

**NTNU - NORWEGIAN UNIVERSITY OF SCIENCE AND
TECHNOLOGY**

Using Mobile Technology to Treat Asthmatic Children

by

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

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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
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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*

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Abbreviations

API	Application Programming Interface
BLOPP	Barns LegemiddelOPPlevelser
CAPP	Child APPlication made by Aaberg et. al.
GAPP	Guardian APPlication made by Aaberg et. al.
GUI	Graphical User Interface
KAPP	Karotz APPlication made by Aaberg et. al.
NAAF	Norges Astma- og Allergi-Forbund
MMO	Massive Multiplayer Online game
NTNU	Norwegian University of Science and Technology
REK	Regional Committee for Medical and Health Research Ethics
RFID	Radio Frequency IDentification
TUI	Tangible User Interface

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 parents¹, 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?

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

²Center for Disease Control : HSRV - <http://www.cdc.gov/rsv/>

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

1.4 Research Method

The first step of our research was to do find recent trends in our research area. We did a literature study that gave us some principles to start with.

Based on the literature study, we started developing prototypes. The Android application Aaberg et. al. built was modified, introducing gamification elements to AsthmAPP. Starting from scratch, we created a tangible user interface by developing an application running on a Raspberry Pi, and placing the Raspberry Pi inside a teddy bear. This tangible user interface was given the name AsthmaBuddy.

After the first prototypes were developed, we interviewed domain experts, by using a “semi-structured” interviewing-approach. The goal for the interviews was to receive feedback on the prototypes and it’s reward system and to explore new functionality we could incorporate in AsthmaBuddy and AsthmAPP. By interviewing domain experts we were able to receive feedback that we could not have obtained by continuous user testing on children, as children may be nervous or excited and have difficulties in explaining their thoughts and opinions.

Our interview subjects consisted of parents of two different children with asthma, a person 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 a industrial designer previously involved in the BLOPP project.

After finishing the interviews we did a round of user tests of AsthmaBuddy on fellow students, to test the “Token+Constraint” approach (see Section 5.4.1) of AsthmaBuddy. As the students were considered inexperienced with regards to asthma, these user tests were also able to uncover whether or not AsthmaBuddy was able to explain the treatment process in an easily understandable manner. Based on the feedback gathered from the domain experts and the user tests, we did an additional development cycle of AsthmaBuddy and AsthmAPP.

After the last development cycle, we tested the prototypes on N children *INSERT REFERENCE*. The purpose of the user tests was to hear children’s opinion on the prototypes, discover difficulties when they interacted with AsthmaBuddy, and to explore whether or not the gamification system worked in the short run.

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 4 will give the reader an introduction to gamification, with discussion around some of the principles that are being used. Chapter 5 discusses the origins and use of tangible interfaces. Chapter 6 gives an introduction to the principles behind usability. Though it is not a primary part of our thesis, we consider it important to keep in mind, especially when designing applications for children. Chapter 7 provides a product description of AsthmAPP, our prototype for gamifying children's experience with a smartphone, while Chapter 8 provides a description of AsthmaBuddy, our tangible interface. Chapter 9 provides the results we have discovered during our research. Chapter 10 provides the final conclusions of our thesis, with discussions around the results given in Chapter 9.

Chapter 2

Background

This chapter will give a brief introduction to the history behind the BLOPP project (Section 2.1). Section 2.2 will 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 society¹. 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 seconds².

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

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

²There 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 NTNU³. 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 CAPP⁴. As

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

⁴All 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 received 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 acquired. 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.

