willing to develop applications for the Karotz, in addition to the fact that it is pretty cumbersome to configure for a "non-technological" family.

We researched other options than Karotz to create our tangible user interface. The alternatives we looked into was Arduino and Raspberry Pi. Arduino is an open source electronics prototyping platform[66], which allows for many different combinations of configurations. 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[67], which we had little to no prior experience with. Additionally, Arduinos generally have low-powered CPUs, in order to keep them cheap. These low-powered CPUs tend to have problems with decoding MP3-files, which would lay heavy constraints to our system (without using sounds or a display, it is hard to

[1] Karotz - www.karotz.com

communicate with children). Due to these facts, we choose to develop the system on a Raspberry Pi.

Our tangible user interface was planned to contain a lot of the same functionality that KAPP had, with some modifications. The reason we chose to develop on a different platform was to make the system more user friendly, specifically lower the requirement for technical knowledge needed to introduce AsthmaBuddy to an inexperienced user, by following the “Plug and Play” principle.

7.2 Technology

7.2.1 Raspberry Pi - Specifications Overview

The Raspberry Pi was initially intended to teach british school children about computer programming[68]. 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 7.1. Figure 7.1 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 7.1: Raspberry Pi specifications

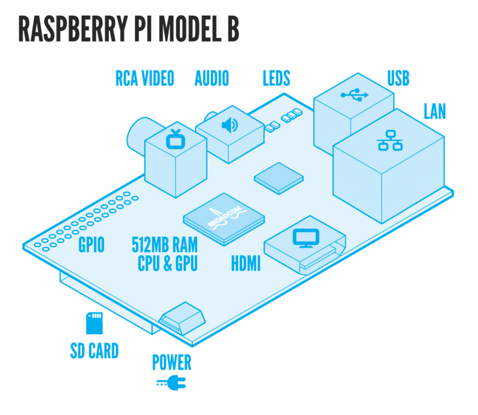


FIGURE 7.1: Raspberry Pi Model B architecture. *Image source: http://raspberrypi.org/faqs*

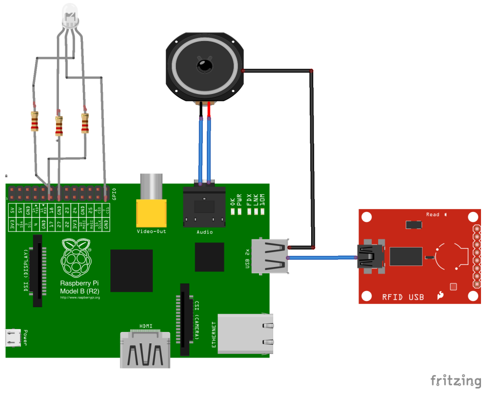


FIGURE 7.2: Digital schematic of the components

7.2.2 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 In order to interact with AsthmaBuddy, children can register RFID-tags against AsthmaBuddy's stomach. The RFID-reader we used was a Sparkfun ID-12LA [2] . The requirements when choosing the reader was that it should be able to connect through an USB-port, and be able to communicate with UNIX-systems.

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.

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 7.5).

Figure 7.2 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

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

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.

7.2.3 Components Considered for Use

In addition to the components mentioned in the last section, we considered using buttons, touch sensors and a microphone. Even though we did not use these components, we simulated them during user tests using the Wizard-of-Oz technique.

Buttons One or more buttons could have been used on AsthmaBuddy. Buttons could have been used to manage boolean values, for instance if the progression of an instruction needed a yes/no answer. We did not include buttons, as it could disturb the impression of AsthmaBuddy as a regular teddy bear, i.e. it would look more mechanical. Additionally, we were not able to restrict the amount of buttons needed.

Touch sensors A touch sensor could serve the same purpose as a single button. We did not include this component, as it would require a set of low level programming skills.

Microphone A microphone could be used for speech recognition purposes. However, the Raspberry Pi does not have the processing power required to do speech recognition. Additionally, it would require writing code that is able to distinguish between noises[3]. We belive it could have been a cool feature that would help establishing a relationship between the user and AsthmaBuddy.

7.2.4 Frameworks and Libraries Used in AsthmaBuddy

Pi4j We wanted to write the code on our Raspberry Pi in Java, as it was our most familiar programming language. However, it is cumbersome to use Raspberry Pi's GPIO-ports and serial communications with Java and no frameworks. Pi4j [4] solved this problem, by making the necessary abstractions.

Gson Refer Section 6.1.2 for a description of Gson.

[3] We were not able to find any open source libraries that are able to do speech recognition for the Norwegian language

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

JLayer We used JLayer [5] to handle the decoding of our recorded mp3-files.

7.3 Design Rationale

7.3.1 Why a Teddy Bear?

When designing AsthmaBuddy we choose to use a teddy bear as an avatar for our system. There are several reasons as to why we think a teddy bear is an appropriate avatar. Teddy bears are well known toys, and have been loved by children for a long time. They are considered gender-neutral[69][70] and in our subjective opinion it is a toy that could be discretely placed in a child's room. With the appearance of a teddy bear, AsthmaBuddy can easily be placed among other toys and not stand out. It was also important for us to choose a teddy bear of some size. A too thin a bear could lead to problems when fitting the system inside the bear, and could in could be met with scepticism by the children. AsthmaBuddy will have similarities to Tamagotchi[71] and Furby[72], but AsthmaBuddy's purpose is to motivate, instruct and teach children about asthma, not be a toy purely for playing with.

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

Norwegian fire fighters have used a teddy bear in order to calm down children who find themselves in dramatic situations [6] . 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 worth mentioning in our research.

A teddy bear has also been used as an avatar for giving instructions on how to apply a treatment correctly. Glaxo Smith Kline, a leading company within consumer health care, uses a teddy bear in their instruction manual for the use of asthma medicine and the breathing chamber[73].

Below are two pictures of how AsthmaBuddy looks in its final form.

[5] Javazoom JLayer - http://www.javazoom.net/index.shtml

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

FIGURE 7.3: AsthmaBuddy holding a mask and an inhaler

FIGURE 7.4: AsthmaBuddy with his nose light turned on

7.3.2 Interaction design

When we started developing the interaction design of AsthmaBuddy, we had a brainstorming session with the intention 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.

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 7.2: Rationale behind AsthmaBuddy's interaction design

7.3.3 Answering to Champoux's Development Framework

In Section 5.5.1 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 must have their inhaler and mask stored within a short distance of AsthmaBuddy. Their RFID-tags are attached to 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 a grown-up
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?]

7.3.4 Dealing with Bellotti's challenges

Section 5.5.2 introduced some of the challenges that are encountered when designing tangible interfaces. In the following we will discuss how we handled the challenges encountered, by answering those of Bellotti's questions which 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 are likely to pick things up and carry them around. If a child picks up AsthmaBuddy, it could be interpreted as an interaction. We solved this potential problem by only starting treatments in one of two ways, either because it is triggered by an alarm or because an RFID-tag attached to an inhaler is read by AsthmaBuddy. The RFID-reader is only capable of reading the tag from a distance of 3 - 5 cm. Thus, as long as no alarm is triggered, and no 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? As mentioned previously, AsthmaBuddy has a LED-light on it's nose. When the light is green, the user can expect that the system is running in idle mode.

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 to AsthmaBuddy speak, the user should be aware of what is happening. There is not a lot of room for human error in this connection. By following the normal sequence of operation, the worst thing that may 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? A part of the challenge is to recover from mistakes that have occured. For instance, if the user proceeds further than what was actually intended, and missed out on an instruction they needed, AsthmaBuddy should have a way to revert to the missed instruction. AsthmaBuddy has functionality to replay instructions, but it needs to be told to do so by keyboard input from the "Wizard-of-Oz". During user tests, children were told to say "Repeat" loud and clear, in order to replay an instruction. Moving beyond the "Wizard-of-Oz", this could be handled by a separate form of interaction, eg. shaking AsthmaBuddy's head.

7.4 System Overview

7.4.1 Use Cases

Figure 7.5 shows a general overview of the use cases we have included in our prototype. A medication process can be started set off two ways: A parent can register an alarm by using AsthmAPP. This alarm is then set of by the `AsthmaBuddy` instance running[7], giving the child a notification that it is time to take the relevant medicine.

The alternative to a registered alarm is if a child needs to take the medicine by need. In such case, the child or parent simply registers the RFID-tag before the child is guided through a quicker process (see Manuscript E).

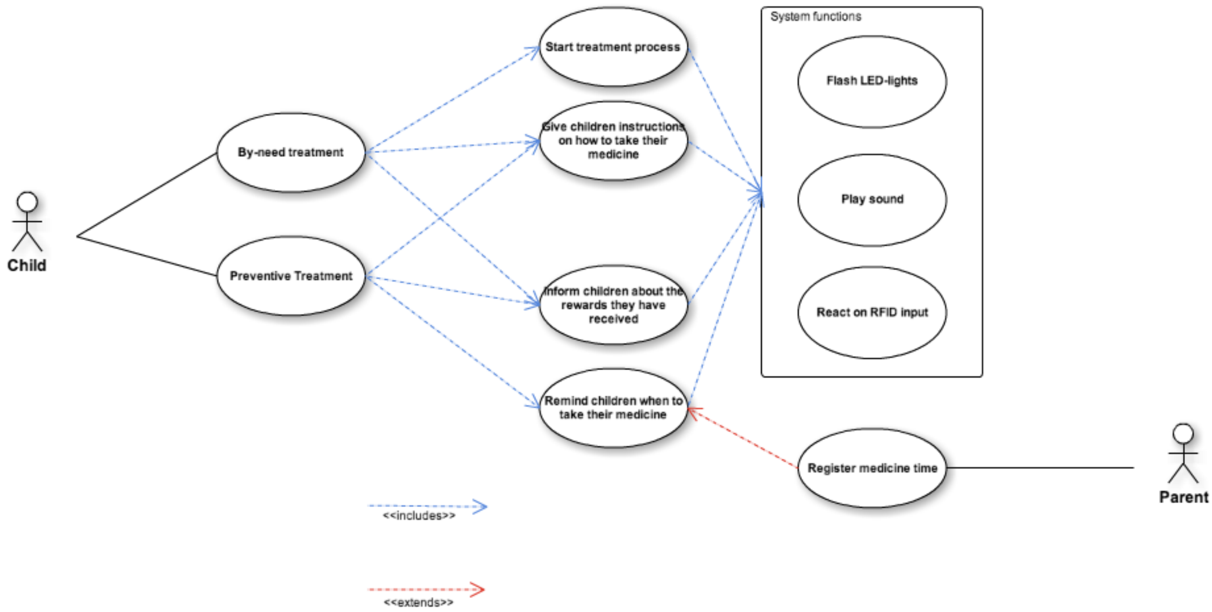


FIGURE 7.5: AsthmaBuddy Use Cases

[7]The reader should take notice that the tangible user interface AsthmaBuddy differs from the program running on the Raspberry Pi, which is called `AsthmaBuddy`(note the change of font)

7.4.2 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 number 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 7.3: 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 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 number of stars. 16. System makes a HTTPGet call to the server to find the total number 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 7.4: Textual use case: By need treatment

7.4.3 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.

