

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

Using Mobile Technology to Treat Asthmatic Children

by

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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:

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- 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.

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

- George Michael Bluth

NTNU - NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Abstract

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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. We have researched and planned the development of AsthmaBuddy, a tangible user interface, 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
GAPP	Guardian APPlication
GUI	Graphical User Interface
KAPP	Karotz APPlication
NAAF	Norges Astma- og Allergi-Forbund
MMO	Massive Multiplayer Online game
NTNU	Norwegian University of Science and Technology
REK	Regional Committees 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 state the purpose, motivation, research questions and the research method for the study.

1.1 Purpose

The goal of this project is to evaluate the use of mobile applications and a tangible user interface in the treatment of asthmatic children. The project is based on a system made by Aaberg, Aarseth, Dale, Gisvold and Svalestuen in 2012[1]. We intend to improve their versions of CAPP and GAPP (see Chapter 2) and in addition create a Tangible User Interface from scratch. The new and improved version of CAPP and GAPP will be combined to one application, called *AsthmAPP*. The tangible user interface will be called *AsthmaBuddy*.

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

1.2 Motivation

1.2.1 Asthma among children

According to NAAF, 20% of the Norwegian population has or has had asthma by the age of 10, and 8% of the adult population suffers from asthma[2]. Many of the children find it unpleasant to use their medicine as they often do not understand why the medicine

must be taken. Research done by Åsheim showed that children suffering from HRS-virus¹ were easily distracted and motivated to finish treatments when shown a non-interactive flash-video during the treatment[3]. We aim to research whether use of mobile technology may make the children more aware of their disease and thus make them better understand why they must take their medicine on a daily basis.

1.2.2 Ways asthma affect the parents

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

1.3 Research Questions

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

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

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

1.4 Research Method

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

1. We will start out by interviewing parents and domain experts to find out more about children's medication habits. Additionally, we will arrange focus groups for brainstorming purposes.

¹Center for Disease Control : HSRV - <http://www.cdc.gov/rsv/>

2. Next we will develop a TUI and a mobile application prototype based on the knowledge we have gathered.
3. The prototypes will then be tested by potential users and parents of asthmatic children.
4. Based on feedback from the user tests, we will design new prototypes.
5. Step 3 is repeated once.

The rationale for doing Step 1 is to create a foundation to build upon on the later steps. Collecting information about how children take their medicine under normal conditions gives us insight into the main problems in relation to taking medication. We also want to gather ideas for how the TUI should be designed in terms of functionality and look.

The mobile application was already built on the start of this project. The main focus for the mobile application will be to test the gamification elements and general usability testing of the mobile application. The initial plan for the TUI is to build a system using a Raspberry Pi and different elements to play sounds and emit lights. A detailed description of the TUI is given in Chapter [7](#).

Our first prototype of AsthmaBuddy will be a “dumb” version, where we can test out different forms of interaction without actually programming the TUI for them. A list of the different forms of interaction is given in Chapter [7](#).

The prototypes will then be user tested through usability testing and co-design sessions. Both users with knowledge of the project and users without prior knowledge of the system should participate in the system in order to not bias results.

Based on the feedback we will make prototypes iteratively, in a total of three iterations.

Chapter 2

Background

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

2.1 BLOPP Project

The BLOPP project aimed to explore how design and technology can motivate children with respiratory diseases to take prescribed medication and to promote positive interactions between children and caregivers, thereby increasing adherence to medical treatment. They have previously worked with [FYLL INN].

2.2 About Asthma

Asthma is a disease that affects the lungs. Asthma causes wheezing, breathlessness, chest tightness and coughing. It is a chronic disease, but asthma attacks will only occur when something is bothering the lungs. It may be hard to tell if someone has asthma, especially in children under the age five.

An asthma attack may include coughing, chest tightness, wheezing and trouble breathing. The attack happens in the body's lungs, the airways tighten, letting less oxygen pass through. According to the Norwegian Ministry of Health and Care Services, acute asthma attacks was the most common reason for hospitalization of children during 2008



FIGURE 2.1: Main menu of partent partition



FIGURE 2.2: Starting a treatment

[4]. About 20 per cent of children are suffering from the disease, which causes economical consequences for the society ¹. However, asthma can be controlled and asthma attacks avoided by taking medicine at regular intervals. Some of the medicines are taken as a preventive measure to avoid asthma attacks from occurring. These medicines are Sereotide and Flutide. Ventoline is taken before exercise or when an asthma attack occurs, in order to stop/shorten the length of the attack.