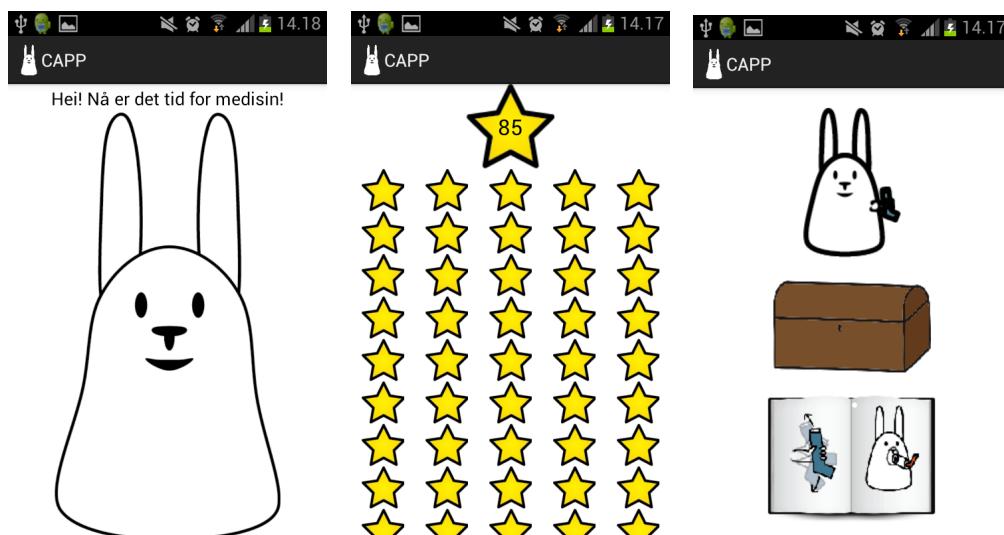


FIGURE 2.3: Starting a treatment

FIGURE 2.4: Inside the treasure chest

FIGURE 2.5:
CAPP main menu

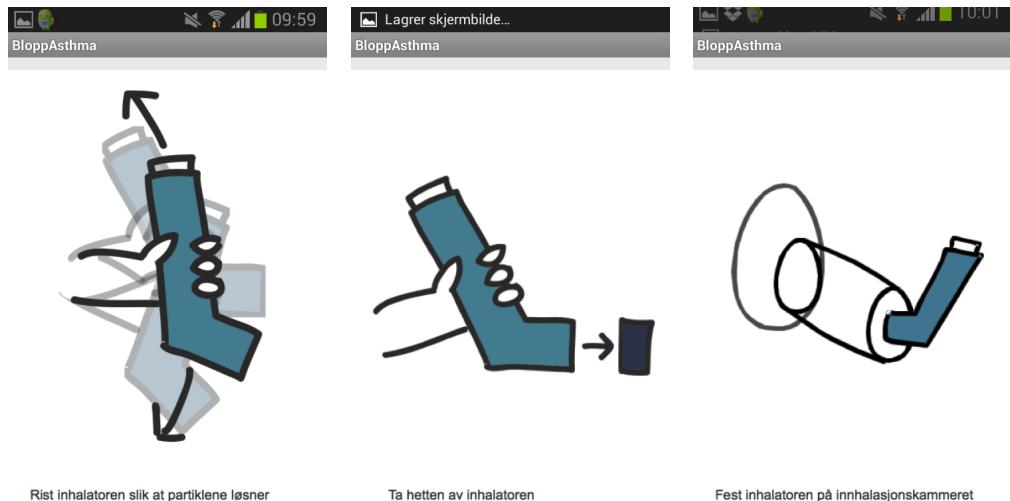


FIGURE 2.6: Instructions 1

FIGURE 2.7: Instructions 2

FIGURE 2.8: Instructions 3

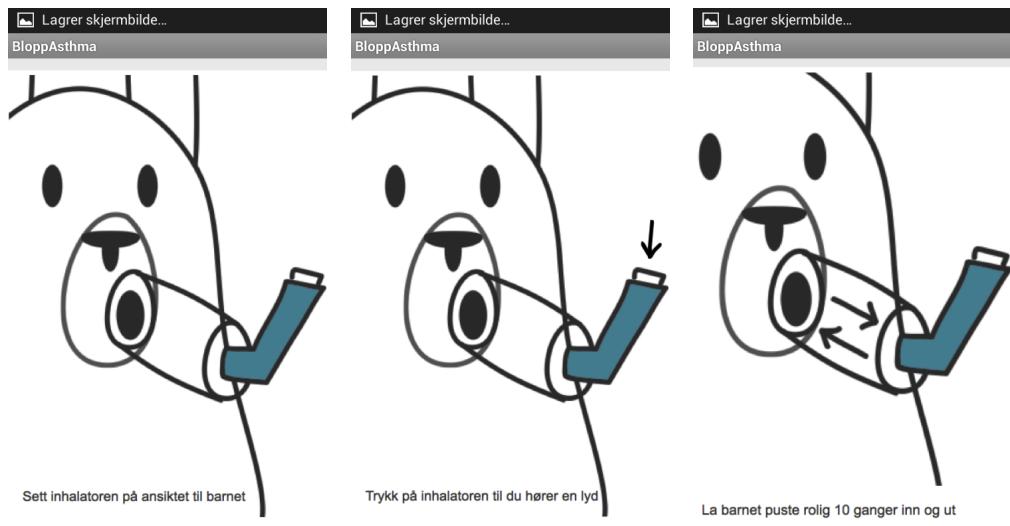


FIGURE 2.9: Instructions 4

FIGURE 2.10: Instructions 5

FIGURE 2.11: Instructions 6

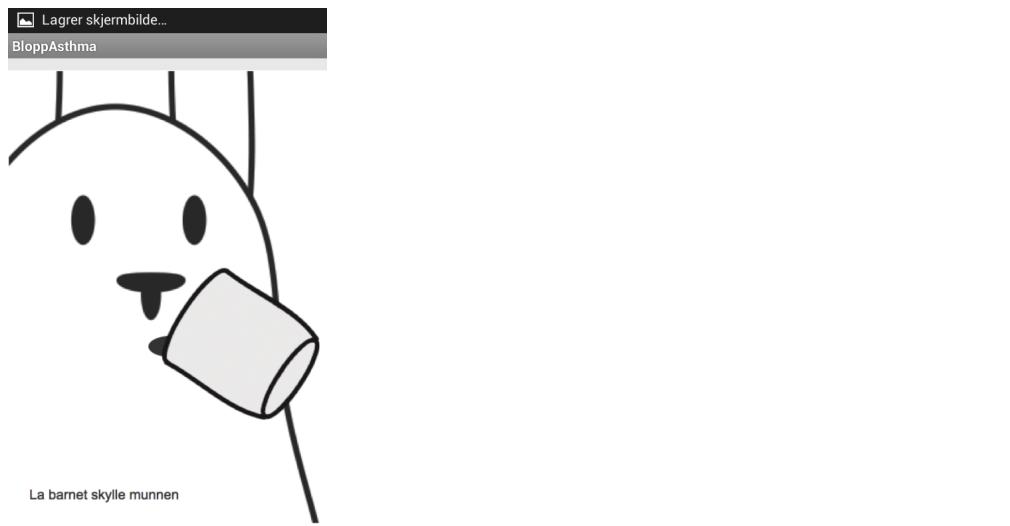


FIGURE 2.12: Instructions 7

2.3.2 KAPP

KAPP is the TUI-application targeted at children. The application runs on a Karotz⁵, 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 G.

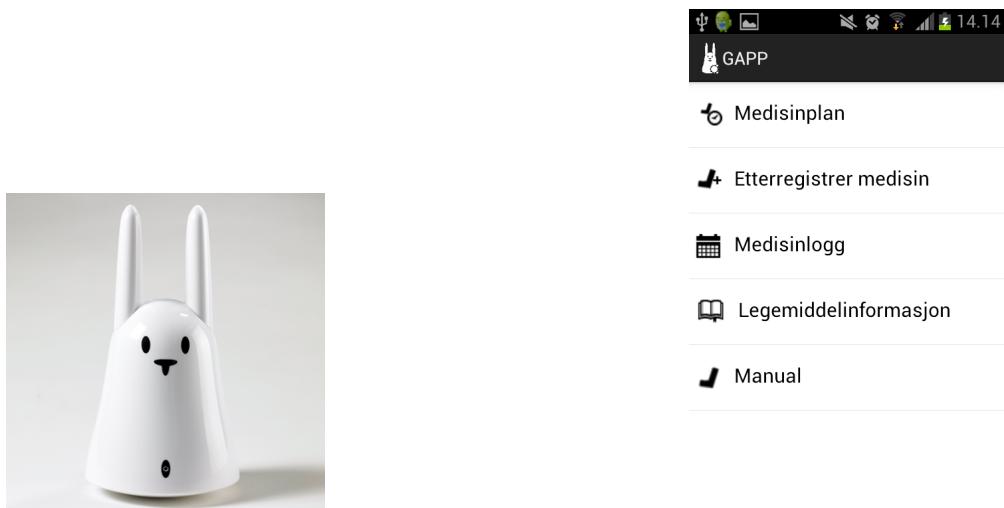


FIGURE 2.13:
Karotz. *Image source:*
<http://karotz.com>

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 purpose 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](http://karotz.com) - 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 7.9 shows a screen shot of this functionality. A red circle marks the current day. A child's health state is displayed by the Green/Yellow/Red bar at the top of each day. In the bottom left corner, it is possible to show how much medicine was taken on a given day. In the bottom right corner, Aaberg et. al. intended to show the pollen distribution for a given day. However, the pollen distribution data is only available during spring and summer, and thus Aaberg et. al created an artificial pollen distribution for demonstration purposes.

Manual The 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

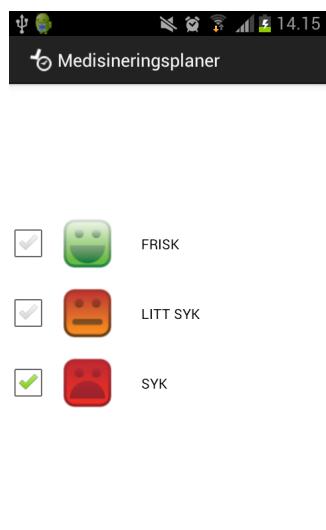


FIGURE 2.16: View plans



FIGURE 2.17: Information 1



FIGURE 2.18: Information 2

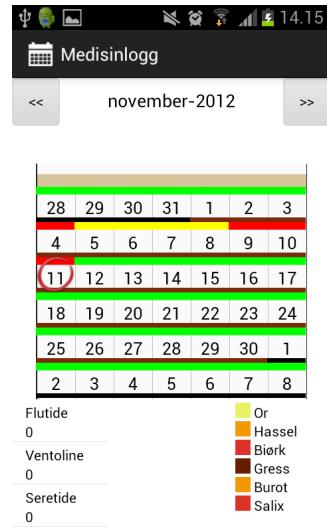


FIGURE 2.19: Medicine log

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 H (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 feasibility 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

According to the Norwegian Media Authority's⁶ 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.

⁶Norwegian 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.

⁷Google Play - <http://play.google.com>

⁸Apple 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

Sisom⁹ 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 communication had a better quality, and the child participated more during the consultation^[16].

2.5.3 Meassuring Blood Pressure

iHealth¹⁰, Withings¹¹ 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 measurements 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/) - <http://www.communicaretools.org/sisom/>

¹⁰[iHealth](http://www.ihealthlabs.com/wireless-blood-pressure-monitor-feature_32.htm) - http://www.ihealthlabs.com/wireless-blood-pressure-monitor-feature_32.htm

¹¹[Withings](http://www.withings.com/en/bloodpressuremonitor/features) - <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 measuring 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

¹²Cellnovo - <http://www.cellnovo.com/>

¹³Røykeslutt - <https://play.google.com/store/apps/details?id=no.lhl.roykeslutt>

¹⁴Wii 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 fundamental for our project. In order to find reliable research, we used Google Scholar ¹ and the IEEE Xplore Digital Library ².

Early on in the project, we discovered two key search phrases; “Gamification” and “Tangible User Interfaces”, that 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 discover if an article was relevant or not, 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 find new sources of potential information. Once we decided we had a decent overview around a specific topic, we narrowed our search down with more keywords.

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 and comments on the respective article. If the critiques were relatively negative, 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](https://scholar.google.com) - scholar.google.com

²[IEEE Xplore Digital Library](http://ieeexplore.ieee.org/) - 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 intimidated 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.

[TODO: NEED QUOTES AND MORE]

3.3 Usability testing

3.3.1 Introduction to Usability

[Should we have a small section here to discuss basic usability, and what is has to do with our system?]

3.3.2 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 improvement and design ideas for the product.

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.

3.3.3 Test Method

The execution of the usability tests were based on the theory described in Section 6.2 and Section 6.3.

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

The participants were given an Android mobile device to perform tasks on. The different tasks were given one by one. The participants were introduced to the “think-aloud”-method, and will be 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 or in order to facilitate 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 can 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[18].

- 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) - Enhancements to the system. When a participant states that “it would be nice to have this”.

3.3.4 Scenario and Tasks Given to the Users

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

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

3.4 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* .

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

Huotari and Hamari[20] 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[21] 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 places¹. Apple developed a Game Center for iOS in 2010, giving every iPhone/iPod and iPad

¹Foursquare - 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 singularly 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[22]. Their website defines serious games as:

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

This definition has been criticised for being too narrow, and for not including any reason as to why businesses should care. An anonymous author⁷ 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[23], Swedish firefighters have used serious games for training[24] 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[25]. 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) - <http://support.apple.com/kb/HT4314>

³[Cookieclicker](http://orteil.dashnet.org/cookieclicker/) - <http://orteil.dashnet.org/cookieclicker/>

⁴[Farmville](http://www.farmville.com) - www.farmville.com

⁵[Xbox](http://xbox.com) - <http://xbox.com>

⁶[Playstation](http://playstation.com) - <http://playstation.com>

⁷The 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 protease⁸ [26].

Serious games and gamification have many similarities; whereas serious games are mainly targeted towards making education or learning more fun, gamification is used in a number of different ways.

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[27]. Goal setting challenges the users to meet the mark that is set for them, and is known to be an effective motivator[28].

Bogost goes as far as naming gamification as “marketing bullshit”, used as a way of monetizing bad business[29]⁹.

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

“After three hours of consecutive online play, gamers receive 50 percent fewer rewards (and half the fiero¹⁰) for accomplishing the same amount of work.”[31]

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

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

In order to achieve a meaningful use of gamification Nicholson[34] suggests using a user-centered design approach[35] when developing systems with elements of gamification. Since AsthmaBuddy is a computer supported learning system[36] 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.

⁸Mason Pfizer Monkey Virus - http://microbewiki.kenyon.edu/index.php/Mason_pfizer_monkey_virus

⁹While this is not a scientific publication, we found it interesting and relevant to the discussion

¹⁰Fiero is an Italian term for personal triumph[30]

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

4.4.1.1 Achievers

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

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"[37].