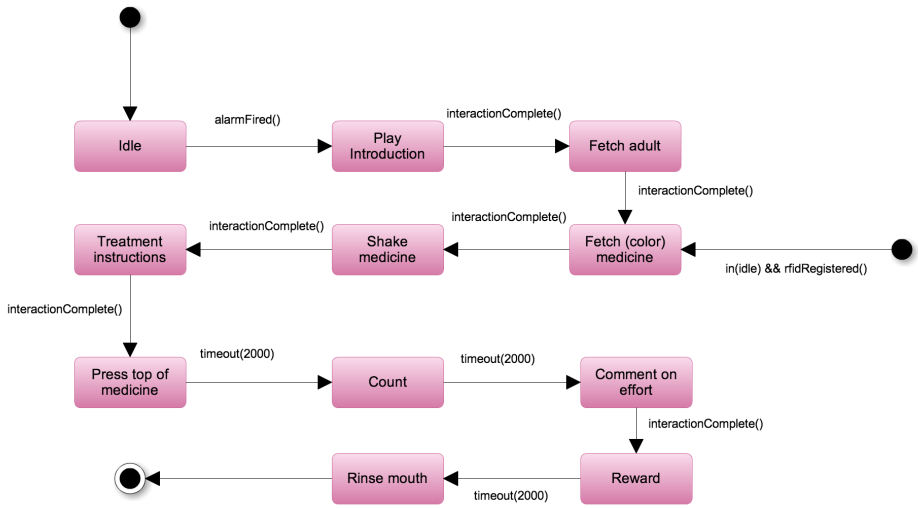


Figure 7.6: AsthmaBuddy State Diagram.

7.4.4 Sequence Diagram

Figures 7.7 - 7.10 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 `Interaction`-objects that is to be played. After this sequence is ended, the system jumps to 7.9.

Planned Treatment If an `AsthmaBuddy` instance is started without any parameters, it starts looking through alarm files (see Section 7.4.5) every 60 seconds. If no alarm is returned from `UserDataManager`, it waits. Once an alarm is found, `AsthmaBuddy` is notified through `onNotificationFired`, which starts the treatment process.