A treatment may be done in different ways, mostly differentiated by the use of a breathing chamber or not. Before use the asthma medicine must be shaken, in order to stir the particles. If a breathing chamber is used, the medicine protection cap is removed and the medicine is mounted on the breathing chamber. The chamber is pressed towards the user's face, covering nose and mouth. The medicine is then pressed, to release the particles into the breathing chamber, and the user breaths calmly for ten seconds. The breathing chamber is most often used by small children, while others may use a disk-formed medicine (see Figure and Figure respectively).

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

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

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 NTNU². During the period of August 2012 to December 2012 they developed a prototype of a mobile information system consisting of two Android applications and a TUI. One application was developed for parents of a child (GAPP) and one application were developed for children (CAPP). Additionally, they created a Karotz Application (KAPP) targeted at children. In this section, we elaborate on these applications, while a full report of their work is available at[1].

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

2.3.1 CAPP

CAPP is an Android application targeted at children³. It’s main purpose is to guide children through the medication process. Figure 2.5 shows the main page of CAPP. As the target group for the application is children below the age of 8, it is reasonable to assume that not all of them are able to read, this application consists mainly of pictures and animations.

In CAPP, it is possible to start a medication in one of two ways. A parent can either set alarms in GAPP (See Section 2.3.3) for preventive medicines, or a child can access the medication process directly by pressing the Karotz showed in Figure 2.5, which is the way to start a by-need-treatment.

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

By clicking the treasure chest, the child is able to see how many stars he/she has aquired. A screenshot showing the inside of the treasure chest is included in Figure 2.4

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

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

³All applications have norwegian as their main language

in order to read the information contained in this functionality. [2.6-2.12](#) shows the information-part of this application.



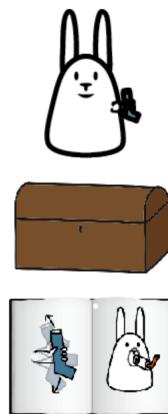
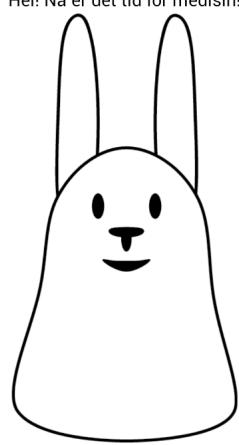
FIGURE 2.3: Starting a treatment