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

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

This implies that socialisers play games in order to connect with new people or hang out with their friends. The youngest children in our target group will probably not 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”[37].

“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 exemplify 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 Acheivements 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

¹¹Xbox - www.xbox.com

¹²Playstation - 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 receive 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 Runkeeper¹³, 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.

¹³Runkeeper - <http://runkeeper.com/>

4.4.2.6 Experience Points

Experience points is an indicator of how much experience the player has gained 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 perceived 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 activities 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 static 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 by 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 Combining Game Mechanisms in AsthmAPP

Mechanism	Included in AsthmAPP	Rationale
Avatar systems	No	We did not have time to implement this during our thesis, but we do believe this could be a good feature if it was implemented in a 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 be 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

[This table should probably go somewhere else]

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 used to distract patients during certain procedures such as dental work, for example.” [38]

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[34].

As McGonigal’s studies show, the effect of gamification tends to wither down after a longer period of time[31]. 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 an 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” [39]. They established the term “Tangible User Interface” (TUI) as a way to move beyond the dominant model of Graphical User Interfaces (GUI). While GUIs show information (bits) in the form of pixels mapped to a display, Ishii meant 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*[39].

“Urp”[40] is an example of an first-generation TUI. Urp is a workbench architects used to determine shadow patterns for models of buildings. By moving a “clock tool” the lighting on the workbench would move according to what time of day was chosen. 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”[41] is an example of a second-generation TUI. Sandscape uses clay, sand, cameras, digital software and lighting to give an overview of a Geographical Information System(GIS). The users could interact with the clay, forming dunes or dig holes and the software would calculate landscape analysis based on the interaction. Sandscape is

dynamical user interface since it may change to several different non-predefined states, also named a “continuous TUI”.

In 2008, Xie et. al. performed a study on how children reacted using different interfaces in order to solve a jigsaw puzzle[42]. The different interfaces were a physical interface (i.e. a standard jigsaw puzzle), a TUI and a GUI. Their 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[43]. Children could then rotate the cube in order to get the correct answer pointing upwards, like a dice. They concluded that the TUI gave children a different set of affordances that prompted a great initial engagement[43].

Information Sharing Hinckley et. al. created a tangible user interface for neurosurgical visualisation[44]. Their tool proved helpful for neurosurgeons to provide physical familiar tools that could display information digitally. Their tool showed possibilities for creating and view cutting planes and planning neurosurgery. Their tool made it easier for them to display 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[45]. 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[46]. 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[47]. Stanton et. al. created a “magic carpet”, giving children possibility to influence a story in the classroom[48].

Social Context The “Marble Answering Machine” is an invention by Durrell Bishop, dating back to 1992[49]. The interface allows users to drop marbles into a play-back indent on the system, which plays a recorded message. 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[50]. 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 pressure, 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 Autistic Spectrum Condition (ASC), when playing with a TUI called Topobo ² [51]. The study compared the level of social interaction when playing with Topobo, compared to playing with LEGO. Their findings showed that ACS children were playing more cooperatively with the TUI than LEGO.

¹Twitter application for Karotz - <http://tiny.cc/karotztwitter>

²Topobo - <http://www.topobo.com/>

Additionally, children with traditional development were able to play more cooperative, solitary and parallel 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[52]:

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[52].

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 supports 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.

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

5.4.3 Constructive Assemblies

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

While there 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?	OC5a: What is the nature of the interaction for each sub task? (Continuous vs Discrete vs Assembly)	FC7: What are the relations between the objects and the actions?
BO2: What are the human tasks?	OC5b: What are the electromechanical and physical ergonomic constraints for this task?	FC8: What is the task order when using the artefact?
BO3: What would the artefact represent and control?		
BO4: What are the conventions?	OC6: Does the sub-task need any relational interaction?	

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 phycical 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 8.3.3.

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 fundamental 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

Usability

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

6.1 What is Usability?

There are many ways to describe the term usability.

The International Organization for Standardization(ISO) uses the following definition[56]:

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

The same document defines the term “context of use” as:

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

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

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

4. Did the user find the use satisfactory?

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

Schneiderman stated eight golden rules in order to achieve a good usability of computer systems[57]. In his rules he mentions consistency, informative feedback, reducing short term memory load and permitting easy reversal of actions. These eight golden rules have since their publication become a central part of usability engineering.

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

6.2 How to Test Usability

There are many approaches to creating a good user experience. Having knowledge of expert opinions is always a good idea, and using user-centered design techniques is also a good choice. According to Rubin's handbook of usability testing[60], developers should receive feedback from users by users tests at different stages of development. According to Rubin, having a user-centered approach will help the developers to address the weakest parts of their system, and give feedback on design decisions.

A user-centered design may be done in many different ways and at different stages of the product life cycle[61], as shown in Table 6.1:

Method	Purpose	Phase of the project life-cycle
Background interviews and questionnaires	To collect data and to understand the user better	When starting the project.
Focus groups	Discover design issues and receive feedback	At an early stage.
On-site observation	To both collect information of the context the system will be used in and find primary problems the users may have.	At an early stage.
Role playing / simulations	To gain a broader understanding of what the user expects from the system.	Early to mid stage of the project.
Automated evaluation	Gives feedback on deviations from standards or best practices. This method excludes actual users but is based on well tested principles	Mid to end of the project.
Usability testing	To measure the usability of the system and provide feedback on very specific elements that are poorly designed.	Abras[61] says it should be at the end of the project while others[62] think it should be done in iterations throughout the project.
Interviews and questionnaires	Gives a qualitative measurement of how good or bad the system. is	End of the project.

TABLE 6.1: Methods of user-centered feedback

Usability Testing The purpose of usability testing is to increase the usability of a system. At the same time, performing these usability tests may save the developers some time and reduce the cost of the project by correcting errors and poor design at an early stage[18].

The usability testing can be performed in different ways[62]. At the early stages of the project, low-fidelity prototypes are a good option since they will provide feedback and take proportionally little time to make, making it easier to have more iterations of testing. The different testing methods include a potential user of the system performing

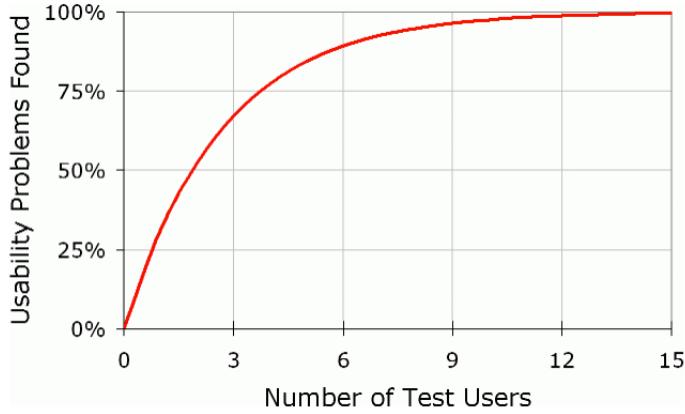


FIGURE 6.1: Number of users needed to find percentage of errors according to J. Nielsen[1]

tasks to provide real data. Observing and recording each usability test may help the developers to analyze the system, and correct the flaws[18].

Before starting the usability tests, the developers should determine goals for what they want to know about the system[63]. This will ensure that the purpose of the test is fulfilled. The developers should then plan tasks according to the desired results. These tasks should allow the user to explore the system, or the parts the developers wish to test, giving the test person some time to perform each task, in order not to stress the test person.

After the planning stage, the test should be run on a number of different test persons. J. Nielsen[1] proved that as the number of test users increases, the number of undetected errors decrease, cf Figure 6.1.

Nielsen states that after five user tests, 85% of the errors were found[1]. Molich states that six test persons is the ultimate number[64]. Faulkner states that while six test persons *may* find 85 % of the errors, they may also find considerably less[65]. In Faulkner's research, a number of five test users found between 55 % and 100 % of the errors, while 20 test persons found between 95 % and 100 % of the errors.

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

Before the test persons arrive, a test leader should be chosen, to guide the test persons through the process. The test leader should be in charge of testing and act as an

interviewer to help the participant to “think-aloud”[66]. The test leader should answer questions from the participants, but be careful not to give away information that may affect the results of the test.

After the tasks are done, it is necessary to gather loose ends and obtain answers to all the questions that may remain unanswered. A system usability scale (SUS)[67] may be a good way to grade the usability of the system together with the observations made during the test. The SUS scale will reflect on how satisfying the usability is in the eyes of the users. Bangor et. al.[68] have made a scale based on the SUS-forms from different system usability tests, in order to make it possible to compare the mean score of a system with what is an acceptable level of usability. In our testing, we made use of a Norwegian version, developed by Svanæs¹, which was answered by the test users or the parent of the test user.

6.3 How to Test Usability on Children and Toddlers

While usability testing on children and toddlers has the same basic approach as testing on adults, there are many more precautions to be taken. Hanna et. al.[69] lays out some of these precautions. They recommend not using children that are skilled with computers since they may find the tasks too easy and will not produce useful data. Since children these days have a higher skill with computers thanks to the invasion of tablets and smart phones[70], this may not be too great a concern.