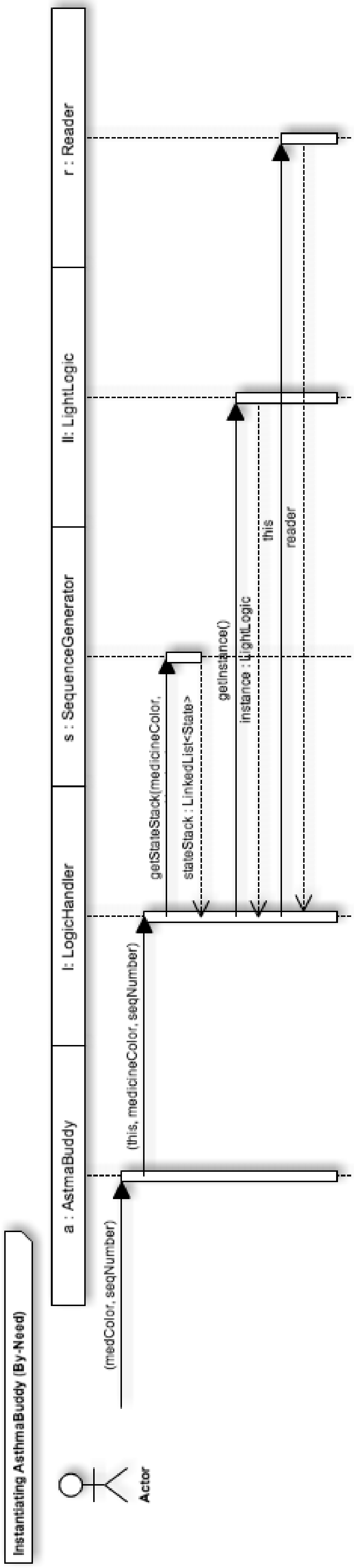


FIGURE 7.7: By Need Treatment - Sequence Diagram

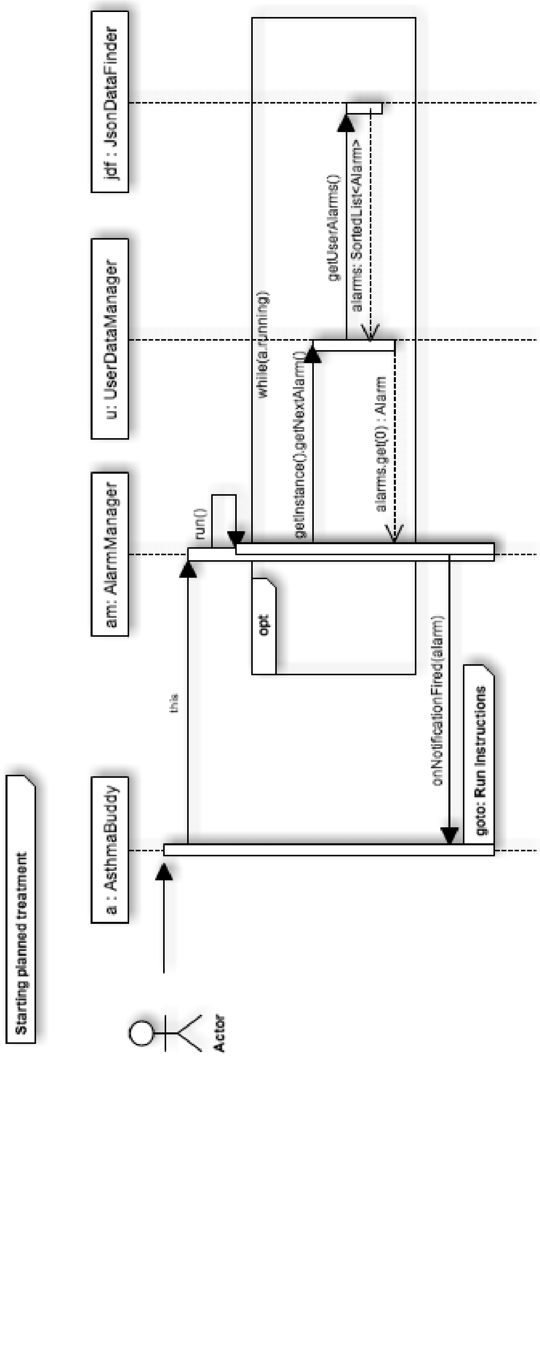


Figure 7.8: Planned Treatment - Sequence Diagram

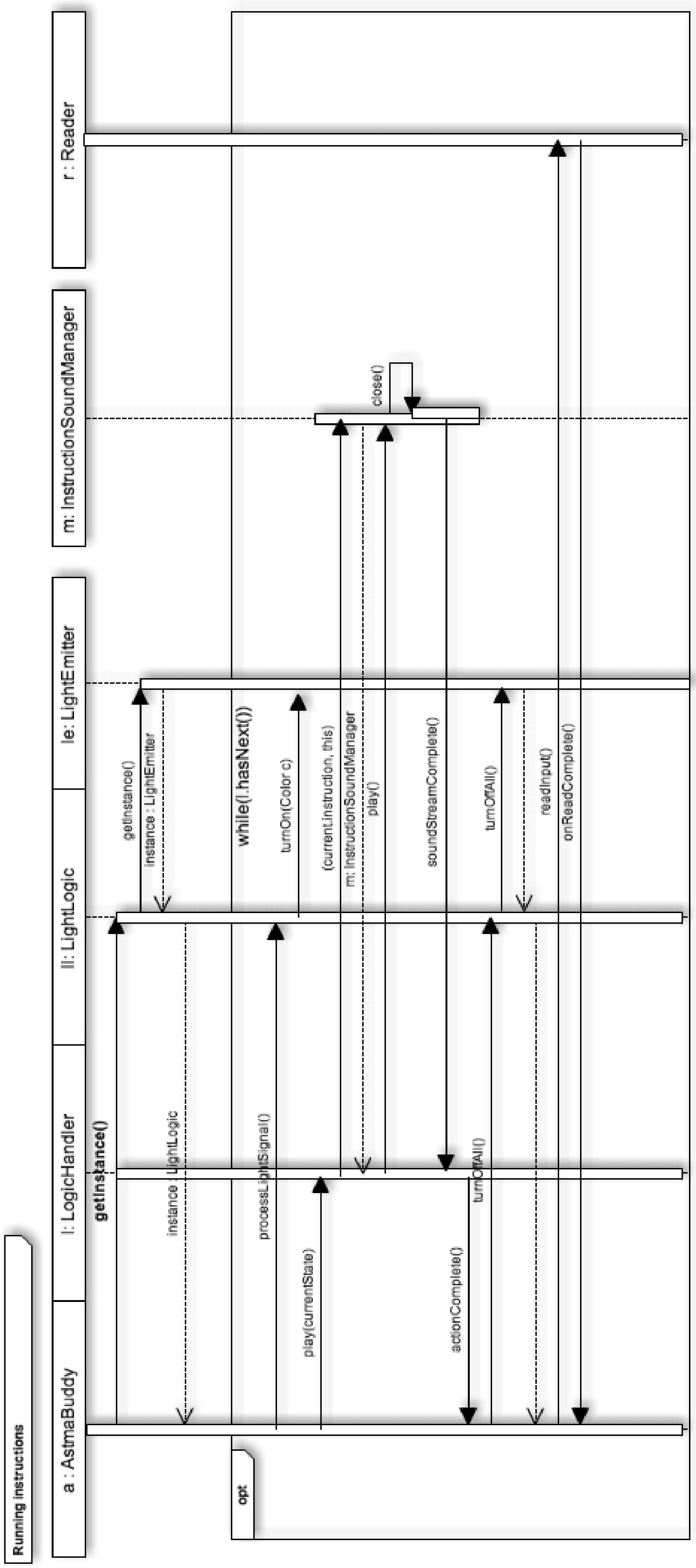


Figure 7.9: Playing Instructions - Sequence Diagram

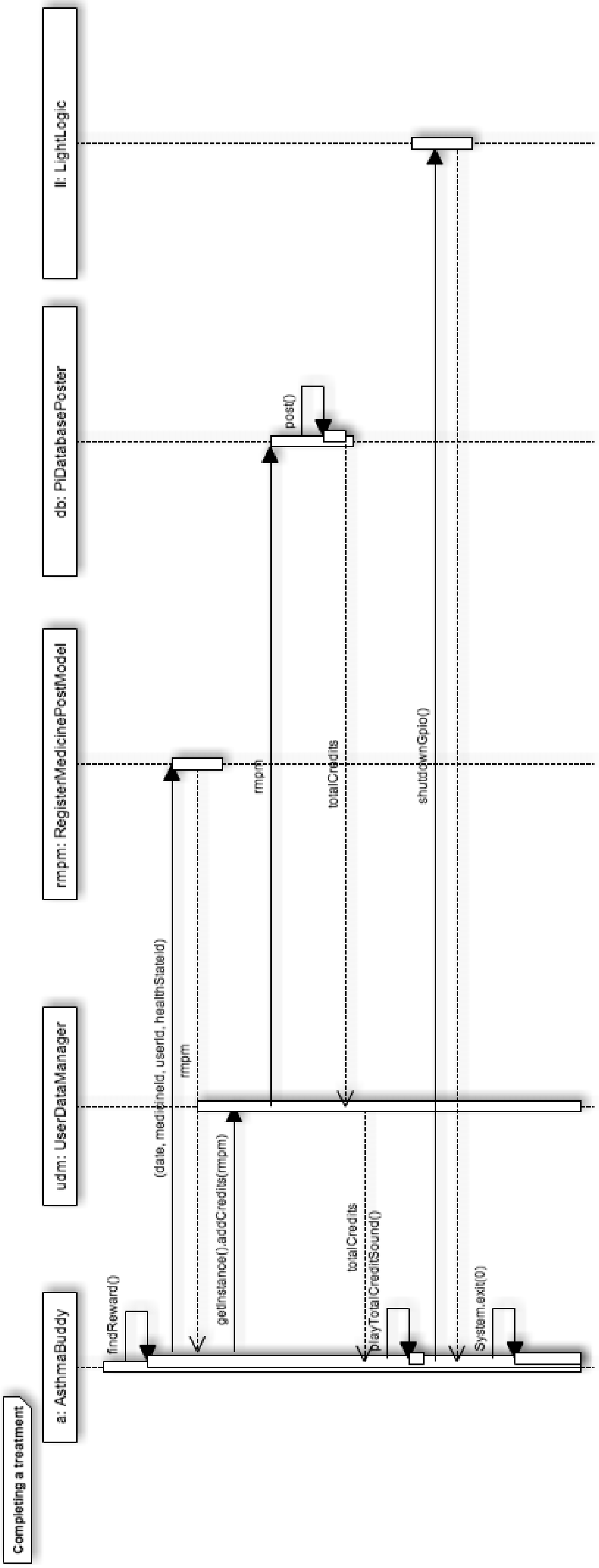


FIGURE 7.10: Finishing a treatment - Sequence Diagram

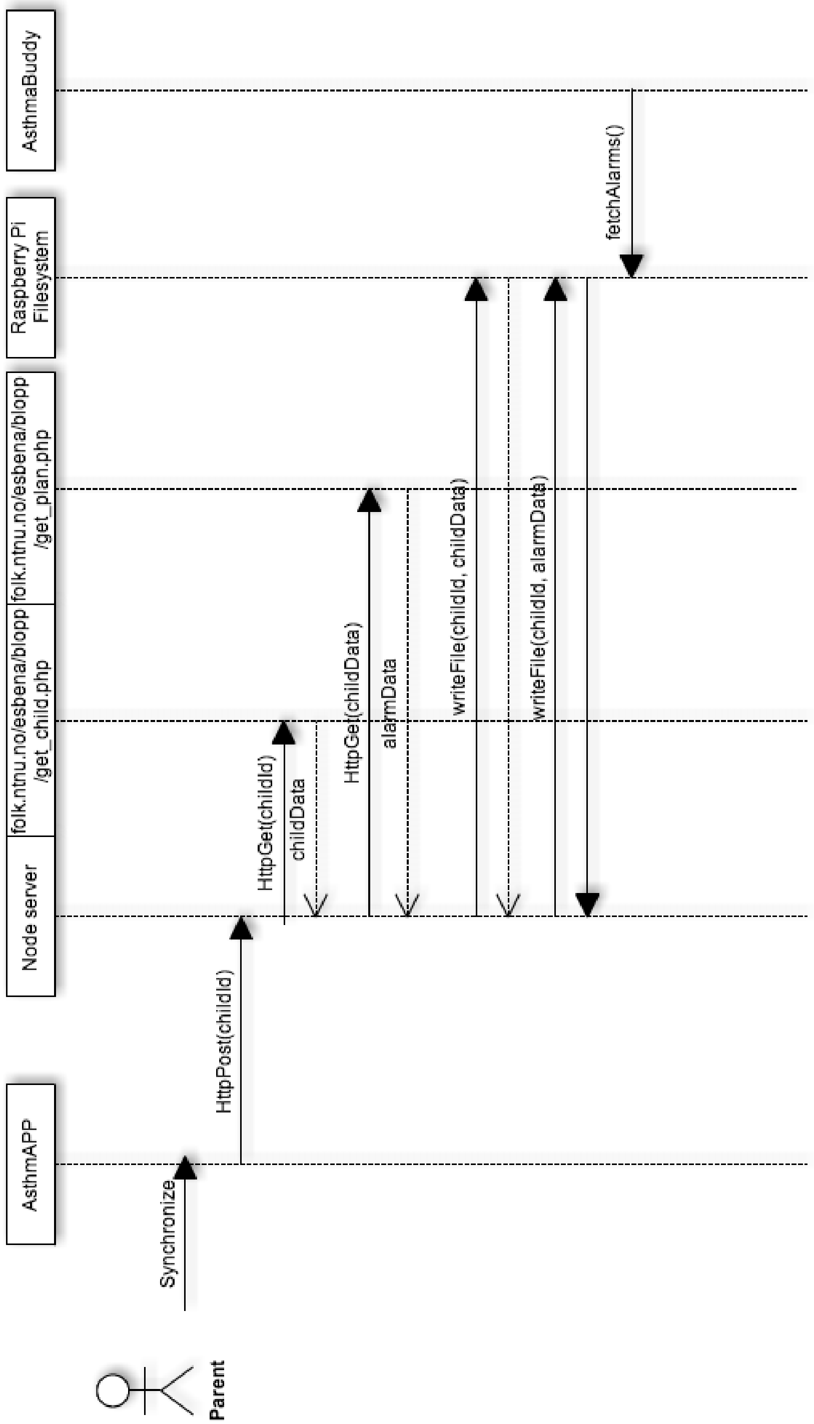


Figure 7.11: Synchronizing - Sequence Diagram

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

Finishing a Treatment When a treatment is finished, i.e. we are out of the `while` loop in Figure 7.9, we register the treatment in the database. This ensures that the child is able to see the rewards in AsthmAPP.

7.4.5 Node Server

In addition to the Java application running on the Raspberry Pi, we developed a Node.js server [8] . 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 using a smartphone), and the alarms set for this user. When AsthmaBuddy starts running, it checks for alarms to be set off every 60 seconds. When a child has finished a treatment, `AsthmaBuddy` updates the database, with the `childId` previously retrieved, and the number of stars a child collected during his/her treatment. With the data retrieved from the database, AsthmaBuddy has the capability to tell the user how many stars a child has collected[9]. This process is shown in Figure 7.11.

7.5 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 which methods of interaction will work with AsthmaBuddy. We did not have the time to implement all of the interaction methods listed. In order to simulate the interactions we used the Wizard-of-Oz technique[74].

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

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

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

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

7.6 Prototype version 2

The improved version of AsthmaBuddy, named AsthmaBuddy 2.0, had some changes done since version 1.0. As stated in Table 8.2, some of the interaction methods were removed. AsthmaBuddy also received some new features, such as a method for letting children more easily check the amount of stars they have collected. By registering an RFID tag, AsthmaBuddy tells how many stars the child has. This was implemented to make AsthmaBuddy more of a stand-alone system, and to avoid the problem were parents may not want the children to use their smart phone to use AsthmAPP.

AsthmaBuddy 2.0 now synchronizes achieved stars automatically between AsthmAPP and AsthmaBuddy. This was done to automate some tasks that previously needed manual interaction, and to create a tighter coupling between the two prototypes.

Some small changes were made to the use of the LED light on AsthmaBuddy's nose. AsthmaBuddy 1.0 changed the color of its nose fairly often. This was intended to make the treatment process more interesting; however, it ended up being more confusing than helpful, and was therefore changed.

7.7 Evaluation of AsthmaBuddy

7.8 Summary

We have developed a prototype for a tangible user interface called AsthmaBuddy, who can be used to guide a child through a treatment process. The software behind the prototype is built upon a Raspberry Pi, which was placed inside AsthmaBuddy. We have designed a set of interaction methods that we figured could be appropriate for children. It is currently capable of reading RFID tags, playing sounds and changing the light of its' nose. During the user tests, we simulated the usage of microphones with voice recognition, sensing touches to it's hand, sensing a smartphone's precence and distinguishing between a touch and a high five.

Chapter 8

Results

8.1 Interviews

We performed interviews on a set of domain experts in order to receive input on the work we had accomplished. Table 8.1 summarizes the interviews we performed, why we interviewed these subjects and the topics we covered during the interviews. Transcripts from the interviews are included in Appendix A.

Where we have interviewed parents of children with asthma, we have named those Parent N (N is a number), in order to protect the identity of their children.

8.2 Testing AsthmaBuddy on Inexperienced Users

Before we did user tests on children, we ran a round of tests to verify AsthmaBuddy's ability to explain the treatment process for inexperienced users. We tested on ten students at NTNU, where one of them had asthma during childhood. While doing so, we also tested the different interaction methods AsthmaBuddy could be used with. The reason we wanted to test interaction methods was to get an overview of how adults perceived the interactions. If adult users are incapable of doing some of the interaction methods, we figured that children were probably incapable of doing the same. Additionally, since we had problems to get a significant amount of children to test the system on (which will be elaborated further in Chapter 9.2.1), we did not want to waste a usability test on a child by initially having a bad interaction design.

The results of the interaction testing is summarized in table 8.2.

Name	Background	Rationale	Topics covered (keywords)	Reference to interview transcript
Nanna Sønnichsen Kayed	PHd in Psychology	Input on reward system	Rewards for children, Gamification, Motivation	Appendix A.1
Marikken Høiseth	PhD cand in industrial design. Experience from the BLOPP project	Collect data to design for children	Reward systems for children, designing for children, interaction design	Appendix A.2
Rose Lyngra	Senior Advisor in NAAF	Has expertise on asthma in general	Asthma among children, smartphone applications, motivation	Appendix A.3
Two nurses	Nurses with expertise on asthma treatment	Collecting data from treatment experts	Information in AsthmaBuddy and AsthmAPP, smartphone applications, problems with asthma	Appendix A.4
Parent 1	Parent of a child with asthma. Has expertise in computer science.	Collecting data from parents	Asthma in the family, smartphone applications, TUI, motivation, rewarding children, asthmatic child at school/kindergarten	Appendix A.5
Parent 2	Parent of a child with asthma. Works in a kindergarten.	Collecting data from parents	Asthma in the family, reward systems, asthma in the kindergarten, teaching inexperienced users	Appendix A.6

TABLE 8.1: Interviews performed during the project

Interaction Method	**Comments**	**Suitable for children?**
Give AsthmaBuddy a "High Five"	Worked out fine. A high five is cool and may make AsthmaBuddy seem more friendly to the children.	Yes
Hold AsthmaBuddy's hand	Easy to understand and use during a treatment. Should give feedback to indicate that the user has interacted correctly.	Yes
Hold smartphone close to AsthmaBuddy's belly	Smart phones are cool, but may be easily damaged if dropped. To risky to let small children handle a smartphone. The size of the smartphone may require use of two hands, which may cause complications for the child.	No
Press AsthmaBuddy's nose	Users tended to press the LED light on the nose. Risk of damage to light.	No
Press AsthmaBuddy's belly	Easy to understand and use during a treatment. Should give feedback to indicate that the user has interacted correctly.	Yes
Hold medicine close to AsthmaBuddy's mouth	Created some complications when the user was supposed to hold the mask to his/her mouth and then hold the medicine close to AsthmaBuddy's mouth to proceed.	No
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	Works OK. Letting children have their "magic token" which interacts with AsthmaBuddy may be cool for them.	Yes
Clap your hands	Worked out OK. At one point the user has to clap hands when having the mask in his/her hands, which may cause some problems, but should not be a big problem.	Yes
A variation of the above interactions	Confusing for users. The confusion may take the fun out of it.	May be considered in a revised form.

Table 8.2: Evaluation of interaction methods for AsthmaBuddy

Operating time The longest duration 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. A normal treatment taken without AsthmaBuddy usually takes 1-2 minutes, according to our interview subjects. Since AsthmaBuddy only takes 0.5-1.5 minutes longer than normal, it should not be considered a time-waster. From another point-of-view, if a child does not want to take his/her medication, it may cause an argument and take more time to complete the treatment. If AsthmaBuddy can help on shortening the time spent arguing with the child, a large amount of time may be saved.

Feedback We got some feedback regarding the *by need* treatments. Some parents stated that they would not use AsthmaBuddy to complete a by need treatment, as their child was suffering from an asthma attack. However, one of the parents noted that if children were used to performing their treatment with AsthmaBuddy, it could create a dependency toward it, i.e. AsthmaBuddy could help the child to calm down. Whether or not the by need functionality would actually be used needs more research, as AsthmaBuddy would need to be placed within a home and be nearby when such an attack occurs.

In order for AsthmaBuddy to be useful for inexperienced users, it could have even clearer and more informative instructions. Even though it may seem self-explanatory to take the cap off the medicine before mounting it on the mask, it may not be that obvious to new users. Since AsthmaBuddy's purpose is to instruct and inform, it should have a completely "foolproof" instructions. For instance some of the test users tried to attach the inhaler to the mask without removing the protective cap from the inhaler. Since the mask's mount is made from rubber, it gave them the idea that one should just push the medicine into the mount by force, which is incorrect.

When using AsthmaBuddy it may sometimes be difficult to hear all the instructions. There should be support for replay of the latest command.