FIGURE 2.4: Inside the treasure chest



FIGURE 2.5: CAPP main menu



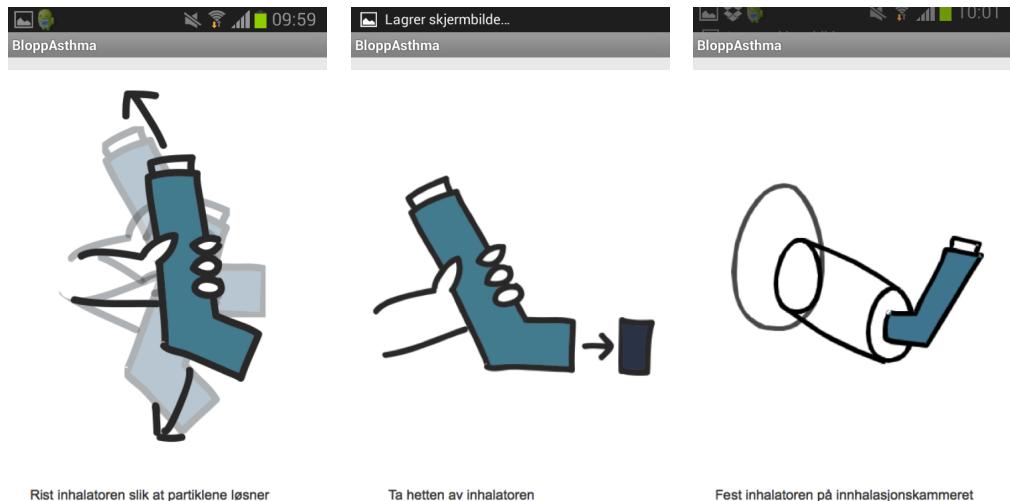


FIGURE 2.6: Instructions 1

FIGURE 2.7: Instructions 2

FIGURE 2.8: Instructions 3

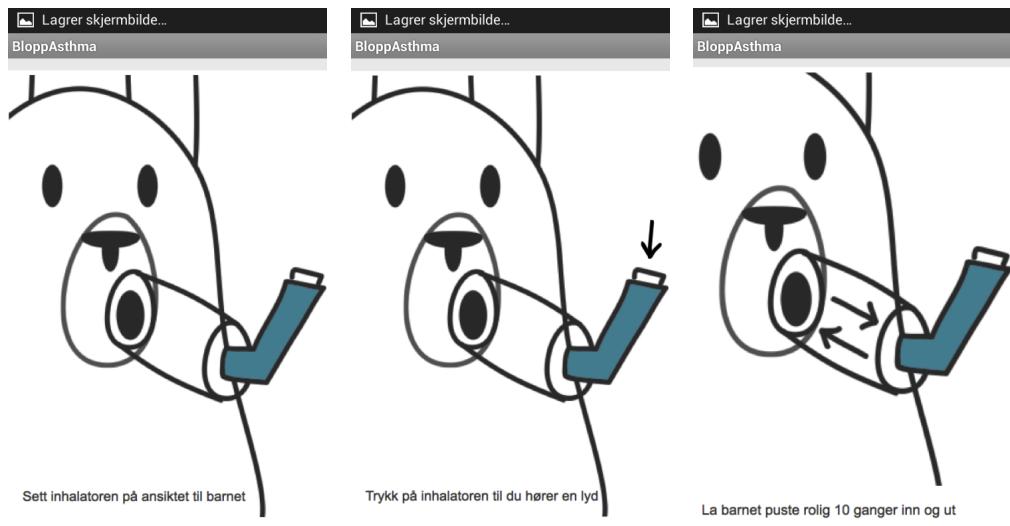


FIGURE 2.9: Instructions 4

FIGURE 2.10: Instructions 5

FIGURE 2.11: Instructions 6

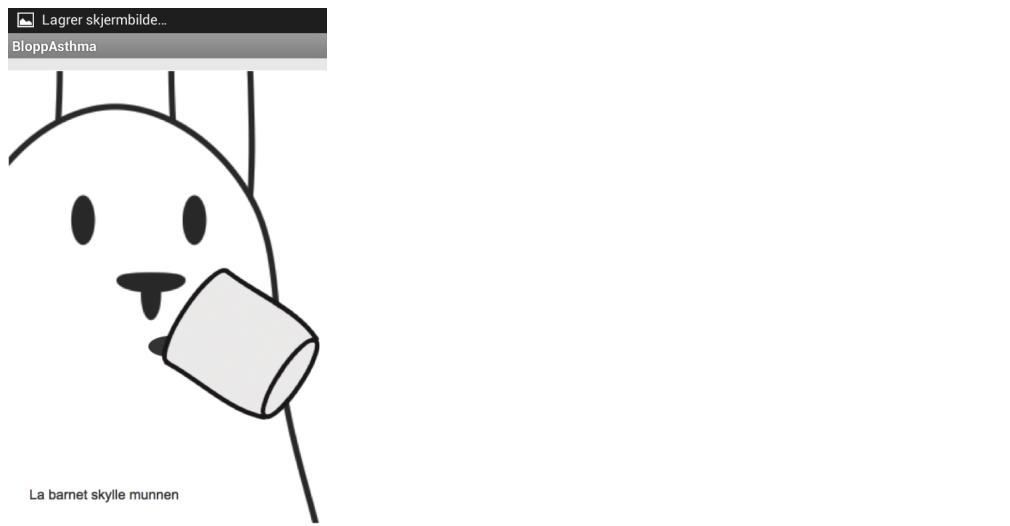


FIGURE 2.12: Instructions 7

2.3.2 KAPP

KAPP is the TUI-application targeted at children. The application runs on a Karotz⁴, which is a small robot bunny (see Figure 2.13). The purpose of the KAPP is similar to CAPP, namely to remind children when it is time to take their asthma medicine and give instructions during treatment. In order to interact with the Karotz, children may use either a Nanoz (a small bunny with an integrated RFID) or by pressing a button on the top of the Karotz' head. It is not possible to do a by-need treatment with a Karotz as a companion.