Since our application is targeted at children with asthma, we wanted to test the system on children suffering from asthma in addition to children from the same age group not suffering from asthma. These children were most likely have a different approach to the system and might give different feedback.

Hanna et. al. also point out changes that should be made to the testing environment as mentioned in 6.2. They recommend making the testing environment more suitable for children by placing colourful posters on the walls. Children of young age may be afraid of “the doctor’s office” and we needed to make adjustments to avoid frightening the children upon their arrival at the test lab.

As mentioned by Donker and Markopoulos[71] talk-aloud is very useful technique when doing usability testing with children. Talk-aloud is a technique where the children talk about what they are doing instead of what they are thinking.

¹Norwegian SUS scheme - <http://www.brukskvalitet.no/wp-content/uploads/2010/01/SUS-norsk.pdf>

Zaman et. al. proposes a way to measure the likeability of tangible interaction with preschoolers[72]. They based their research on work done by Read, MacFarlane and Casey[73], who found that traditional measures for likeability, for instance a smileyometer, proved to give false results. In fact, Read et. al. found that more than 80% of the children being tested gave a “Brilliant” score. Zaman et. al. implies that children are actually lying when giving these scores, which is understandable from a questionnaire perspective. Instead of using scales as a measure of what is likeable or not, they propose a model where they compare different interaction systems against each other. 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.

6.4 Usability Testing on Mobile Devices

We performed our usability tests at a usability testing lab at NSEP²www.ntnu.no/nsep. The application’s main environment for use will be at the user’s home, which may be noisier and more hectic than our testing lab. Kaikkonen et. al. state that the similarity between testing environment and place of use is not too important, the test user will still be able to complete the tasks and find the same number of errors [74]. This claim is supported by Beck et. al. who discovered that the test persons found more usability problems when sitting down, compared to when walking on the street[75].

Schusterich et. al.[76] published a guide on how to build the perfect infrastructure for usability testing on mobile devices, in 2007. They describe how generic infrastructure issues, mobile device-specific issues and usability study context issues should be taken into consideration. Schusterich et. al. recommends having a number of cameras recording from different angles in order to capture unbiased interaction patterns of the mobile device.

6.4.1 Emulator vs. Device

When developing for mobile devices such as Android, it is possible to run an emulator on a pc, instead of running the application on an Android device. The emulator emulates the use of a mobile device on screen. Input must be given by mouse-clicks on buttons/screen elements. The Android emulator emulates use of system resources corresponding to a given Android device, in order to not to act faster or more slowly than a real device.

²NSEP Usability Lab

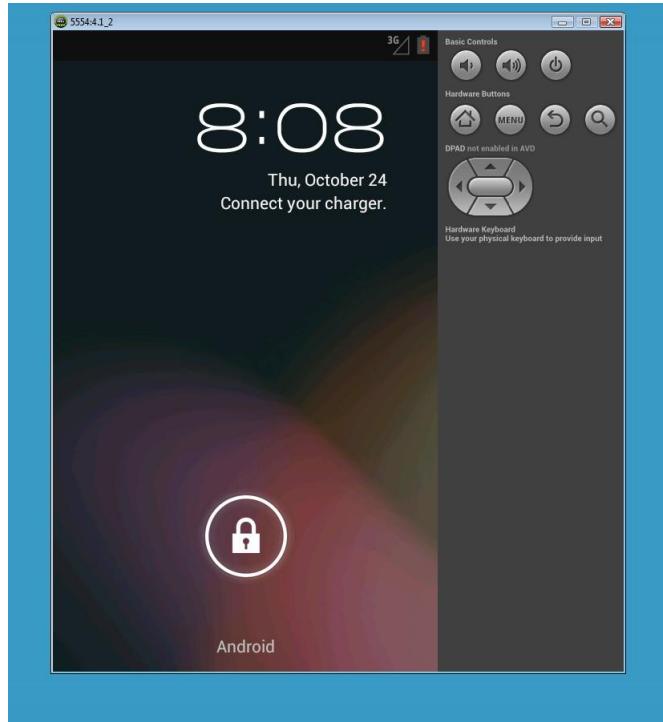


FIGURE 6.2: The Android Emulator running an emulation of Android 4.1

While this may be true in theory, it is not always true in practice. The emulator is often much slower than an actual device.

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

Using a real device has the benefit of being an actual device, and may lead to a more realistic interaction pattern when using the application. While a number of screen recorders for Android devices exist, these require that the device is rooted³, which was not an option for us. The use of a real device also allows the use of gestures, which is a benefit in contrast to the emulator which can only simulate swiping.

Beitol and Cybis[77] compared doing usability testing on a tripod-mounted device to an emulator and using a device in the field. They found that many users found the tripod-mounted device difficult and unnatural to operate. The users found 80% of the usability issues on the emulator, but Beitol and Cybis points out that use of an emulator may depend on the similarity between the emulator and the device.

³Android Rooting - http://en.wikipedia.org/wiki/Android_rooting

6.5 Summary

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

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

Based on the research we read and the fact that NTNU has an excellent usability test lab at NSEP ⁴ we decided to do usability testing indoors, with smartphone devices.

⁴NSEP Usability lab - <http://www.ntnu.no/nsep/brukbarhetslaboratorium>

Chapter 7

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.

7.1 Architecture and Technology

7.1.1 System Architecture

Figure 7.1 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-objects¹.

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.

¹JavaScript Object Notation

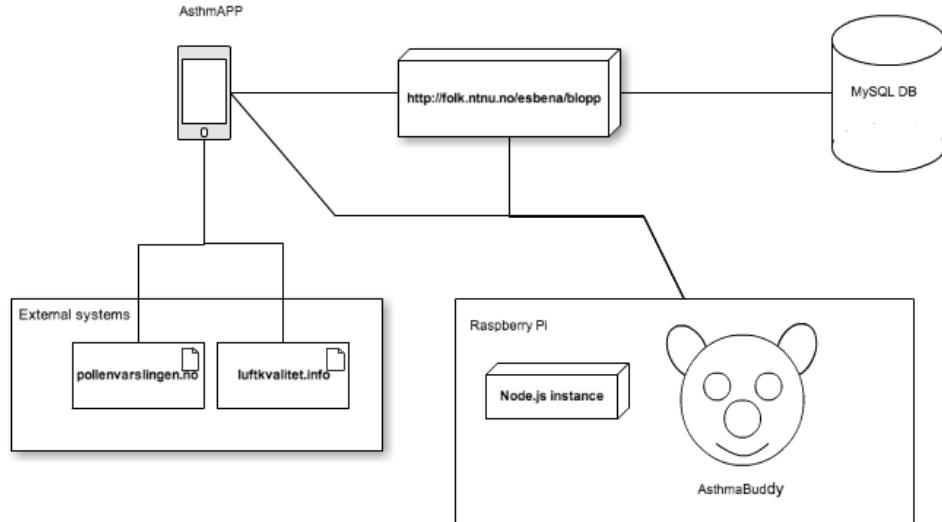


FIGURE 7.1: System Architecture

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.

7.1.2 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 Framework². 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-library³ to deserialize these objects into Java objects.

JodaTime Java's default implementation of time is cumbersome to work with, with a lot of its functionality deprecated. JodaTime⁴ is an open source project that seeks to handle time in a proper manner on the Java platform.

²Android Application Framework - <http://developer.android.com/develop/index.html>

³Google Gson - <https://code.google.com/p/google-gson/>

⁴JodaTime - <http://www.joda.org/joda-time/>

7.2 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[78]. In chapter 6 we described usability and general terms every designer should consider. We have especially taken Shneidermann's eight golden rules into consideration when designing[57] AsthmAPP. 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 preferable one.

7.3 Child partition

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

7.3.1 Treatment

Figure 2.3 shows a screenshot for the application when the child starts his/her treatment. This sequence may be started by one 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 Ystmark⁵.

⁵ A classmate of ours at NTNU

7.3.2 Showing rewards

Figure 2.4 shows a screenshot for the application when the child wants to review how many stars he/she has received, based on the amount of treatments completed. We have made two design decisions for our reward system. 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.

7.3.3 Shop

In the shop, children are allowed to select rewards given by their parent(s). Figure 7.3 and 7.4 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.

7.3.4 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.

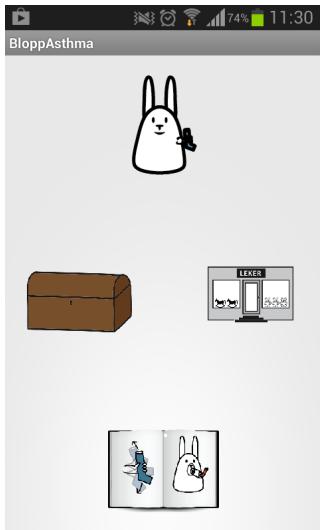


FIGURE 7.2: Main menu of child participation

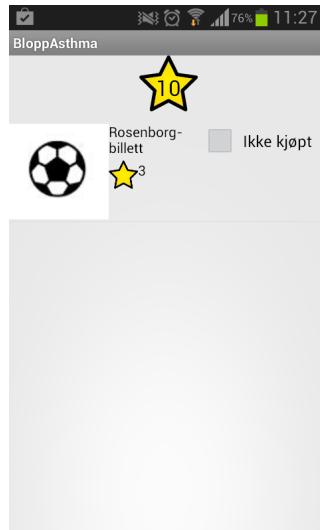


FIGURE 7.3: Possible rewards a child can choose from

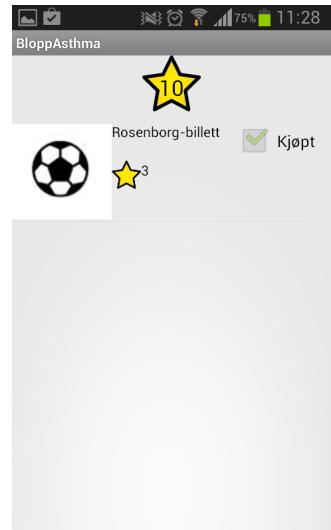


FIGURE 7.4: A child has bought the reward

7.4 Parent Partition

7.4.1 Menu

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

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.