One of the users commented that AsthmaBuddy should be able to operate as a stand-alone system if the parents do not allow the child to borrow a smartphone and the child does not have a smartphone of his/her own. The same test user commented that she would not take the time to use AsthmaBuddy for two minutes every time the child needed to take a treatment, and that AsthmaBuddy might become boring after a period of time.

8.3 Usability Test Results

In order to protect the identity of our test subjects, especially considering the children, we have used identifiers as names. Names starting with the letter "A" is an adult user, and names starting with "C" denotes a child.

8.3.1 Parent partition tests

Name	AU1
Age	36
Date	May 2nd, 2014
Testleader	Aleksander
Observer	Esben

Task	Problem	Cause	Proposal for solution
0	The user where unable to separate between the image for child and parent partition	The images were not entirely intuitive	The image for adults could have a bearded man, or other recognizable features.
1	It was unclear whether he had to press on the healthy medicine plan, as the child was in the healthy medicine plan by default.	Challenging GUI	Could make it clearer for the user which treatment plan is being followed
1	The spinners for hour/minutes should be able to be written into.	The standard Android slider contains a minor bug when one writes into it.	N/A
1	The time that shows when the alarm should fire contained seconds, which the test subject found unnecessary.	N/A	Remove seconds from the timestamp
2	The user expected that he could be able to press the medicine, and not just the checkbox which was the case. He found this a little annoying.	Implementation of listener	Make the entire list item touchable
2	He wanted functionality for adding two medicines at once.	This has not been implemented yet.	Implement it later
3	The view shows a button with “Add Activity”, which he felt was wrong.	This was not intended, as it should have said “Add Reward”	Change it to “Add Activity”
3	The user pressed the back button one too many times. This caused the PIN-challenge to be presented again, which the test user said could be annoying for some users.	PIN-challenge appears as soon a parent returns from the parent partition.	Could implement a timer who checks when the user last completed the challenge.
4	The test user said it was not logical to see where he could check the air quality cast.	Bad task description	Change task description to make it clear
4	The test user wanted functionality for different views, for instance showing the log for a week or a single day.	Too high expectations	This feature could be implemented with more time and resources.

Table 8.3: Usability result

8.3.2 Children partition

Name	CU1
Age	6 years old
Date	May 2nd, 2014
Testleader	Aleksander
Observer	Esben

Task	**Problem**	**Cause**	**Proposal for solution**
2	It seemed like she had a hard time keeping up with AsthmaBuddy's instructions	The voice of AsthmaBuddy was speaking to fast	Record sounds with lower speed
4	It was difficult to drag the medicine above the mask in order to start the treatment	The treatment only starts when the medicine is directly above the mask	Should make this functionality simpler to start.
4	It was hard for the child to keep ut with the voice of the rabbit.	The voice talked to quickly, and AsthmAPP does not have a repeat functionality when a treatment is running.	Should consider implementing repeat.
5	It was hard to get a clean read of the RFID tag.	It was not entirely clear where the user had to put the card in order to get a read.	AsthmaBuddy should have an indicator as of where the card should be held in order to be read.

Table 8.4: Usability result

CU1 was very shy when arriving at the test lab. It quickly became clear for us that we had to leave the area and rather observe from the back room, in order for her to speak up. The parent was instructed with the tasks that were to be performed, and he explained the tasks to her. Once we were back stage, she started responding to the instructions given. We made a note that the observer should sit in the back room and observe from there, in order for the children to respond more easily.

When asked which method CU1 preferred, i.e. AsthmAPP or AsthmaBuddy, CU1 replied "I don't know". CU1 was also asked if both were equally fun, which to CU1 replied "Yes". CU1 was also asked if the usage of AsthmAPP and AsthmaBuddy was more fun than a regular treatment, which to CU replied "Yes"[1]. We asked if this was because of her reward, which was candy, but we were unable to get a reply.

Task	**Problem**	**Cause**	**Proposal for solution**
place	place	place	place
place	place	place	place
place	place	place	place
place	place	place	place

Table 8.5: Usability result

Task	**Problem**	**Cause**	**Proposal for solution**
place	place	place	place
place	place	place	place
place	place	place	place
place	place	place	place

Table 8.6: Usability result

[1]There is reason to belive that the answer was biased due to the reward

Chapter 9

Discussion and Conclusions

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

9.1 Discussion

9.1.1 Gamification

9.1.1.1 Understanding Children's Perception of Rewards

Our proposal for gamification elements contained within AsthmAPP is tightly coupled with the parents' initiative. In order for our reward system to have any motivational effect, parents have to be closely 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:

"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."[75]

In order for our systems to have a motivational effect, parents have to be aware of their children's maturity. Rewards that suit a three year old girl do not necessarily suit a six year old boy. Webster-Stratton further claims that parents should expand the efforts children have to put into a task, in order to receive their reward. We will elaborate more on this in Section 9.1.1.4.

Parents could be under the impression that the rewards given should be something material. However, according to Nanna S. Kayed, researcher/PhD in psychology:

"Rewards do not have to be a material reward, it may be a fun activity or letting the children choose what they will eat for dinner. Doing something entertaining with their parents can be as much of a reward as a physical toy. An example of an easy and fun reward is to eat dinner underneath the table or taking a walk in the woods. It is important for you [the developers] to tell the parents that the reward does not need to be material, but can be simple and easy rewards."

She implies that spending quality time with the family can in fact be just as effective as material rewards. She also pointed out that we should include some sort of manual to our reward system, in order to maintain the maximum motivational effect and ensure that parents understand that the rewards do not have to be material. However, creating a manual for reward systems for children could be an own master thesis in psychology, and we will not delve further into this aspect.

It is reasonable to assume that most parents have used some sort of reward system with their child, for instance to get their child to behave the way the parents want them to. One of our interview subjects had used stickers in order to toilet-train her son. The amount of rewards and their "attractiveness" should be correlated to the task performed by the child.

"Collectors" vs. "spenders"

Children perceive rewards in a different manner. Some children like to collect their rewards and will never choose to spend the rewards as a currency. To these children the collected amount of rewards is important, and they often value the rewards more as a collector's item than as a currency. Some children like to spend their rewards and cash them in as currency. These children often care more about spending the rewards on items rather than saving the rewards, even if the item they spend their reward on is a short-lasting joy, such as an edible item or an arcade credit. AsthmAPP's reward system is made to accomodate the wishes of both "collectors" and "spenders". Since the reward system is a milestone-based system where the rewards do not disappear when a reward is collected, both user types may have what they want. Making the reward system as motivating as possible will be up to the parents.

Understanding the family situation

It may be argued that our reward system could cause internal jealousy within a family. For instance, if a family has three children, where two of them suffers from asthma, the last child could potentially become jealous of the other two, as they may receive rewards which seems unfair for the last child. In such cases, we leave the responsibility to the parents to balance these rewards, such that it does not seem unfair for the healthy children in their family.

9.1.1.2 Bartle's Four Player Types

In Section 4.4.1 we presented Bartle's four player types and how they enjoy gamification. In order to understand how gamification can be used in order to motivate children with asthma, we have explored some solutions for how to build an enjoyable gamification system for the four player types; achievers, explorers, killers and socializers.

"Killers"

In Section 4.4.1.4 we stated that hopefully no children in our target group hope to gamify their experience by imposing themselves on others. We found no positive and meaningful way to support "killers" in our system. The only scenario we could come up with was that children could slow down the progress for others (eg. steal other children's stars), which is against the purpose of AsthmAPP.

"Socializers"

While AsthmAPP has little support for socializers, we believe there is potential for use of social features in a system such as AsthmAPP. An example of such would be the use of an avatar system where the children may share their avatar with others and meet other users of AsthmAPP in a social hub similar to Club Penguin [1] or Farmville [2] .

"Explorers"

AsthmAPP is a concept and has little to explore. However, we believe that there is a potential for functionality to motivate explorers. The use of progress bars, leveling systems or achievements and badges can easily be transferred to a system like AsthmAPP in order to achieve a gamified experience targeted at explorers. Linander's interactive story concept showed how the progress in a story may be tied to the use of asthma medicine[76]. Possibilities for adding new stories over time would create an even more engaging system for children.

"Achievers"

AsthmAPP mainly provides game elements suitable for achievers. The gamification system in AsthmAPP is built around performing a treatment correctly and being awarded

[1] Club Penguin - www.clubpenguin.com
[2] Farmville - www.farmville.com

for doing so. The use of stars as experience points and support for real-world rewards through the shop is applicable for all children, but may be of most interest to achievers. There is endless potential for how gamification may be used to engage achievers, and there are many possibilities for further research on these areas.

9.1.1.3 Reception of AsthmAPP's Reward System

[TODO:Wait until user tests]

9.1.1.4 Gamification over time

According to Webster-Stratton and Herbert, parents have a tendency to not phase out reward systems[75]. When this occurs, children do not receive the message that is in the essence of reward systems; that parents expect their child to perform a task on their own without receiving a reward. In the example Webster-Stratton et. al. describe regarding raising a child, parents could give a reward for making the bed every day for one week. After a week, the parents should expand the task to include making his/her own breakfast every morning. Similarily, parents should increase the cost for receiving a reward in AsthmAPP.

Based on findings we did during Customer Driven Project[4], we believe that gaining access to a new star could be rewarding enough when a child first starts using AsthmAPP. After a while, it will become boring, and parents should provide a means of a tangible reward (material or social). For instance, parents could start out by giving an ice cream sandwich to their child if they take his/her medicine as planned during the first day. Then they could expand the challenge by one day, giving the child some extra allowance if they manage to do it two days in a row. When time passes and their child has gotten used to taking the medicine, the system should be phased out. AsthmAPP in its current state would then serve the purpose of reminding, informing and logging the user's use of medicine.

9.1.1.5 The use of different gamification mechanics

When building AsthmAPP and AsthmaBuddy we chose to focus on the use of real-world awards, mirroring user behaviour and experience points. While these were the elements we chose, there are endless possibilities for other combinations of game elements. In the following, we discuss the potential use of different game mechanics in the future.

Avatar Systems

The use of avatar systems has huge potential for gamifying the treatment for children suffering from asthma. An avatar system can be a simple game where the user is awarded with clothing and equipment for their avatar, or too a extensive game where the users use of asthma medicine controls an avatar in a game. Linander's "Concept for Improved Experience of the Treatment of Asthma"[76] showed potential for this.

Achievements and Badges

There are many possibilities for the use of achievements and badges. Examples of this is badges for "Follow treatment plan for 5 consecutive days" or "". The use of achievements are two-edged sword. They must not be of a manner that may lead to a non-positive behaviour, ie. "Not have an asthma attack for one week" where the user may not want to use Ventoline, in order to win an achievement.

Real-World Rewards

Our application is built around real-world rewards. We believe there are many possibilities for the use of real-world rewards when it comes to treating children with asthma. We also believe that having real-world rewards will motivate the children over time, since a candy bar, a trip to the local lake or a ticket to the local football match will not wither over time. Real-world rewards demands more from the users, since it demands that a parent or an adult gives the child the rewards. While this might help motivate the children it may also put too much work on the parents, and they may see the reward system as too demanding.

Mirroring User Behaviour

Mirroring user behaviour has recieved positive results from younger users, and there have been an increased amount of applications using this gamification technique. Applications such as the Grush toothbrush [3] is built around mirroring user behaviour. We find user behaviour a positive and useful technique.

Leaderboards

We have trouble finding how to implement leaderboards in an ethical and positive manner. Using a leaderboard risk breaking Norwegian privacy laws, which is unacceptable. Making the use of medicines into a competition would probably recieve heavy critique, since it may be viewed as a move to increase the income of the companies manufacturing medicine. While the use of anonymous avatars and usernames may combat the privacy concerns, it may still be viewed as unethical and a bad marketing scheme.