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

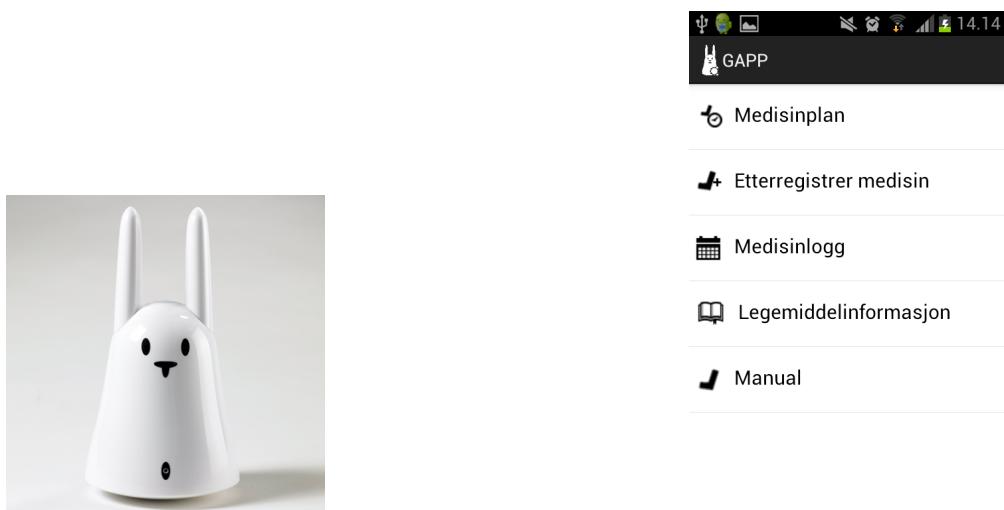


FIGURE 2.13:
Karotz. *Image source:*
<http://karotz.com>

FIGURE 2.14: GAPP main
menu

2.3.3 GAPP

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

Figure 2.14 shows a screenshot of the main menu of GAPP. The main functionality is separated into *Medical Plan*, *Register Treatment*, *Medicine Log*, *Medical Information* and *Manual*.

⁴[Karotz](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 H). A child has three separate plans, such that an alarm that is set on the *Healthy*-plan is not automatically set on the *Sick*-plan.

Register Treatment The *Register Treatment*-option gives parents the possibility to register a treatment that is taken in case the child for some reason did not go through the process in CAPP or KAPP. This way, children will be rewarded with stars accordingly. Figure 2.15 shows a screen shot of this process.

Medical Information *Medical Information* gives general information about different medicines, what they do and what they are used for. The three medicines that are currently in the system is Flutide, Seretide and Ventoline. Figures 2.17 and 2.18 shows screenshots from this functionality.

Medicine Log *Medicine Log* shows how many times a child has taken his/her medicine the last couple of days. Figure 2.19 shows a screen shot of this functionality. A red circle marks the current day. A child's health state is displayed by the Green/Yellow/Red bar at the top of each day. In the bottom left corner, it is possible to show how much medicine was taken on a given day. In the bottom right corner, Aaberg et. al. intended to show the pollen distribution for a given day. However, the pollen distribution data is only available during spring and summer, and thus Aaberg et. al created an artificial pollen distribution for demonstration purposes.

Manual The *Manual* is to help “newcomers” to medicate children. For instance, if a relative is watching children with asthma, she could use the application as a reference on how to do the process. At the time being, the manual shows Figures 2.6-2.12.



FIGURE 2.15: Register treatment

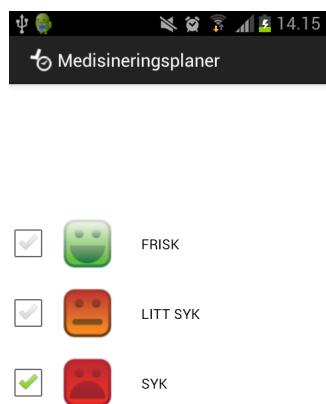


FIGURE 2.16: View plans



FIGURE 2.17: Information 1



FIGURE 2.18: Information 2

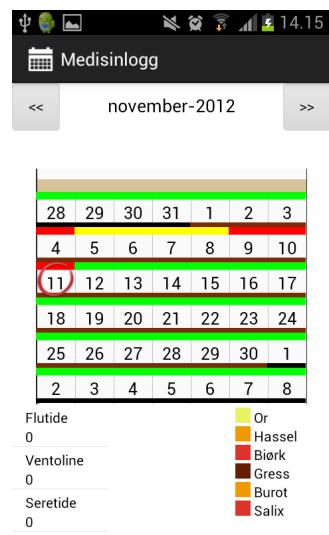


FIGURE 2.19: Medicine log

2.3.4 Known areas for improvement

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

- Reward System
- Distraction sequence for children
- Web application

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

2.4 Existing Research

This section will give a foundation on some of the 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 your asthma condition has already been carried out. Much of this research was carried out by using SMS (Short Messaging System) technology. In 2009, Andhøj et. al.^[5] 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.