7.4.2 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 7.6 and 7.7 shows the view in which one may

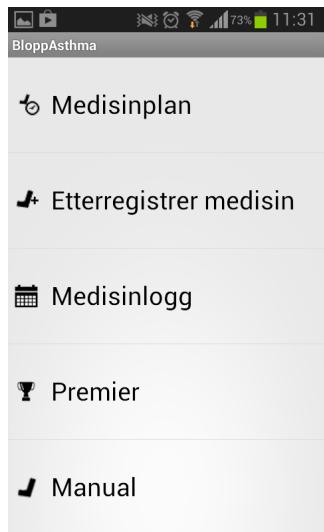


FIGURE 7.5: Main menu of partent partition

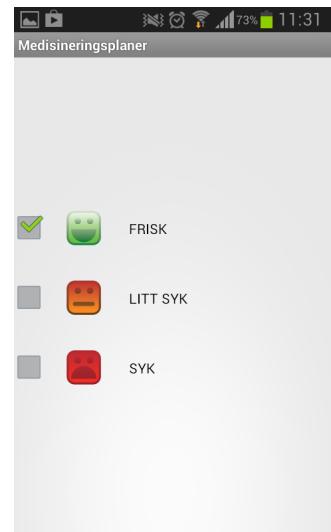


FIGURE 7.6: Available medicine plans

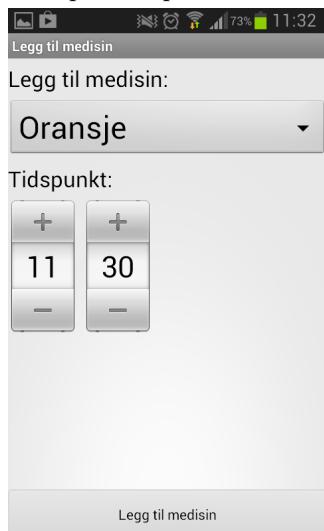


FIGURE 7.7: Adding a medicine to a plan



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



FIGURE 7.9: Medicine log

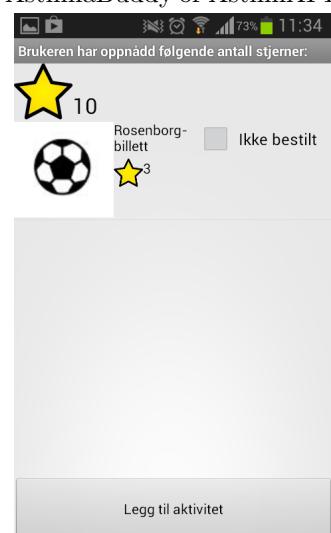


FIGURE 7.10: Overview of rewards a child can get

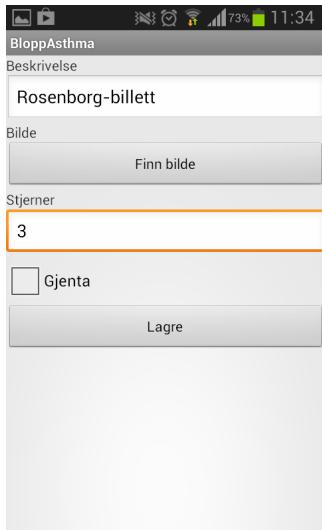


FIGURE 7.11: Creating a reward. Parents can either choose a reward from our standard image set, or they can take one from their gallery

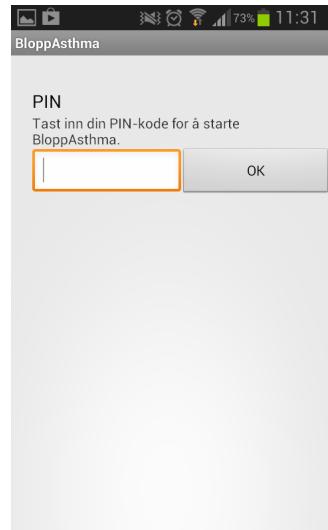


FIGURE 7.12: In order to access the parent partition users have to complete a PIN-challenge

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.

7.4.3 Register Treatment

If a child need to take their medicine, but do not have the possiblity 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 7.8 shows how this is solved in AsthmAPP.

7.4.4 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 7.9 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 Trondheim⁶. The right panel shows the pollen distribution of the 6 most common pollen types⁷. 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.

7.4.5 Manual

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

7.4.6 Reward

Figure 7.10 shows the list of possible rewards a child 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 7.11 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.

7.5 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.

⁶Measured by NILU - <http://luftkvalitet.info/>

⁷Measured by NAAF - <http://www.pollenvarslingen.no/>

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.

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 highly individual. Preschoolers would need rewards almost every day, while 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 8

AsthmaBuddy

8.1 Background

As mentioned in Chapter 2; in 2012, we did a similar project using Karotz¹ 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[79], 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[80], 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

¹Karotz - 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.

8.2 Technology

8.2.1 Raspberry Pi - Specifications Overview

The Raspberry Pi was initially intended to teach British school children about computer programming[81]. Since its release, it took an unexpected turn when lots of computer enthusiasts bought the product to do their own mini projects for a cheap price.

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

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

TABLE 8.1: Raspberry Pi specifications

RASPBERRY PI MODEL B

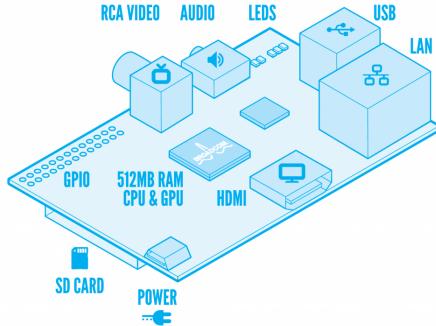


FIGURE 8.1: Raspberry Pi Model B architecture. *Image source:* <http://raspberrypi.org/faqs>

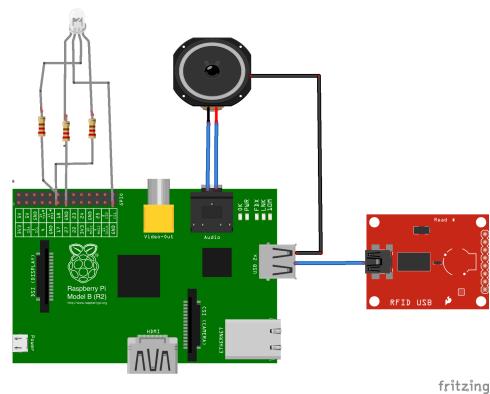


FIGURE 8.2: Digital schematic of the components

8.2.2 Additional Components

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

RFID Reader In order to interact with AsthmaBuddy, children can register RFID-tags against AsthmaBuddy's stomach. The RFID-reader we used was a Sparkfun ID-12LA². 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 8.5).

Figure 8.2 shows a digital overview of AsthmaBuddy. The green figure to the left is our Raspberry Pi. While it is also connected to a power supply and an internet cable, we chose not to include these in our figure. The red figure to the right is the RFID reader. It is connected to the Raspberry Pi through an USB cable. The black figure on top

²Sparkfun 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.

8.2.3 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 noises³. We believe it could have been a cool feature that would help establishing a relationship between the user and AsthmaBuddy.

8.2.4 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. Pi4j⁴ solved this problem, by making the necessary abstractions.

Gson Refer Section [refsec:techandframeinapp](#) for a description of Gson.

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

⁴Pi4j - <http://pi4j.com>

JLayer We used JLayer⁵ to handle the decoding of our recorded mp3-files.

8.3 Design Rationale

8.3.1 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[82][83] 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[84] and Furby[85], 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 situations⁶. 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[86].

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

⁵JavaZoom JLayer - <http://www.javazoom.net/index.shtml>

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



FIGURE 8.3: AsthmaBuddy holding a mask and an inhaler



FIGURE 8.4: AsthmaBuddy with his nose light turned on

8.3.2 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 pressure sensor combined could verify that a high five has been received.
Hold AsthmaBuddy’s hand	Demonstrates to children that AsthmaBuddy is friendly.	Pressure 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.	Pressure sensor within the nose of AsthmaBuddy could solve this.
Press AsthmaBuddy’s belly	Same as above.	Same as above.
Hold medicine close to AsthmaBuddy’s mouth	Demonstrates that AsthmaBuddy also needs his medicine.	An RFID-tag attached to the medicine, and an RFID-reader inside the nose of AsthmaBuddy could be used here to control the flow.
Hold RFID-tag close to AsthmaBuddy’s mouth	Is a relatively easy way to proceed with the process.	A loose RFID-tag could be used together with an integrated RFID-reader, in order to proceed.
Hold RFID-tag close to AsthmaBuddy’s belly	Same as above.	Same as above.
Clap your hands	Should be a fun way of interacting with systems, considering the age of our target group.	Sound recognition could be used here.