Social Networking

[3] Grush - https://www.indiegogo.com/projects/grush-the-gaming-toothbrush-for-kids# home

One should be very careful when designing social networks for people who suffer from a disease. There are many privacy concerns to take into account. An anonymous social network may be positive for parents with asthma. They may share success stories, ask questions and recieve help through the network.

Progress Bar

There are possibilities for the use of a progress bar within an application for health care. While it will be impossible to evaluate the progress towards being cured from a disease, there are other uses. Combining a progress bar with experience points is easy to implement and have many possibilities for how developer wants to make use of the gamification element.

Experience Points

As mentioned previously, experience points there are many possibilities for the use of experience points. The main challenge with using experience points is to make them have a meaningful value over time. As McGonigal argues, gamification withers over time and there is risk for boring the user[40].

Contests

As with leaderboards, making the use of medicines has it's risks. One might think of contests such as "remember to follow treatment plan perfectly for a long period of time" as a suitable contest, since it has a positive competition. However, this will be in conflict with Norwegian privacy laws.

9.1.2 Tangible User Interfaces

During our project we discovered different areas where tangible user interfaces may be of use for asthmatic children, their parents and other caregivers. The main areas include learning, motivating, distracting and informing. Other areas where TUIs could be of use are elaborated on in Section 9.1.3.

9.1.2.1 TUI as a Tool for Learning

When a child gets diagnosed with asthma, his/her parents receive a lot of information at the doctors. It occurs that the parents are not paying attention, do not understand the information received, or do not communicate the information correctly to other caregivers. As two asthma nurses stated in an interview:

"We always make sure to teach the parents and the children how to apply the medication correctly, however, they may forget it over time. If the parents do not remember how and when to give the children medications, it may have a negative effect on the treatment of the child's asthma."

AsthmaBuddy can be used to relieve parents from the responsibility of remembering exactly how and when the medicine should be taken. Parents will probably remember the process after a couple of days, but AsthmaBuddy could help them with the start up.

Hospitals hand out flyers and treatment schemes to parents when children are diagnosed with asthma. However, flyers are often lost, and miscommunication often occurs when parents leave their child with other caregivers, like grandparents, babysitter, etc. By sending the child off together with AsthmaBuddy, the implications of any miscommunication could be minimized.

Teaching children

In addition to teaching parents about asthma, AsthmaBuddy could be used to teach children about their disease. In some cases, parents do not explain to their children why they are sick, and what is causing their breathing problems. After a child has taken a dosage, AsthmaBuddy could proceed to read a book about asthma, specifically written for children. As more treatments have gone by, new chapters can be read, increasing children's knowledge and awareness of their disease.

Information correctness

When informing children and parents about asthma, it is vital that they receive correct information. If the information provided contains errors, it could have significant consequences for the asthma treatment. The information provided should be approved by either medical doctors or organizations like the NAAF. This will provide a quality assurance, in addition to gaining potential families' trust.

Motivating

"Children below your target group (i.e. younger than 3 years old) can be even harder to motivate, as children in the group 3 - 5 years old have an understanding as to why they need to take their medicine." Children in the age of 3 - 5 years old understand that they get better from taking their medicine. However, not all parents actually tell their child 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.]

9.1.2.2 TUI as a Tool for Motivating

Feedback

Tangible user interfaces could be used to give feedback to children about their treatment. They could for instance notify how good they have been at taking their medicine during a week, and notify if they have forgotten a medicine at a day. This feedback should however be discrete and implemented in a non-obtrusive manner, as parents could interpret AsthmaBuddy as yet another annoying toy in the house.

Calming children down before a treatment

If children are scared before they take their medicine, tangible user interfaces could help calming children down. A friendly character such as a teddy bear might help distract the children from the situation and make them forget about what scared them in the first place.

Turn the process into a game

TUIs could be used to motivate children by turning each treatment into a game. At the moment, AsthmaBuddy and AsthmAPP makes the long run process into a game. A TUI could be used to turn a single treatment into a game, eg. by saying that *"If you take the cap off the medicine, you get ten points"* and *"If you breathe for ten seconds, you get a hundred points"*. Then children could do the math to calculate their total sum, that the TUI can state is correct or incorrect.

Responsibility

A TUI could be used to make children more responsible regarding their own disease. Children could for instance be prompted to check whether there is enough medicine in their inhaler, and be responsible for telling their parents if they need new supply. AsthmaBuddy could be used for the same purpose by waiting to fire off an alarm, and check to see if the child reacts upon this. If the child reacts, it could provide positive feedback, and if the child does not react, it could give a strict notice that they can't rely entirely on a stuffed animal[4].

9.1.2.3 TUI as a Tool for Distracting

Distracting children while taking a medicine In its current state, AsthmaBuddy distracts children while taking their medicine by counting to 10, which is the number of

[4] This could prove to have a negative effect, but is an option to give children more responsibility.

seconds a child should breathe in his/her breathing chamber. Additionally, the LED-light at its nose is blinking, which we will discuss further in Section 9.1.3.3.

Since we only have 10 seconds to work with, there are big limitations on what AsthmaBuddy can actually do in order to distract them in a natural way. It could be argued that having AsthmaBuddy by their side is actually enough distraction, as they have something to look on. If a TUI with movable parts had been developed, these parts could be used to give children something else to look on, by for instance introducing them to a new dance once in while.

A more interesting case would be to distract children that are using a nebulizer in their treatment, as these often lasts for about 10 minutes or more. Children would then have to rely on something more exciting, like an audio book.

Distracting children between medicines

Children often have to take two different medicines after eachother, but not immediately. A reguler scheme is to first take Ventoline, then wait for five minutes, before a dosage of Flutide should be taken. One of the interview subjects pointed out that:

"The teddybear could help children to keep up with the time while they're waiting to for the next dosage."

He further noted that it was easy to get "overly excited" and take the Flutide dosage earlier than 5 minutes after Ventoline has been taken, which will reduce the effect of Ventoline. AsthmaBuddy could in this case distract the child from taking the medicine too early, by for instance reading an audio book, playing songs or even count down to the next dosage. The effect this distraction could vary from child to child. If a child really hates to take his/her medicine, having AsthmaBuddy count down to the next dosage could seem frightening for the child.

9.1.2.4 TUI as a Tool for Informing

For children with astma there is a lot to remember. We have already discussed the theme of learning about asthma, which is a very important aspect. There is still more to remember, and we have found some ideas for what the tangible user interface may help for.

Counting doses left in the inhaler

One of the interviewees noted that:

"It is annoying when medicines go empty, so we're keeping a journal"

Since the inhalers have a certain amount of doses in them, and the amount of doses varies between different medicines and their vendors, it may require an effort to remember how many doses are left. The disk-formed medicine often come with an indicator, while inhalers do not. Inhalers make a "poof" sound when pressed, and this sound may occur regardless of whether or not there are any doses left. By using a RFID on the medicine and a RFID-reader on the TUI, may keep up with how many doses have been taken, and the system automatically warns the user when the number of doses is running low. There are many other ways to solve this digitally, but we believe that having AsthmaBuddy count how many doses are left and tell the user by sound could be fun for children and helpful for parents.

Pollution levels and pollen forecast

There are many different applications and web pages for reading and recieving information about air quality and pollen forecast. These web sites often offer data to third party services. AsthmAPP has the functionality for getting air quality readings and pollen forecast in the same application (see Section 6.4.4). AsthmaBuddy could help the children with the same functionality, starting the day by telling how the air quality and pollen readings are for the day.

In a future version, AsthmaBuddy could calculate and foresee the amount of medicine needed when there is much pollen or bad air quality and update its alarm schedule based on the knowledge gathered. However, this is a functionality which will require research and we do not have the knowledge to judge if this is possible to implement or whether it is useful for the users.

Reminders

AsthmaBuddy has functionality for firing alarms based on the treatment plan set in AsthmAPP. This makes it easier for the children and parents to remember to apply the treatment at the planned time. While taking medicine is often a routine for families with asthmatic children, AsthmaBuddy could be a useful embodyment of a reminder.

In a future version AsthmaBuddy should be able to know that if a treatment has been completed within a short time before a planned treatment, the planned treatment will not be necessary. For a user having completed their planned treatment, an alarm firing 5 minutes later can be annoying. AsthmaBuddy's purpose is to help the user to remember, and if the user has already completed the treatment, AsthmaBuddy should be satisfied.

9.1.3 Other Aspects

During the project we discovered different areas where AsthmaBuddy could be of use, some of these did not sort under the topics learning, motivating, distracting and informing. These findings are presented in this subsection.

9.1.3.1 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 do not 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 does not take their medicine properly on 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 its 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.

9.1.3.2 Tangible Interfaces to Help Parents Help Children

When children suffer from asthma, they often have to rely on their parents in order to maintain control of the disease. Parents have to maintain a clean house and they have to keep an eye on pollen, as pollen and asthma are often related. One of the features AsthmaBuddy could have in order to help parents is a morning forecast, 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 [5] , which in turn could start cleaning. AsthmaBuddy could also indicate the air humidity at the child room, starting up the air condition.

9.1.3.3 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 night. It is also possible to buy a WiFi shield for the Raspberry Pi that could process communication to a server. This would solve mobility within a home. However, it would not solve the problem when a child is travelling, for instance by car. Being able to use AsthmaBuddy in a car would require their parents to have created a hotspot.

Use of colored 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*

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

sound may affect the children in different ways, but that will have to be explored in user studies."

We believe that the use of colored lights as a distraction method during a treatment is a complete field of research on it's own. There already exists some research, such as Mæhlum's "Concept for Increased User Acceptability When Treating Children With Respiratory Infections[77]". During our project, we have not conducted enough research to draw conclusions on the use of colored lights during treatments.

Interaction Methods

AsthmaBuddy in its prototype form was not able to sense interaction, and was operated by using a "Wizard-of-Oz technique"[74]. 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.

9.2 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.

9.2.1 Difficulty Finding Test Users

When performing user tests and interviews involving gathering personal medical information, there are requirements to be followed. Before contacting potential test users, the research project must be evaluated by an ethical committee [6] , and while the paperwork have easy-to-follow standards, this took some time[7].

The hunt for potential test users proved more difficult than anticipated. We contacted different hospitals and persons with expertise on asthma. We asked them to help us recruit test persons for our project. In order for the hospitals to help us, we needed an approval from their marketing/ethical committee. In our efforts we were a bit unlucky. After applying for an approval, we did not hear from the hospital in a while. After numerous phone calls and e-mails, we got the answer that the person responsible for our processing our application had been on sick leave for a long period of time. In

[6] Regional Etisk Komite - https://helseforskning.etikkom.no/ikbViewer/page/forside?_ikbLanguageCode=n
[7] Our project was authorized in January 2014, under case number 2012/159

hindsight we understand that this process should have started some months before the actual project, in order to allow for such unforeseen events.

In parallell to the contact with hospitals and doctors we tried recruiting test persons through friends, colleagues, social media and mailing lists from NTNU and local organizations. This proved less fruitful than we hoped. We have no concrete feedback as to why we had so little response, but we have our assumptions. Firstly, the user group is a very specific group. There might not be that many children living in Trondheim at the age of 3 - 7 years, suffering from asthma, who also have parents willing to participate in our research. Secondly, people tend to not care if they do not get an attractive reward for helping, and since we had little to offer in terms of economical compensation or rewards, the interest might have withered away for some people. Thirdly, there may have been scepticism from the potential test users. While all the different paperwork was in order and the project may prove positive for the children and parents within the target group, the fact that we are two students writing a master thesis may be less encouraging[8].

9.2.2 Co-Design Sessions

Our original plan was to arrange co-design sessions with several experts present at the same time. We believe this would have helped the creativity of the feedback for AsthmAPP and AsthmaBuddy. However, this proved too difficult to arrange. The persons we wanted to invite were very busy and after several failed attempts to find a time suitable for all experts, we gave up trying to arrange co-design sessions.

9.3 Conclusions

The research questions presented in Chapter 1.3 provides a basis for summarization of results discussed in Chapter 8.

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?