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

2.4.2 Children and Mobile Devices

In 2013, www.babies.co.uk posted results on a poll they had posted on how many toddlers are using smartphones or tablets each day^[7]. Over 1000 participants responded, and according to the survey, 14% of the responders allowed children to use smartphones or tablets more than 4 hours a day. Considering the normal awake time of a small child, they spend a considerable amount of their day playing with a smartphone. With this in mind, we aim to make an application that is used for a short period of time with each use. AsthmAPP and AsthmaBuddy is not a toy or a game. AsthmAPP and AsthmaBuddy will be tools for helping the children.

2.4.3 Children and Gestures

Abdul Aziz et. al.^[8] performed a study on which gestures children are able to comprehend when playing with an iPad. She tested 33 children's ability to do gestures on a variety of applications suited for children. The children were between the age of 2-12 years old, 3 children in each age group. The study showed the following restrictions:

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

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

2.4.4 Assessment of Existing Asthma Applications

In 2012, Huckvale et. al.^[9] conducted an assessment on the existing asthma-related applications on both Google Play ⁵ and App Store ⁶. They assessed 103 different apps with English as the native language. Out of these applications,

"No apps for people with asthma combined reliable, comprehensive information about the condition with supportive tools for selfmanagement"^[9].

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

2.5 State of the art

Mobile computing is evolving at a rapid pace, and finding new ways to use it in health care is a rising research problem. This section covers the state of the art of some of the

⁵Google Play - <http://play.google.com>

⁶Apple App Store - <http://www.apple.com/itunes/features>

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

2.5.1 Get Up and Move (GUM)

Penados et. al.[10] created GUM an interactive toy to measure and stimulate physical activity. GUM is a small creature that needs to be taken care of by a child. The child's objective is to make his/her GUM healthier and happier by moving with it, feeding it and playing with it. GUM is healthy and happy when it has been through a minimal amount of daily physical activity, and since GUM can't move by itself, the child needs to do it. As GUM grows healthier, lighted stars will appear in its ears, until it reaches a maximum healthy state. To increase the number of stars, the child needs to progressively increase and later maintain its physical activity level. Penados et. al. argues that GUM had a positive effect on reducing sedentary behaviour and motivate physical activity with young children. The findings presented by Penados et. al. [10] gives us reason to believe that AsthmaBuddy will show positive results when tested on children with asthma.

2.5.2 Sisom

Sisom ⁷ is a software created to increase the communication level between physicians and children. It is an interactive game, where the user follows an avatar through different "worlds" of health care subjects. For instance, the avatar takes a boat to a hospital. Here the users can look around in the room and express how they feel when they are giving a blood sample. The results showed that when children played the game before a consultation with his/her physician, children were better prepared and the communication had a better quality, and children participated more during the consultation [11].

2.5.3 Meassuring Blood Preassure

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

⁷Sisom - <http://www.communicaretools.org/sisom/>

⁸iHealth - http://www.ihealthlabs.com/wireless-blood-pressure-monitor-feature_32.htm

⁹Withings - <http://www.withings.com/en/bloodpressuremonitor/features>

2.5.4 Controlling Your Diabetes

Cellnovo ¹⁰ has created a system that helps controlling diabetes. It consists of a hand-held device for measuring blood sugar level, a pump that controls the flow of insulin and a web interface that allows one to access the information. The interface helps users to check for trends and patterns in their blood sugar level, which motivates users to continue applying the correct treatment. It also allows users to send information to physicians, which helps them make decisions regarding how patients are managed.

2.5.5 Quit Smoking

There are lots of mobile applications that are helping people to quit smoking. For instance, *The Norwegian Heart and Lung Patient Organization* has developed an app called “Røykeslutt” ¹¹. The application shows what the body is going through after a specific amount of days, which is a huge motivational factor, considering what we have read in the reviews of the application. Additionally, they show how much money a user has saved at a particular time, which can be seen as “gamifying” the element of money in order to motivate users.

2.5.6 Wii Fit Plus

Nintendo Wii has gamified the way people train at home with Wii Fit and later Wii Fit Plus ¹². It gives a user the ability to choose their own training programme, including Yoga, Strength and Aerobics. Users can easily track their progress over several months. Additionally, it allows children to stay healthy, by having games that depend on their movement. For instance, if a child flaps their arms up and down, they fly a bird on the screen.