TABLE 8.2: Rationale behind AsthmaBuddy’s interaction design

8.3.3 Answering to Champoux's Development Framework

In Section 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?]

8.3.4 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 within 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 its 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? Again, as long as the user pays attention to what AsthmaBuddy is saying, and does the intended interaction. A part of the challenge in this connection is to recover from mistakes that have happened. For instance, if the user goes further 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. This was handled by having a separate “back”-interaction method. [TODO: Finn en interaksjon som kaller Back].

8.4 System Overview

8.4.1 Use Cases

Figure 8.5 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 off by the **AsthmaBuddy** instance running⁷, 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 G).

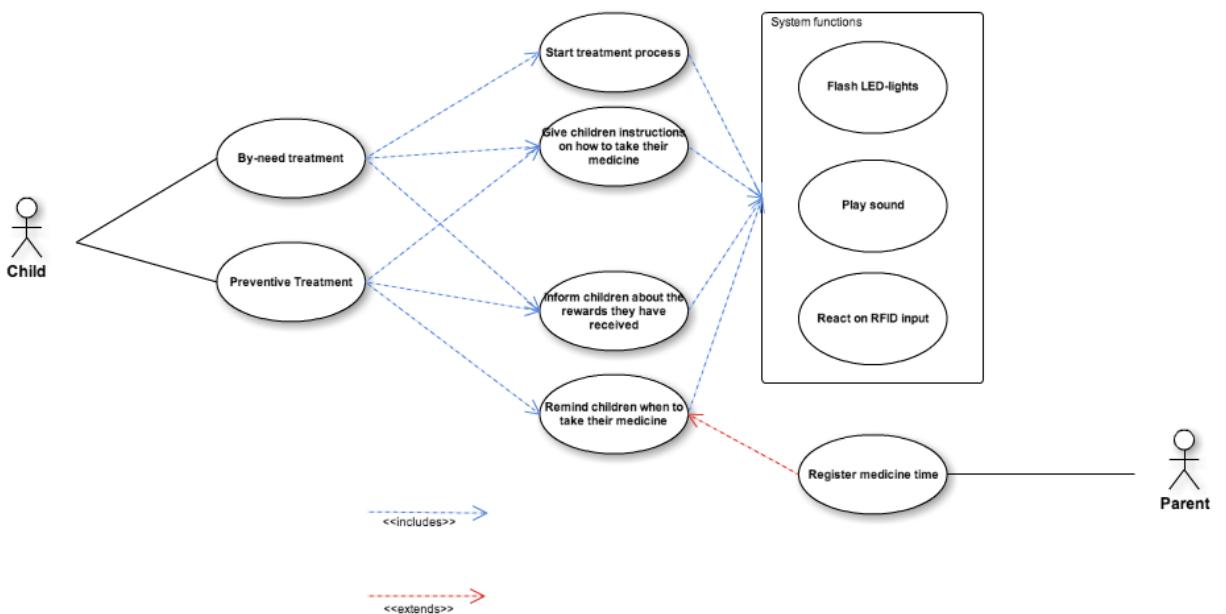


FIGURE 8.5: AsthmaBuddy Use Cases

⁷The 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)

8.4.2 Textual Use Cases

Title	By need treatment
Preconditions	-
Scenario	<ol style="list-style-type: none"> 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 8.3: Textual use case: By need treatment

Title	Planned treatment
Preconditions	The current time corresponds with the time for a planned treatment.
Scenario	<ol style="list-style-type: none"> 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 8.4: Textual use case: By need treatment

8.4.3 State Diagram

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

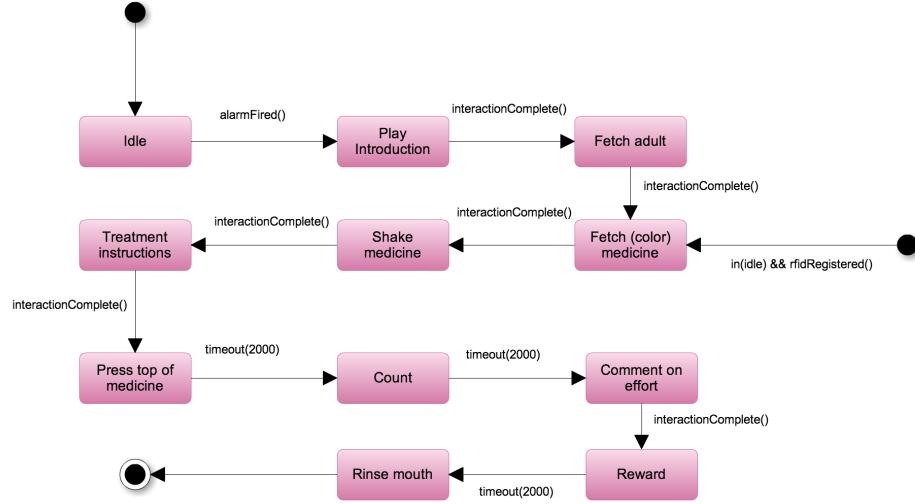


FIGURE 8.6: AsthmaBuddy State Diagram.

8.4.4 Sequence Diagram

Figures 8.7 - 8.10 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 8.9.