[8]We *belive* that if the researchers were publicly acknowledged, it would have been a bit easier to recruit users

Chapter 10

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 4.3, 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?]

10.1 Future Vision

In order to tie together loose ends, we have created a scenario for the use of AsthmAPP and AsthmaBuddy.

John is a 5 year old child who has recently been diagnosed with asthma. He is the oldest child in his family, and his parents do not have any prior knowledge of asthma. After consulting with John's pediatrician, his family has acquired AsthmaBuddy and AsthmAPP to help them make the transition easier.

Johns parents wake him up at 7:00 AM a cold winter morning. They get dressed and start to make their way to the kitchen. On the way, they stop by AsthmaBuddy, who greets them with the morning status regarding asthma. AsthmaBuddy informs the parents that the air quality is poor outside, due to heavy traffic and the cold air. He also mentions that there is currently no pollen in the air today. AsthmaBuddy asks whether or not he should add an additional treatment to the plan for today, in order to comply with these conditions. His parents shakes AsthmaBuddy's hand in order to indicate that this is wanted. John eats his breakfast, and goes back to his room.

While John is getting ready for kindergarten, an alarm is fired on AsthmaBuddy, indicating that John is due to take his medicine before leaving. John calls for his mother, and together they are guided safely through the treatment. John is now ready for another cold day, and leaves for kindergarten, where they have planned an activity day outside. John wants to take AsthmaBuddy with him to kindergarten, since the new version of AsthmaBuddy is portable. John's parents does not think this is a good idea, since it may be lost or broken if all the children want to play with AsthmaBuddy, and thus AsthmaBuddy must stay at home.

At home, AsthmaBuddy senses that there is a high amount of dust in John's bedroom. AsthmaBuddy contacts the family's Roomba, who starts dusting and mopping the floors. AsthmaBuddy turns on his red light and sends a push notification to AsthmAPP, indicating to the parents that the floor has been cleaned.

At noon, John gets an asthma attack after playing some serious rounds of tag. The kindergarten teacher, Lucy, is the closest grown-up around and runs over to help John. She's new on the job, and has little experience in how to handle the situation. Luckily, she has a kindergarten version of AsthmAPP, where she can press the emergency button in order to receive guidance on how to help John. With the help of AsthmaBro, AsthmaBuddy's digital brother, they are guided safely through the treatment. John's parents receives a call about the incident, in order to let them know that everything is fine. They register the medicine on AsthmAPP, in order to ensure that John gets his stars.

During the day, John's parents meet at the pediatrician's office for a follow-up meeting. They display AsthmAPP's log for the doctor. The doctor recommends to follow the yellow treatment plan, given the recent high pollution and cold air. He also tells them that if John keeps getting asthma attacks, he should change to the red treatment plan.

Before picking John up at the kindergarten, John's parents have added a reward, which allows John to choose today's dinner. The reward is received when John has gained a total of two stars, which he currently has accomplished. On his way home, John cashes in this reward; deciding to order pizza for the family. When they arrive at home, his parents starts dusting John's room. During dusting, John's father turns his attention to AsthmaBuddy. He is uncertain about the number of dosages left in the inhaler, as he does not know how often he needs to purchase a new inhaler. He holds the medicine towards AsthmaBuddy's belly, who informs that there are a large number of dosages left. AsthmaBuddy tells him that he will schedule an alarm when there are 15 dosages left.

Before John goes to bed, he needs to take his preventive medicine, which is scheduled for 8:00 PM. However, John has had a long and eventful day, and starts to get tired. He takes his medicine at 7:45 PM, and AsthmaBuddy removes the alarm scheduled at 8:00 PM. After taking his treatment, AsthmaBuddy starts reading a chapter from a book about how the dragon Seath once conquered the magical land of Ooo, after gaining control of his asthma.

Appendix A

Interview Transcripts

The following appendix contains brief interview transcripts we made during interviews. *Italic* font is used when we as interviewers asked a question.

A.1 Nanna Sønnichsen Kayed

PHd in Psychology. Expertise on reward systems when raising a child.

Date: 25th of March

Place: Trondheim

How do children react to reward systems such as the one in AsthmAPP?

Children react very differently regarding reward systems. Some children find the rewards interesting, while some may not care at all. A common problem is that they may not be able to see the value of a reward given in the future. Younger children tend to choose rewards given immediately instead of a bigger reward given in the future [78]. The difference in how children percieve the value of a reward is very individual and there may be huge differences between age groups.

Is there a possibility that children may manipulate the reward system by pretending to be sicker than they are?

It is difficult to determine if there is a risk of children pretending to be sick. Children often do not like going to the doctor's office, which may stop them from pretending to be sick.

The parents set the rewards themselves, how do you think this will work?

The rewards has to be interesting for the individual child, and must be tailored to their interests.

Do you think the reward system can lead to jealousy between children?

Children percieve rewards differently, and a reward for one child may not be interesting for the other child. However if one child gets a reward that is much more valuable than the other children, if may lead to a situation where the children who recieve lesser rewards may be jealous. The parents of the children in the same class/kindergarten can make an agreement on what rewards should be set, in order to give equal rewards. It is important to find a reasonable level for the value of the rewards, to ensure it will not be a burden to the parents.

Rewards do not have to be a material reward, it may be a fun activity or letting the children choose what they will eat for dinner. Doing something entertaining with their parents can be as much of a rewards as a physical toy. An example of an easy and fun reward is to eat table sitting underneath the table or taking a walk in the woods. It is important for you [the developers] to tell the parents that the reward does not need to be material, but can be simple and easy rewards.

Can the reward system lead to differences between children that use the application and recieve rewards and children that do not use the application?

There at not that many children with asthma in each kindergarten. I believe that parents will talk to each other and share experiences which may result in positive sharing of knowledge.

The stars earned in the application are not removed. Will this cause a problem with regarding teaching children the value of money and rewards?

This is different from one child to another. Some children are "collectors" and would not spend the stars if they go away, but instead hoard them. There will be a risk that these children never spend their stars on rewards if they have to remove stars to get rewards.

[Demonstration of how AsthmAPP works]

Have you [the developers] thought about letting the players play a game as a reward? Games such as Flappy Bird [1] are very popular with children, and a round doesn't take such a long time.

It is also important to remember that the reward must be reflected in the severity of the task.

[1] Flappy Bird - http://flappybird.io/

[**Demonstration of AsthmaBuddy**]

I believe that a cute bear like this may help in making children more positive to remembering their medicine. For a small child the bear itself may be enough of a reward.

The use of AsthmAPP and AsthmaBuddy are quite repetitive over time. Do you think it can be boring over time?

A treatment takes less than 2 minutes, which will help. The app should have support for experts children, so they do not have to follow the instructions when they have become expert users.

I do not see any negative aspects with the system. Leaving the reward system for the parents to choose is a good solution, but will require advice and information in order for it to work as a positive manner for both parents and children. You must also remember that it must not take a long time between the activity and the rewards, since children may not see the connection.

A.2 Marikken Høiseth

PhD candidate in industrial design.

Date: 26th of March, 2014

Place: Trondheim

[**Interview started with a demonstration of AsthmAPP and AsthmaBuddy**]

It's a good idea that the stars represent something different than the digital picture itself. The stars by itself may lose value after a short period of time. Children and parents can decide the rewards together. This could become a social activity for them. It seems smart to guide them as far as the rewards goes, and it does not necessarily need to be material. It is entirely up to the user to choose the amount of effort they'll put in it, and they decide how they reward their children. It is easy to forget that stuff like deciding where the sunday trip goes could be rewarding enough. It is important not to limit these rewards.

Do you have any experiences as far as repetivity goes for this usage pattern?

It is a lot of difference between children in the different age groups. It is important that the application is an aid to help them, and not something they're forced to use. The application could help during the startup of their treatment. Then parents can decide whether or not they should continue using it. It is important to creative a positive frame around the treatments. In the best case scenario, the child understands why they use their medicines. The application could help by creating a better attitude around the use of medicines.

Do you have other ideas to what AsthmaBuddy can be used for, besides guiding them through their treatments?

It is important not to exaggerate the amount of functions it can have. It will become annoying if AsthmaBuddy required a lot of attentions. We had a case where we had to put Furby into a closet because it become to needy. It is important that the user remains in control, and that AsthmaBuddy is subtle. It depends on how AsthmaBuddy is presented and introduced. The user has to be able to control the tool. It is important to include the end user in the development. So that we (designers and developers) can learn about them and make products that are adapted to their lives.

Do you have any ideas regarding the interaction methods between the child and AsthmaBuddy?

It is useful to build a relation between AsthmaBuddy and the child. It is important to show what can be done in order to get a technological response. It is also important to reduce interactive touch points. As far as ideas go, maybe ability to speak with AsthmaBuddy could be an idea?

Regarding use of lights/sounds/pictures in applications targeted towards asthmatic children. Do you have any experiences or do's and don'ts we should know of?

People's perception of and preference for sensory stimuli differs. You should take a look at Tori's master thesis[2]. The use of lights and sound may affect the children in different ways, but that will have to be explored in user studies.

In AsthmAPP we use pictures of the Karotz as an avatar. What are your thoughts on this?

Have you considered using pictures of the bear, in order to create a connection between the application and the bear? It is preferable to have a relation between icons in the application and the look of the bear. If the bear is not present at all times, the bear within the application could be the little brother to the big bear to create a tighter relation.

[**Demonstration of AsthmaBuddy in use**]

There is no feedback that the bear knows you have interacted?

The bear will continue talking after the user interacts.

That may not be enough feedback for the child. It is smart to show the child that he/she interacts in the right way. You should also look for how the color of the light affects the user. The change of color of the light may be confusing, but that will have to be user tested.

You should remember that interaction between the bear and the user can be difficult when taking taking a medicine. The user only has two hands.

The teddy bear could help with other things such as remembering to brush teeth for a long enough time or similar activities that may be boring for children.

[2] DIPP - Utvikling for konsept for økt brukeraksept innen medisinsk behandling av barn med luftveis-infeksjoner

A.3 Rose Lyngra

Senior advisor at NAAF.

Date: 26th of March, 2014

Place: Trondheim and Oslo [3]

[The interview started with an explanation of AsthmAPP's reward system]

Are there any aids that are used on a regular basis?

At the hospital or during a treatment, there are a lot of people who read for the child, or play an audio book, use an iPad to watch a movie or play an easy game. In order to distract the youngest children, they sometimes use a toy (something with sound or light that are "active"). Having something interesting to distract the children usually works good. These tactics are also used for children with eczema, where they have to sit in a bath for 15-20 minutes. During shorter treatments, the children usually gets a reward after the treatment, as the treatment is too short to distract them from anything.

Do parents remember to apply the medicine at the right time? And do they use any tools in order to help them keep up with the plan?

Usually, they medicine are given at the morning or by evening. Some children need medicines more often, and this must be explained to employees at the kindergarten or at the school. Children often have to take responsibility, as they can't necessarily calll their parents to check. It is possible the employees use this (tools), but I'm not sure about the security. There are a lot of temporary employees in the kindergartens, and they do not necessarily have the same overview as the full time employees. A tool specifically targeted at temporary employees could be useful.

Do parents use forecasts for pollen and air quality?

NAAF has an app for pollen casts. I consider it useful to gather more information in one application.

Do you see any problems regarding logkeeping of medicines?

Is it only the parents who have access to the data? *Yes, but the idea is that other caregivers could use the application.* You should ask the Norwegian Data Protection Authority in order to be sure.

I recommend you checking out the application "MinAstma".

[3] Performed over the phone

Regarding ACT-test, is this something the child would benefit from showing to the doctor?

Some take ACT tests at home and bring them to the doctor, these results are useful for the consultation.

Will the doctor/nurse consulting the child have any benefit from having detailed logs of the use of medicine?

If it is a log showing the use over a period of time, it will be very useful. "The dream" is to have a complete record of what medicines were taken and the health state of the child. Sending such logs to the doctor ahead of an appointment will be useful. I personally believe this will become standard in the future, when the tools for easy log keeping have become widespread.