¹⁰Cellnovo - <http://www.cellnovo.com/>

¹¹Røykeslutt - <https://play.google.com/store/apps/details?id=no.lhl.roykeslutt>

¹²Wii Fit - <http://wiifit.com>

Chapter 3

Gamification

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

3.1 What is Gamification?

“Gamification” as a term was first mentioned by Currier in 2008[12], but did not become a wide-spread term before 2010.

There are many different ways of describing gamification. Deterding, Dixon, Khaled and Nacke[13] define Gamification as:

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

Huotari and Hamari[14] defines gamification as:

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

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

Today gamification is a much used term both in programming and in the spoken language. Smartphone applications and manufacturers have helped make the term gamification a widespread notion. Examples of this is the application Foursquare, which is built around gamifying “checking in” at restaurants, historical sites and similar 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 has 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 critiqued for using gamification to lure players into playing.

3.2 What is Serious Games?

The term “serious game” became a concept with the emergence of the Serious Game Initiative in 2002 [15]. Their website defines serious games as:

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

This definition has been critiqued for being too narrow, and 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 has later grown to becoming a multi-billion industry. Pilots are being trained in simulators, lecturers make lecture quizzes for students[16], swedish firefighters have used serious games for training [17] and persons suffering from diabetes have the ability of using serious games for learning about the illness. These are just a few of the many ways of using serious games.

Foldit is a very interesting example of how a serious game may lead to knowledge and solving bigger problems than the game itself[18]. Foldit is a massive multiplayer online game (MMO). The objective for the player is to fold protein following a set of rules.

²[Apple Game Center](http://support.apple.com/kb/HT4314) - <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.

The system records how players fold protein and learns patterns for interaction. Humans have much higher skills at interacting with 3D objects than computers, and the system learns patterns and techniques from the players. By playing Foldit, researchers were able to solve the crystal structure of the M-PMV retroviral protease⁸ [19].

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

3.3 Discussion about Gamification

Gamification is a much discussed theme, where there does not seem to be an agreement as to which gamification is a useful or not. Antin and Churchill argues that gamification may be used for goal setting or instruction[20]. Goal setting challenge the users to meet the mark that is set for them, and is known to be an effective motivator[21].

Bogost goes as far as naming gamification as “marketing bullshit”, used as a way of monetizing bad business[22]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.”[24]

Steinung arguments for gamification not being powerful enough to make a task interesting[25]. Simply adding points, badges, a leveling system or similar, won’t 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[25]. Zichermann makes a similar statement, saying gamification needs to take ethical precautions[26].

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

In order to achieve a meaningful use of gamification Nicholson[27] suggests using a user-centered design approach[28] when developing system with elements of gamification.

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[23]

3.4 Summary

Stapleton argues that:

“A variety of [serious game] applications can be thought of here [in Health Care] such as games as a form of motivation and reward for patients undergoing some form of treatment. Games could also be to distract patients during certain procedures such as dental work, for example.” [29]

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

In AsthmAPP we aim to use gamification as a distraction and rewarding element for the children. Instead of putting a lot of predefined badges, rewards, experience points or other rewarding elements, we let the users choose their own rewards, which implies that users can decide what works best for them. This stands to reason with the arguments of Nicholson[27] regarding how to design gamification.

As McGonigal’s studies show, the effect of gamification tend to wither down after a longer period of time[24]. We aim to solve this problem by letting the user choose their own rewards. While putting the responsibility for the reward system in the hands of the user will lead to more work for the user, we believe that the positive effect of the reward system will make it worthwhile.

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

The rewards will appear on a “milestone” basis. We do not want children to feel they lose something if they buy a reward, which some might experience if stars were taken away from them. We do not want to force parents into giving away rewards they can not afford or do not wish to use. Therefore we will be testing the application without the gamification elements, in order to find how introduction of gamification elements will

affect the use. The use of rewards is also optional and decided by the user, making the user in control of how they wish to gamify the experience. We do not wish to have the children spending too much time using the application, since using a tablet or phone at such a young age is considered unhealthy, which is taken into consideration with making an application which is mostly used “outside” the digital application itself. The children may receive rewards and use the TUI without touching the smart phone.