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

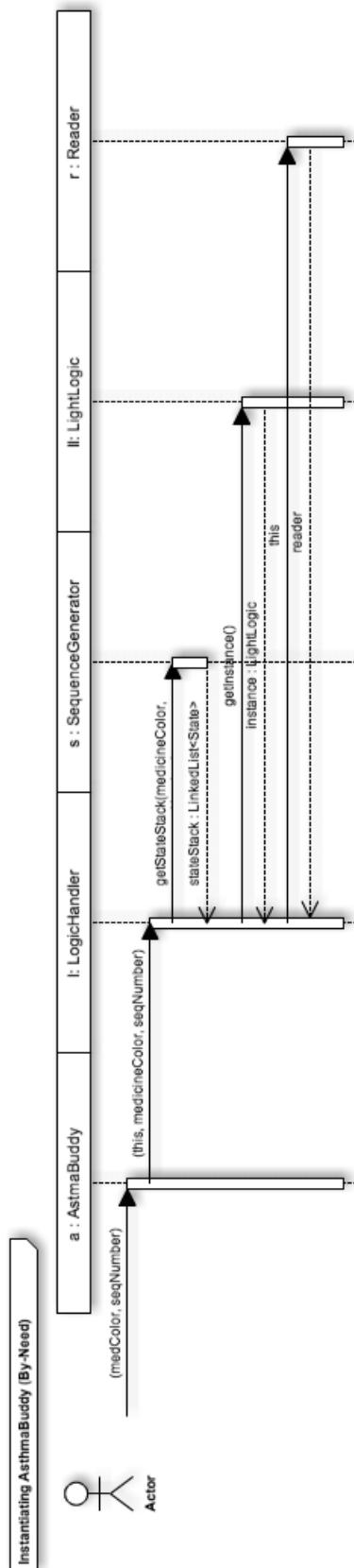


FIGURE 8.7: By Need Treatment - Sequence Diagram

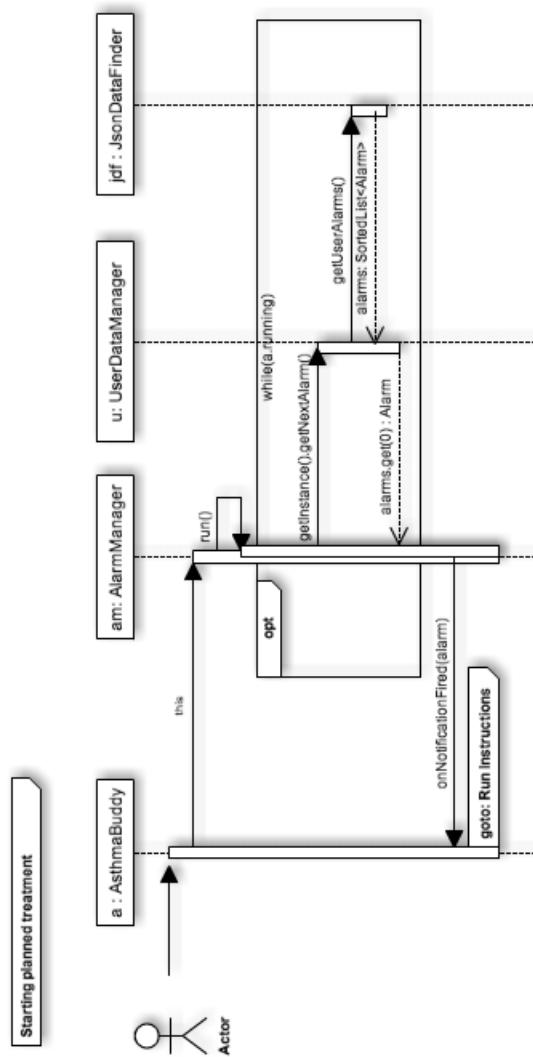


FIGURE 8.8: Planned Treatment - Sequence Diagram

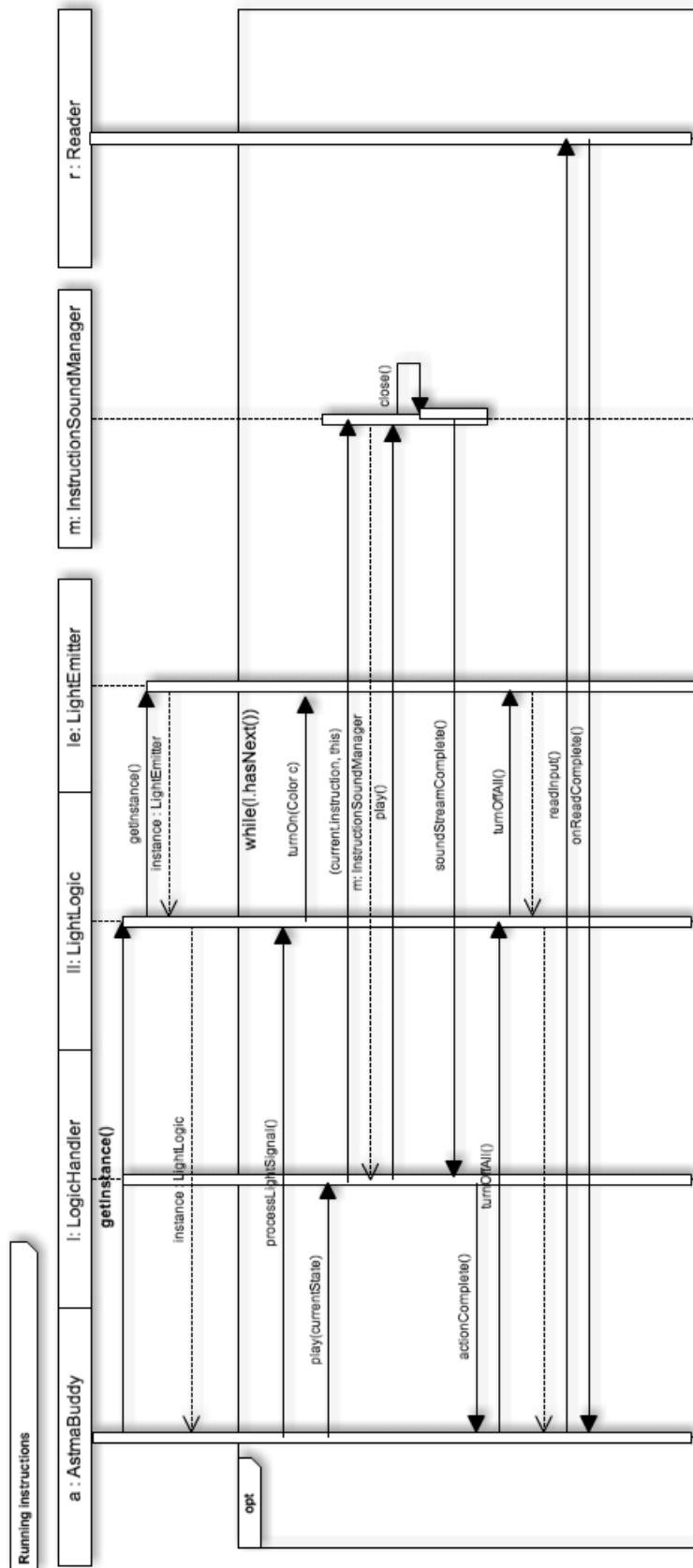


FIGURE 8.9: Playing Instructions - Sequence Diagram

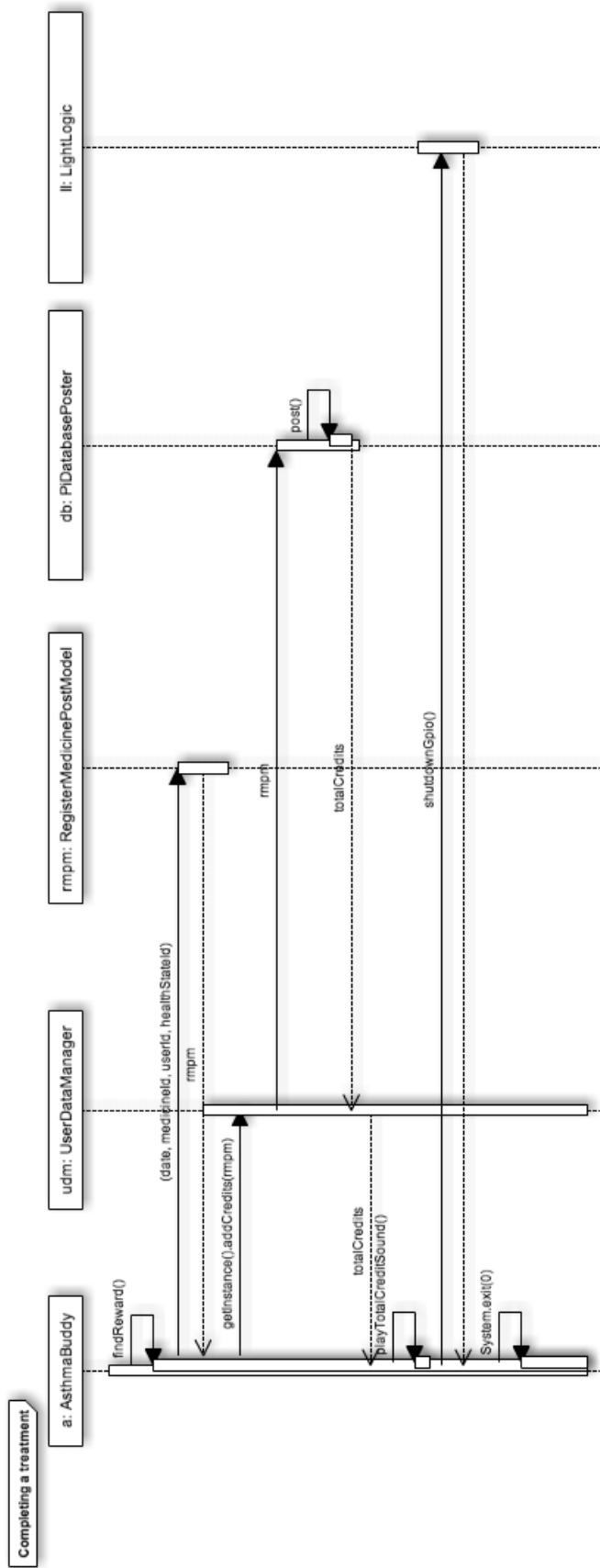


FIGURE 8.10: Finishing a treatment - Sequence Diagram

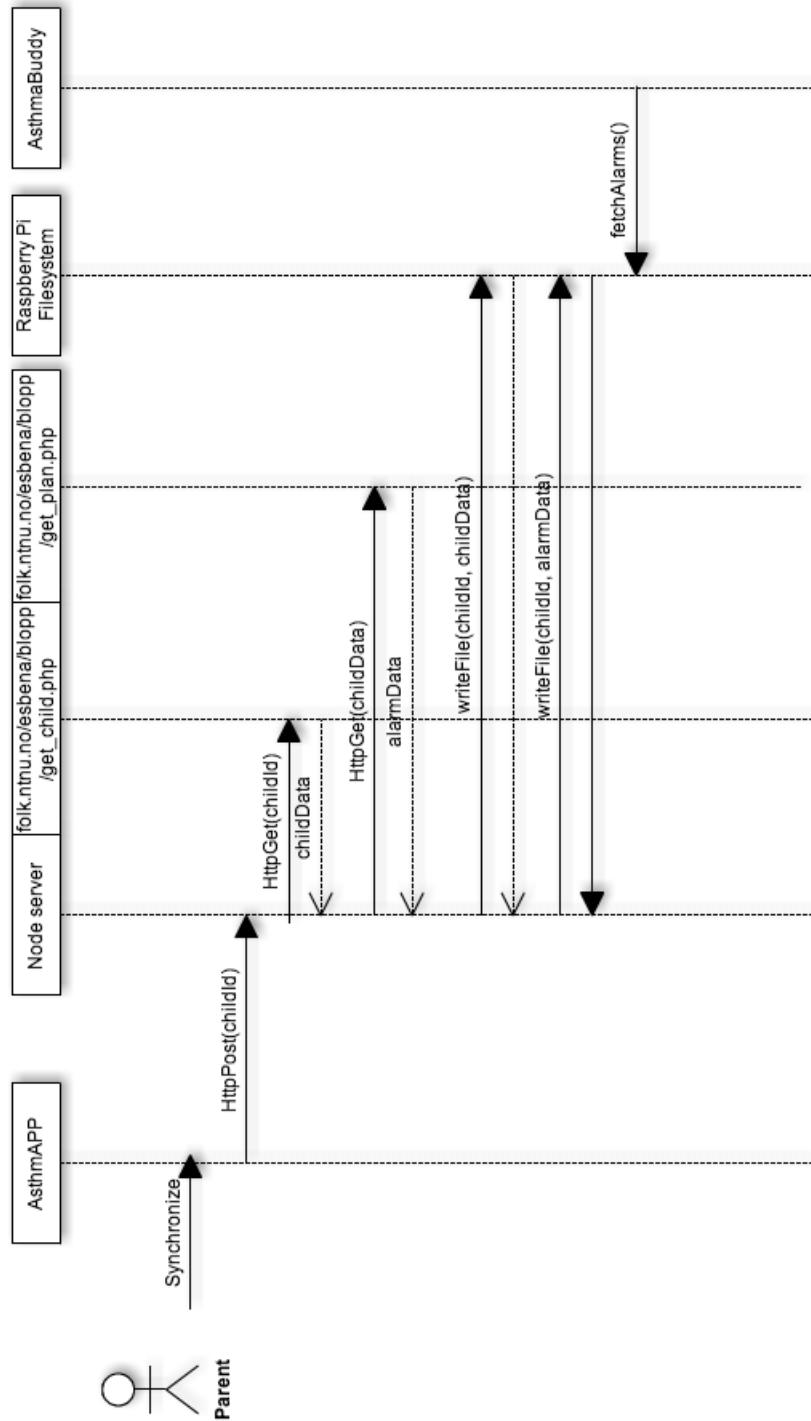


FIGURE 8.11: Synchronizing - Sequence Diagram

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 8.9, we register the treatment in the database. This ensures that the child is able to see the rewards in AsthmAPP.

8.4.5 Node Server

In addition to the Java application running on the Raspberry Pi, we developed a Node.js server⁸. 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 retrieves 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 collected⁹. This process is shown in Figure 8.11.

8.5 Prototype version 1

Our first prototype was a “dumb” version with the purpose of testing out different methods of interaction. We wanted to get as many different experiences as possible, in order to find 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[87].

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

⁸Node.js - <http://nodejs.org/>

⁹Since 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

8.5.1 Evaluation of prototype version 1

Interaction Method	Comments	Will it be in version 2?
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 8.5: Evaluation of interaction methods for AsthmaBuddy

Evaluation of interaction methods

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.

8.6 Prototype version 2

The improved version of AsthmaBuddy, named AsthmaBuddy 2.0, had some changes done since version 1.0. As stated in Table 8.5, 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.

8.7 Evaluation of AsthmaBuddy

Chapter 9

Results

9.1 Gamification

9.1.1 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." [88]

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 9.1.4.

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.

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.

It could 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.

9.1.2 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.

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.

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. [TODO: Is this positive? Can it cause jealousy?]

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[89]. Possibilities for adding new stories over time would create an even more engaging system for children.

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

9.1.3 Reception of AsthmAPP’s Reward System

[Wait until user tests]

¹Club Penguin - www.clubpenguin.com

²Farmville - www.farmville.com

9.1.4 Gamification over time

According to Webster-Stratton and Herbert, parents have a tendency to not phase out reward systems[88]. 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. Similarly, 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.

9.1.5 How can Gamification be used in the future?

[or something]

9.2 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 9.3.

9.2.1 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." [Wait for quote checking]

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.

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.

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.

"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, few 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.]

[Hva kan buddy hjelpe med]

9.2.2 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.

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 animal³.

9.2.3 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 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 9.3.3.

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

³This could prove to have a negative effect, but is an option to give children more responsibility.

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 regular 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.

9.2.4 TUI as a Tool for Informing

For children with asthma 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 receiving 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 7.4.4). 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 embodiment 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.

9.3 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 section.

9.3.1 Helping Kindergartens, Schools and Caregivers

During our interviews, we discovered a potential problem when children are in the kindergarten or at pre-school. It may occur that the caregivers 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.

9.3.2 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 ⁴, which in turn could start cleaning. AsthmaBuddy could also indicate the air humidity at the child room, starting up the air condition.

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

Mobility When developing a TUI for children it is important that the TUI is mobile. Children become attached to their toys and like to take them with them. To make the most out of a tool such as AsthmaBuddy it is important that the children may take it with them. The problem of power usage may be solved by a battery. The problem of recharging can be solved by charging at 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 sound may affect the children in different ways, but that will have to be explored in user studies.*”

We believe this is a complete field of research on its own. There already exists some research, such as Mæhlum’s concept for increased user acceptability when treating children with respiratory infections[90], and we have not done 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”[87]. 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

⁴iRobot Roomba - <http://www.irobot.com/us/>

confusion and uncertainties among users as to whether they interact correctly. *INSERT REFERENCE*

[NOE OM INTERAKSJONSMETODER? HAR DET VERDI?]

9.4 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.

Chapter 10

Conclusion

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

10.1 Discussion

[Pieter: Slik vil vi legge opp denne seksjonen]

10.1.1 General Discussion

10.1.2 Process Evaluation

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

10.1.3 Difficulty Finding Test Users

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

10.2 Conclusions

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

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?

Chapter 11

Further Work

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