The children receive more stars if they are following the yellow or red treatment plan. Do you think children will exploit this?

Yes, I believe children may want to trick the system. Children are sneaky, and all children are different. It will be important to talk to parents in order to find a suitable reward system that will work over time.

[**Oral explanation of AsthmaBuddy**]

Do you have ideas for what else our system can do, such as measure the indoor climate?
The indoor climate is a combination of many factors, how are you planning to measure all the different factors? It is problematic to measure all the parameters in order to achieve a complete overview of the situation.

Children often care very much about their stuffed animals. They often play with them and carry them with them wherever they go. To parents it will be important to be able to wash the stuffed animals, since it get dirty over time. Parents to children suffering from asthma often wash stuffed animals even more often. I would advice having a teddy bear with some durability.

A.4 Asthma nurses

Two nurses working at St. Olavs Hospital, with expertise on asthma.

Date: 27th of March, 2014

Place: Trondheim

[Brief demonstration of AsthmAPP]

The colors (of the medicines) differs between different companies, which should be kept in mind. Children of 3-8 eight years usually remember their medication as their parents keep control and remember to give them their treatment. Youngsters are among the hardest, as they have to take care of themselves and often do not remember or do not want to take their medication. The application has to belong to parents (reminding parents that their children should give medicine to children).

We're developing a physical user interface which we'll try to use for motivational purposes among children. It contains light, sound and sensors that will communicate to children.

Not all children wants to take their medicine. They fight with parents because it is boring. 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.

Do you have any tools that are provided to parents for taking medicine, remembering their children's medication, or to motivate them?

Some companies have developed reward systems, but we don't give them to children.

Why is that?

These tools often come with commercials for other tools from the company, which causes us to not want to use them.

Do you have any suggestions for a reward system? It could be nice to use reward systems, as they often help the motivation for doing activities children normally don't want to perform. Do you have any past experiences with parents that have created reward systems for their children? We can't remember being told that parents have created award systems. It could be that parents don't tell us about it, or they simply don't do it. Taking an asthma medication is quickly over with, and children often realize that they get better by taking their medication.

We're thinking about displaying pollen forecast and information about air quality. Is this information something you notify parents about, with regards to paying attention every day?

Yes, we talk a lot about pollen, as it has a direct relation to asthma. We also mention air quality, especially when it is cold outside. Highly trafficated streets will also have worse air quality, and parents should be aware of this.

[**More detailed demonstration of AsthmAPP**] *Users can register a medicine after it has been taken, instead of going through a 2 minutes long sequence]*

The medicine log is really nice. To ask a user how they've been today is important, as they won't remember how they felt a few weeks ago.

Children don't need to wash their mouth after taking the blue medicine. This could create confusion if they should take it ahead of exercising.

If parents were to use the log, do you believe parents could cheat, in order to make it look better when they're at the doctors office?

A lot of parents are already writing a journal, and consider it useful.

How do you provide information about usage of medicines?

We hand out some flyers and talk to tgem. We demonstrate how they should use their medicines, in addition to distributing a treatment form. Parents also receive information specific to the medicine they are given.

When the parents receive the medications and the instruction of how to take the different medications, do they have problems with understanding and remembering how to use the different medications?

We always make sure to teach the parents and the children how to apply the medication correctly, however, they may forget it over time. If the parents do not remember how and when to give the children medications, it may have a negative effect on the treatment of the child's asthma.

When school teachers, grandparents or babysitters take care of the children, parents will have to relay the information about the medicine and the treatment. Have you experienced or been told of problems with this relay of information?

This is very individual. Some parents are very good at telling other caretakers about how to do the treatments. There is of course the risk that if a parent remembers the information incorrectly, the information relayed will be wrong, which may have effect on the treatment of the children. In order to make AsthmAPP or AsthmaBuddy be of help, it is important that the information stored within the app and the bear is correct and easily understandable. Having false information in the application would be negative for the user.

[**Demonstration of AsthmaBuddy, through a video**]

The bear looks like a nice tool for the youngest children. Here at our clinic we have a bear called “Asbjørn”. We use him to demonstrate to children and parents how you should take the different medications.

A.5 Parent 1

[WAIT FOR QUOTE CHECK]

Father of a 6 year old girl suffering from asthma.

Date: 1st of April, 2014

Place: Trondheim

Do you use the traffic light scheme? No, I use a treatment scheme instead, but the details are essentially the same as the traffic light scheme. Are you under the assumption that the child don't want to take the medicine? *Yes. If not, everything is fine, and the application will be obsolete* She had difficulties during the first couple of weeks. After a while, she realized that she became healthier by taking her medicine.

The reward system works by receiving stars after a treatment. It is up to the parents to choose a suitable reward (which implies that it does not necessarily need to be materialistic rewards)

It is annoying when medicines go empty, so we're keeping a journal. The different medicines has a set amount of doses. The application could give a warning/notification that a medicine will soon be empty.

[**Demonstrating AsthmaBuddy**]

RFID-tags attached to the medicine could be useful way of interacting with AsthmaBuddy. Does your application require that children have their own smartphone? *No. Parents should have this application installed on their own phone.* I think it is custom for children to have their own smartphone. By giving the application to children, it could give them a sense of responsibility.

Has it been a problem to get your child to take her medicine?

She was 4 years old when she first started. It was a problem then, as she was scared of taking her medicine. It took about a week before she understood that she needed it, and after that it has not been a problem.

Have you used reward systems to motivate her?

Yes. We promised her a trip to to the local water park if she took her medicine correctly the first week. Financially, it could be cumbersome if this ought to be a habit. You have to be careful when designing how the rewards, as there is a lot of differences across children.

We have previously spoken to a child psychologist. She recommended that the reward comes quickly after a treatment.

In my case, the fact that she breaths more easily after a treatment was rewarding enough, and it was worth more than the material reward she got.

Did you use an alarm on your phone or similar in order to remember when she should take her medicines?

No. Mainly, we just had to remember to give it to her before sending her to school and before she went to sleep. If she had an asthma attack, she's supposed to take the blue medicine, then wait for 5 minutes, before taking the orange medicine. The teddybear could help children to keep up with the time while they're waiting for the next doses.

Do you think the teddy bear could have told a story or similar to make those 5 minutes seem shorter?

My child is very understanding, but other children might become impatient. In that case, it could be useful to have something that could distract them.

Did you use a journal to keep up with the dates where your child switched treatment plans?

No, I have pretty good memory. I usually remember when she has been feeling ill.

When the child is in kindergarten/school. Have problems with not taking medicine occured?

The child does not need to take preventive medicine during the day. The child only need to take medicine if an asthma attack occurs. The child always carries extra equipment in the backpack to be prepared. 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 for them.

When you leave the child with relatives/other caretakers; do you spend much time explaining how to apply a treatment?

Yes, we always make sure that the relative/caretaker knows how the medicine is applied and what to do if an asthma attack occurs. We also tell the caretaker that the child is not allowed to take the medicine on its own, and they need to watch that the medicine is taken correctly.

AsthmaBuddy is very stationary. What do you think of the fact that it can't be moved?

If you have to set up the bear every time it is unplugged that may be a problem for some. For my child I don't think it would be a problem that the bear is not present at all times.

Do you have any other ideas for functionality or areas that AsthmaBuddy can be of use?

Pollen forecast is a useful tool, but it can often be too general. I have trees in my backyard, they may release pollen before other trees and the general pollen forecast may not pick that up.

Regarding dust sensors, what should they be used for? If the dust sensors may communicate with my robot vacuum cleaner, that could be a cool and helpful tool.

When your child has an asthma attack. Do you think you would take the time to use AsthmaBuddy as a help tool?

No. Taking the time to locate the bear and start the treatment would take to long time. It is more important to apply the medicine quickly. Although, I think that the functionality for registering the use of medicine afterwards would be a useful functionality.

How long time does it usually take to apply a treatment of preventive medicine?

It usually takes about 1-2 minutes.

A.6 Parent 2

[WAIT FOR QUOTE CHECK] **Mother of a 4.5 year old boy with a "weak" form of asthma.**

Date: 17th of March, 2014

Place: Trondheim and Bergen [4]

Do you have to "fight" with your children when applying the asthma medicine?

No, usually it is over quickly.

Is it hard to keep up with the treatment plan

I find it a bit difficult.

Have you used any tools in order to keep up with the plan?

No. I miss an app that can easily structure when and how much a medicine have been taken. I also find it difficult to meet up at a doctors appointment, and remember when I have switched the medicine plans.

How do you calm him down when he is stressed with regards to taking the medicine

Usually by either singing or counting while he's breathing.

[**Explanation of our reward system**] *Have you experimented with the use of rewards, either in the context of treamtents or similar?*

We have used bumperstickers on a sheet of paper while giving him toilet training. In my opinion, this was rewarding enough. I do belive that your reward system could be useful for other kids though. A target group consisting of children between 3-7 years old is a very differing group in terms of cognitive development, and you should keep this in mind.

Do you use demonstration to prove that the treatment is harmless?

Demonstration works pretty good, but is not necessary in the long run. The demonstration helped calming him down during the start phase.

What do you think of having a tangible user interface (a bear) that helps him taking his medicine?

[4] Performed over the phone

I'm positive to that. But I do not think it could replace the role of the parent, as someone has to watch that he actually takes his medicine.

What do you think of the requirement to have a shorter sequence for by need treatments? I do not really see the need, as it would slow the process down (finding it, starting it, etc.). On the other hand, children are often stressed out when they have an asthma attack, so having a teddybear could help during the process in order to calm them down.

Do you have any further comments? As a kindergarten teacher, I give several children help to take their medicine. An application that are able to help reminding kindergarten teachers when a specific child was to take their medicine would be much appreciated.

Also, teaching children about their disease could be given more of an effort.

All in all, I think a shared mobile application that can help other caregivers as well as parents can be very benefitiary, as I often have to explain how and when to give a medicine to others. I regard the alarms as the most important feature.

Appendix B

Draft for Interview Conducted after Usability Test

After each usability test, we asked some questions to the test users, in order to make sure we collected as much feedback as possible. The questions asked to adult users and child users differed, and are listed below.

Questions asked to adult test users

Do you have any thoughts or comments on how the test went?	
Where there any aspects of the test that you found difficult?	
Why was it difficult?	
Have you used any similar application(s) earlier?	
Any other comments/ideas/thoughts we should take notice of	

Questions asked to child test users

Which method did you prefer with or without AsthmaBuddy?	
Which method did you prefer? AsthmAPP or AsthmaBuddy?	
Do you want to play with AsthmAPP or AsthmaBuddy one more time?	

Appendix C

Scenario and tasks

The following is a translation from Norwegian of the scenario and tasks given to test users.

C.1 Test for adult users

You are the guardian of a child who has recently been diagnosed with asthma. In order to keep track of taking the medication on the right time in the right manner you have downloaded the application AsthmAPP. The system does not require you to register your name or any other personal information, since you do not want this information to be obtained by others. In order to make the best possible use of AsthmAPP, you must complete some tasks.

Task 0: Navigate to the adult partition of the application. you will be asked to register a PIN-code. Set this to “1111”.

Task 1: You shall now set up a medication plan according to the recommendation from the doctor. To start you must set up the plan for the “Healthy” health state. You can start by adding an Orange medicine to 1:37PM and a Purple medicine to 6:30PM. Thereafter, choose to follow the “Healthy” treatment plan.

Task 2: Your child already took a dosage of medication when you were at the doctor’s office. In order to start the logging, you must add the use of a Purple medicine to the log.

Task 3: In order to motivate your child to take his/her medicine, you wish to add a reward he/she may get when he/she has followed his/her treatment plan for some time. Navigate to the menu for adding rewards and add a reward named "Ticket to a football match". As a picture you may choose the picture of a football from the menu of standard icons. Set the number of stars to three stars. The reward shall not be repeated.