Chapter 4

Tangible User Interfaces

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

4.1 About Tangible User Interfaces

In 1997, Ishii et. al. presented an article called “Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms”. They established the term “Tangible User Interface” (TUI) as a way to move beyond the dominant model of Graphical User Interfaces. While GUIs show information (bits) in the form of pixels mapped to a display, Ishii meant for TUIs to represent the bits in form of physical objects. The objective of TUI was explained to *augment the real physical world by coupling digital information to everyday physical objects and environments*[30].

Urp[31] 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 makes this a first-generation TUI is the fairly simple and state-determined operations.

Sandscape[32] 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 “Continous TUI”.

4.2 Examples of Use

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

Learning Terrenghi et al. designed a cube for learning, giving children quizzes where answers had the shape of text or images[33]. 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[33].

Collaborative Learning Scarlatos et. al. created a system called TICLE (Tangible Interface in Collaborative Learning), which are used to help children solve a Tangram[34].

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[35]. Stanton et. al. created a “Magic Carpet”, giving children possibility to influence a story in the classroom[36].

Social Context Marble Answering Machine is an invention by Durrell Bishop, dating back to 1992[37]. The interface allows users to drop marbles into a play-back indent on the system, which plays a recorded message.

4.3 TUIs Used in Health Care

In 2003, Wada et. al. conducted a study on how the introduction of robotics affected the elderly[38]. They conducted a study at a day service center in Japan, where they placed a robotic seal, named Paro, together with the elderly. It had recently been found that animals have a positive effects on blood pressure, depression and loneliness. They placed a robotic seal in the care center, and analyzed the reactions from the elderly.

The results showed that their mood was better after interacting with Paro over five weeks, and became worse once Paro was removed. In addition, nurses burnout rate decreased during the experiment, which implied that the subjects had easier days when Paro was there. The study showed that their quality of life improved after Paro was introduced.

Farr et. al. did a study on children with Autistic Spectrum Condition (ASC), when playing with a TUI called Topobo¹ [39]. The study compared the level of social interaction when playing with Topobo, compared to playing with LEGO. Their findings showed that ACS children were playing more cooperatively with the TUI than LEGO. Additionally, children with traditional development were able to play more cooperative, solitary and parallel when using a TUI, suggesting that

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

4.4 Are Tangible Interfaces more fun?

In 2008, Xie et. al. performed a study on how children reacted using different interfaces in order to solve a jigsaw puzzle[40]. The different interfaces were a physical interface (i.e. a standard jigsaw puzzle), a TUI and a GUI. Their findings were mainly that children enjoyed playing with the different interfaces equally. However, the children were more likely to start a puzzle over again if the interface were physical or tangible, which implies that a repeated task is more likely to be performed if they’re playing with a tangible or physical interface, while it becomes boring to do the same task over and over again on a graphical user interface. It is worth mentioning that the puzzles were being solved by groups of two, and considering the GUI was a computer with one mouse, they didn’t get the same sharing experience as with the other interfaces.

4.5 How to create a TUI

Ullmer states that a tangible user interface should embody the following four properties[41]:

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

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

¹[Topobo](http://www.topobo.com/) - <http://www.topobo.com/>

Ullmer proposes three different classes of TUI's: Interactive Surfaces, Token and Constraints, and Constructive Assemblies. These classes are partly based on varying degree of support for continuous and discrete forms of interaction[41].

4.5.1 Token + Constraint Approach

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

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.

4.5.2 Design Approach to TUI's

A lot of material exists on the potential benefits of TUI's, but few exists on how to actually create them. Champoux proposes a mechanism to design TUI's based achieving fitness between the form and its context[42]. He proposes three classes of questions, which corresponds to the different development phases of TUIs:

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

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

We consider Question **OC5b** as irrelevant for our purposes, as we will have a stationary artefact without any electromechanical and physical ergonomic properties, i.e. moving arms, waving ears, etc. The other questions are relevant to the development of AsthmaBuddy.

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

TABLE 4.1: The eight questions stated by Champoux[42]

4.6 Challenges when creating TUI

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.[43] has found several research challenges with creating usable TUIs and ubiquitous systems. This section will elaborate on some of the questions we have to ask ourselves when we are creating our TUI.