As stated in Section 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?]

Appendix A

Questionnaire. Demographics

Vennligst besvar spørsmålene under, før vi begynner testen.

Kjønn
Alder
Utdanning
Yrke

Appendix B

Interview conducted before usability testing

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

Appendix C

Draft for Interview Conducted after Usability Test

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

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

Appendix D

Scenario and tasks

Slett AsthmAPP's brukerdata på forhånd.

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

D.1 Foreldre

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

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

Oppgave 1: Du skal sette opp en medisineringsplan i henhold til anbefaling fra legen. I første omgang skal du kun sette opp medisineringsplanen som gjelder når barnet er frisk. Legg til en varsel for "Oransje" kl 13:37 og en varsel for "Lilla" kl 18:30. Velg deretter å følge denne medisineringsplanen.

Oppgave 2: Barnet ditt tok allerede en dose med medisin da dere var hos legen. Du ønsker å starte loggføringen med en gang. Etterrigstrer en dose av "Lilla" for dagens dato.

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

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

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

Du har nå gjennomført testen. Vi vil gjerne spørre deg noen spørsmål om hvordan du opplevde dette. *Aleks stiller spørsmål fra Appendix D.*

D.2 Barn

Selv om dette er en oppgaver som går ut på å ta medisinen din, så er ikke dette en ekte medisin, så den vil ikke ha noen effekt. Hvis du ikke har lyst til å gjennomføre testen kan du bare si i fra.

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

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

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

[Kjør til Blipp har tatt medisinens sin]

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

Demonter medisin fra masken

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

Oppgave 5: Bjørnen passer på selv om du ikke tar medisinen sammen med bjørnen. Ved å holde dette kortet foran magen hans, kan han minne deg på hvor mange stjerner du har samlet. Kan du holde kortet foran magen hans?

Oppgave 6: Nå har du samlet mange stjerner. Sjekk i butikken om du kan kjøpe deg en premie, og kjøp den hvis du har råd.

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

D.3 Nødplaner

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

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

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

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

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

D.4 Bakromsoppgaver

Ha to terminalvinduer oppe (T1 og T2)

T1 Kjør følgende kommandoer:

- \$ ser
- \$ node index.js

La serveren kjøre gjennom hele brukertesten.

T2

- \$ bloop
- \$./v2.sh CN

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

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

Appendix E

AsthmaBuddy Manual

The following Appendix works as a user manual for AsthmaBuddy.

Appendix F

Asthma Traffic Light System

Emergency Department

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



Triggers: Respiratory infections
Other: _____

Need info: Call ER at 983-8637

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

Use these medicines EVERY DAY even when well		
MEDICINE	HOW MUCH	HOW OFTEN / WHEN
Pulmicort OR Flovent	1 ampule 1 to 2 puffs	1 or 2 times daily 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

Want to take an Asthma Class: Call 983-6336

GREEN ZONE: DOING WELL

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

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

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

Continue Green Zone control medications and add:

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

Move to the RED ZONE if no improvement

Take these medications and CALL YOUR DOCTOR NOW

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

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

KMCWCH ED Ver. Nov 4, 2009

Appendix G

AsthmAPP Manuscript

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

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

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

G.1 AsthmaBuddy

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

G.1.1 Instructions

The following are the instructions a child receives, and where the manuscript reads “(Interaction)”, one of the interactions in [G.1.2](#) are inserted. 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.*

G.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.*

G.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 H

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 or have been brought up during discussions and meetings with the stakeholders.

H.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.

H.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

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

²This 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.

H.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.

H.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.

H.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.

H.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 considered using accounts for the guardians connected to the children, in case of the guardians having more than one asthmatic child.

H.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 I

Constraints

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

I.1 The Health Register Act

Norway has specific laws for storing of medical information. The most significant law is “The Health Register Act¹”^[91]. This law regulates who is allowed to store health records and how they store the records.

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

In addition, we need permission from *REK*² in order to store medical records in the application. This document is attached as Appendix [INSERT REFERENCE]. If the mobile application were ever to be deployed to Google Play, or AsthmaBuddy commercialized, we would need permission from *The Data Protection Authority*, but it is not required if the application is just for research purposes.

I.2 Measures for Anonymization

Pursuant to section 16 of the Health Register Act [91] all information that may identify a person, must be encrypted, i.e. it should be impossible to find which person a specific record corresponds to by looking at a database dump.

¹Lov om helseregistre og behandling av helseopplysninger

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

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