Task 4: Look for information about your child's progress towards getting the reward you just listed. Tell us what information you find.

Task 5: You wish to check the air quality readings for today, before your child leaves for football practice. Take a look in for the air quality readings and check if you should take preventive measures before going to practice.

You have now completed the test. We would like to ask you some questions regarding the use of the application.

Test leader asks questions from Appendix B.

C.2 Test for child users

Even though this test will require you to take a dose of medicine using the inhaler, this is not real medicine. This is a placebo inhaler which only contains compressed air, and it will not have any effect on your asthma. If you do not wish to continue the test, it is okay, and you do not have to continue if you do not want to.

Task 0: This is AsthmaBuddy. He has recently been diagnosed with asthma, and since he is a bear, he needs some help taking his medication. Can you say hi to him and ask if he is ready to complete his treatment.

Task 1: If help AsthmaBuddy completing his treatment, you may earn a reward. Can you take a look in the toy shop in AsthmAPP to take a look for rewards. How many stars do you need in order to buy the reward?

Task 2a: Now it's time to help AsthmaBuddy taking his medication. If you are ready to help him, you must clap him on the head. In order to help him, he will instruct you on how to do it.

Task 2b: Now it's your turn to take some medicine. Follow the instructions given by AsthmaBuddy. Maybe you will earn some stars for taking your medication.

[Disassemble the mask and medication before continuing. Then set an alarm using AsthmAPP]

Task 3: Soon an alarm will ring on AsthmAPP. You will need to follow the instructions given on the AsthmAPP. If you follow the instruction, you will be awarded with more stars.

Task 4: AsthmaBuddy keeps track of your stars even if you do not take the medicine together with him. By holding your card in front of his belly, AsthmaBuddy will tell you how many stars you have collected. Can you try if it is working?

Task 5: Now you have collected many stars. Check in the shop if you have earned enough stars to buy a reward. If you have earned enough, you may choose your reward and buy it.

C.3 Emergency plan

In order to make sure the children are not intimidated by the test lab, we tried to limit the amount of unfamiliar persons in the test room together with the children. We also brought coloring pencils and mobile games the children could play with if they were bored.

What will we do if the children do not want to play with AsthmaBuddy?
- We ask the parents if they want to finish a treatment in order to demonstrate for the children that it is not dangerous. If the parent does not want to demonstrate, we will demonstrate by ourselves. - We tell the children that they do not need to take the medicine, but they can give it to AsthmaBuddy twice instead. - If the children seem shy, we will leave the room leaving the child and parent alone in the room, and follow the test using cameras.

If power-/internet-cord is disconnected from AsthmaBuddy We tell the children that AsthmaBuddy is no super-hero, and that he needs power to function properly, like a television or a lamp. He is not damaged, and we just need to put the cords back in their place. In the meanwhile the children will have to wait.

If the children do not finish the test, and we have to abort If the children do not wish to finish the test, we give them a gift card for three stars. The gift card can be exchanged for a reward on their way out.

What will we do if the children start crying/become frustrated? We ask the parents if they can talk to the children and try to calm them down. In the meanwhile we leave the room and turn off the cameras recording.

Appendix D

AsthmaBuddy Manual

The following Appendix works as a user manual for AsthmaBuddy.

D.1 Introduction

The source code is specifically written to be run on a Raspberry Pi. As such, the program WILL NOT work on other computers.

D.1.1 Dependencies

We have used a couple of frameworks in order to make the development process easier. Downloading and placing them in the correct folder is important in order to compile and run the application.

Java As of September 2013, all Raspberry Pis are shipped with Java by default. If your version of Raspberry Pi was bought before this, Java can be downloaded and installed through this command:

```
sudo apt-get update && sudo apt-get install oracle-java7-jdk
```

Pi4J Pi4J can be downloaded from the following URL: `http://pi4j.com`. To install it, simply follow the installation guide at the same page [1] .

[1] Pi4J Installation guide - http://pi4j.com/install.html

Google Gson Google's Gson can be downloaded from the following URL: https://code.google.com/p/google-gson/downloads/list. Put it in the folder

`/home/pi/Downloads/`

The path to gson-2.2.4.jar should be:

`/home/pi/Downloads/google-gson-2.2.4/gson-2.2.4.jar`.

JLayer JLayer can be downloaded the following URL: http://www.javazoom.net/javalayer/javalayer.html. Put the file `jl1.0.1.jar` in the folder

`/home/pi/jlayer/JLayer1.0.1/`,

which should make the path to the file:

`/home/pi/jlayer/JLayer1.0.1/jl1.0.1.jar`.

Joda Time Joda Time can be downloaded from the following URL: http://www.joda.org/joda-time/. Put the file `joda-time-2.3.jar` in the folder

`/home/pi/Downloads/joda-time-2.3`,

which should make the path to the file:

`/home/pi/Downloads/joda-time-2.3/joda-time-2.3.jar`.

Node.js Node.js can be downloaded from the following URL: http://nodejs.org/. Finding the source code for our Node.js server is found in Section D.4

D.2 GPIO setup

In order for AsthmaBuddy to work properly, you need to use an RGB LED diode, which is connected to the Raspberry Pi through the GPIO pins. This section will elaborate on the details of this process.

Figure D.1 shows the RGB LED-diode we used to emit light signals. As you can see, there are four pins: Blue (1), Ground(2), Green(3) and Red(4). Pins 1,3 and 4 are connected to a 220 Ohm Resistor. Figure D.2 shows an overview of the available Gpio ports. Table D.1 shows how the pins are then wired to the Raspberry Pi.

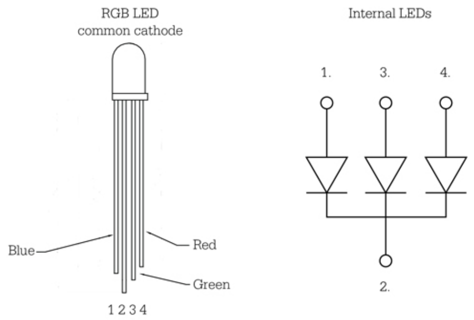


FIGURE D.1: RGB LED diagram. [a]

[a] Image source: courses.cs.purdue.edu - http://courses.cs.purdue.edu/cs25000:lab3

FIGURE D.2: Raspberry Pi GPIO. [a]

[a] Image source: elinux.org - http://elinux.org/File:GPIOs.png

LED Pin	Wired to GPIO port
Blue (1)	GPIO 17
Ground (2)	Ground
Green (3)	GPIO 18
Red (4)	GPIO 21/27 (Revision 1/Revision 2)

TABLE D.1: Wiring LED pins to GPIO

D.3 RFID reader

We used the Sparkfun ID-12LA RFID-reader. This was connected through the bottom USB port on the Raspberry Pi. The application needs the port name of the USB reader. This can be found by the following command:

```
ls /dev | grep USB
```

If the output is not equal to `/dev/ttyUSB0`, you can insert your name in the variable `comPort` in the file `src/com/blopp/pi/readers/RFIDReader.java`.

D.4 Source code

[TODO: Wait for clarification from Pieter, Ole and Elin] [TODO: Remember the node server]

D.5 Running AsthmaBuddy

D.5.1 Compiling

If the guide in D.1.1 was followed carefully enough, the program can be compiled by running:

```
./src/compile.sh
```

Alternatively, you may extract the exact command from `compile.sh`, and run it directly from the terminal window.

D.5.2 Running

The program can run by using the following script:

```
./src/v2.sh
```

Alternatively, you may extract the exact command from `v2.sh`, and run it directly from the terminal window.

Parameters Once the program is running, it checks for alarms stored for the user.

Once the message *"Did not find any alarms"* appears, you can type in parameters on this format: *CN*.

C is the color of the medicine that is to be taken. C $\in \{b = Blue, o = Orange, p = Purple\}$.

N is the interaction method you want to use. N $\in \{0, 1, 3, 4, 6, 9\}$. The interaction methods provided are summarized in Table D.2.

An example on a valid input is:

```
b1
```

N	Interaction method
0	*Clap your hands*
1	*Variation of those provided in this table*
3	*Hold AsthmaBuddy's hand to proceed*
4	*Hold your card against AsthmaBuddy's stomach*
6	*Give an high five*
9	*Press AsthmaBuddy's stomach*

Table D.2: Guide for interactions in AsthmaBuddy.

After this, you can press *Enter* every time the user has interacted with AsthmaBuddy, and the windows says *Ready for User Input*.

Appendix E

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. N $\in \{1, 3, 5\}$, depending on the current health state of the child.

E.1 AsthmaBuddy

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

E.1.1 Instructions

The following are the instructions a child receives, and where the manuscript reads "(Interaction)", one of the interactions in E.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.*

E.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*

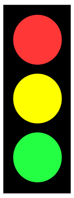
7. Hold kortet ditt foran magen min for å gå videre. *Hold your card in front of my belly in order to proceed*
8. Hold kortet ditt foran nesen min. *Hold your card in front of my nose*
9. Klapp hendene dine for å gå videre. *Clap your hands in order to proceed.*

E.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 F

Asthma Traffic Light System



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

Triggers: Respiratory infections

Other:________________

Need info: Call ER at 983-8637

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	

KMCWC ED Ver. Nov 4, 2009

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

Appendix G

Aaberg et. al.'s 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.

G.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.

G.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.

G.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.

G.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.

G.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.

G.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.

G.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 H

Constraints

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

H.1 The Health Register Act

Norway has specific laws for storing of medical information. The most significant law is "The Health Register Act[1]"[79]. 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 I. 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.

H.2 Measures for Anonymization

Pursuant to section 16 of the Health Register Act[79] all information that may identify a person, must be encrypted, i.e. it should be impossible to find which person a specific

[1] Lov om helseregistre og behandling av helseopplysninger

[2] Regional Committees for Medical and Health Research Ethics - https://helseforskning.etikkom.no/

record corresponds to by looking at a database dump. We chose to rename medicines mentioned in the application, in order to obscure their connection to their real-life counterparts.

Appendix I

Consent Form

Included below is the decision made by REK Midt-Norge regarding our project.

TODOTODOTODOTODO

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 asthma- og allergiforbund - fakta om astma. URL http://www.naaf.no/astma/fakta_om_astma/.

[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] 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.

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

[11] 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.

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

[13] Medietilsynet. Foreldre om småbarns mediebruk. 2014.

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

[15] 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.

[16] 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.

[17] Philip R Cohen and David R McGee. Tangible multimodal interfaces for safety-critical applications. *Communications of the ACM*, 47(1):41–46, 2004.

[18] 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.

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

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

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

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

[23] 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.

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

[25] 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.

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

[27] 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.

[28] 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/.

[29] 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.

[30] 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.

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

[32] 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.

[33] 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.

[34] 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.

[35] 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.

[36] 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.

[37] 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.

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

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

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

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

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

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

[44] 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.

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

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

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

[48] 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.

[49] 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.

[50] 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.

[51] 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.

[52] 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.

[53] 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.

[54] 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.

[55] 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.

[56] 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.

[57] 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.

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

[59] 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.

[60] 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.

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

[62] 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.

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

[64] 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.

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

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

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

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

[69] 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.

[70] 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.

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

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

[73] Glaxo smith kline - aerochamber plus. URL http://hcp.gsk.co.uk/content/dam/Health/en_GB/HCP_Home/content/aerochamber/How%20to%20use%20child%20facemask.pdf.

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

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

[76] Hanne Linander. Utvikling av konsept for forbedret opplevelse av behandling av astma. 2013.

[77] Tori Klakegg Maehlum. Dipp - utvikling av konsept for kt brukeraksept innen medisinsk behandling av barn med luftveisinfeksjoner, 2013.

[78] Walter Mischel, Ebbe B Ebbesen, and Antonette Raskoff Zeiss. Cognitive and attentional mechanisms in delay of gratification. *Journal of personality and social psychology*, 21(2):204, 1972.

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