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

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

TABLE 4.2: The challenges of interacting with TUI[43]

4.7 Co-design

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

4.7.1 What is co-design?

Co-design is a product, service, or organization development process where design professionals empower, encourage, and guide users to develop solutions for themselves. Co-design encourages the blurring of the role between user and designer, focusing on

the process by which the design objective is created[44]. By encouraging the trained designer and the end user to create ideas and solutions together, the final result will be more appropriate and acceptable to the end user[45]. Albinsson et. al.[45] discovered that having a co-design approach to development of a e-mail sorting system lead to the ability of easier conflict management, ability to centre innovation on the client/customer and made it easier to manage a project with an unknown outcome. While co-design has been around for over 40 years, it draws it's roots from user-centered design and participatory design. Co-design differs from user-centered design approaches in that it acknowledges that the client or beneficiary of the design may not be using the artifact itself[46].

4.7.2 Using co-design to build AsthmaBuddy and AsthmAPP

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

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

Regarding the development of AsthmAPP, we will focus mainly on the gamification aspect during the codesign sessions. The test persons will be asked to test out the application at home, and give feedback on how the test went. The first version of AsthmAPP has a very open and user-controlled system for the rewards (see Section ??). While this is an idea we consider appropriate initially, this may change based on user experience and feedback. The reward system using stars will also need testing, since we have little knowledge of how this is percieved by children over time.

4.8 Summary

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

Champoux proposed a design mechanism to create Tangible Interfaces. The design mechanism is somewhat abstract, and misses out on obvious points like how to actually display information to a user, which Bellotti et. al. (see [4.6](#)) exposes as a challenge when creating ubiquitous systems and TUI's. We will use Champoux' approach to a certain extent, and keep Bellotti's challenges in mind when designing our TUI.

Chapter 5

Usability

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

5.1 What is usability?

There are many ways to describe the term usability.

The International Organization for Standardization(ISO) uses the following definition of the term usability[47]:

“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[48]. 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[49]. Proper usability engineering may also lead to lower costs for the developers and higher chances for projects being finished on time[50].

5.2 How to test usability

There are many approaches to creating a good user experience. Having knowledge of expert opinions is always a good idea, and using user-centered design techniques is also a choice. According to Rubin's handbook of usability testing[51], developers should get feedback from users by users tests at different stages of development. According to Rubin, having a user-centered approach will help the developers to address the weakest parts of their system, and give feedback on design decisions.

A user-centered design can be done in many different ways and at different stages of the product life cycle[52], as shown in Table 5.1:

Method	Purpose	Phase of the project life-cycle
Background interviews and questionnaires	To collect data and to understand the user better	When starting the project
Focus groups	Discover design issues and receive feedback	At an early stage
On-site observation	To both collect information of the context the system will be used in, and find the primary problems the users may have	At an early stage
Role playing / simulations	Will give a broader understanding of what the user expects from the system	Early to mid stage of the project
Automated evaluation	Gives feedback on deviations from standards or best practices. This method excludes actual users, but is based on well tested principles	Mid to end of the project
Usability testing	To measure the usability of the system and provide feedback on very specific elements that are poorly designed	Abras[52] says it should be at the end of the project while others[53] think it should be done in iterations throughout the project
Interviews and questionnaires	Gives a qualitative measurement of how good or bad the system is	End of the project

TABLE 5.1: Methods of user-centered feedback

Usability Testing The purpose of usability testing is to increase the usability of a system. At the same time, performing these usability tests may save the developers some time and reduce the cost of the project by removing errors and poor design at an early stage[54].

The usability testing can be performed in different ways[53]. At the early stages of the project, low-fidelity prototypes are a good option since they will provide feedback and take proportionally little time to make, making it easier to have more iterations of testing. The different testing methods include a potential user of the system performing

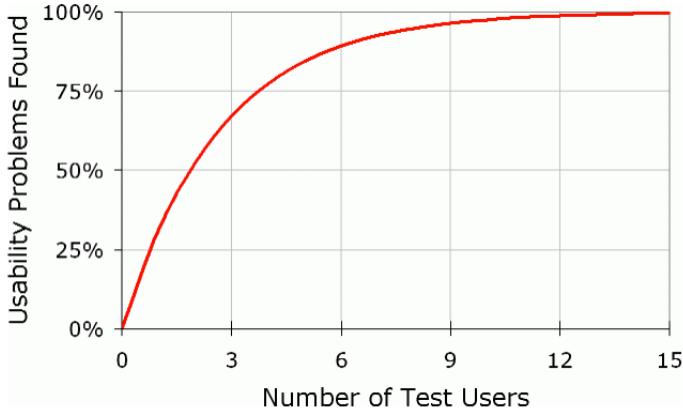


FIGURE 5.1: Number of users needed to find percentage of errors according to J. Nielsen[56]

tasks to provide real data. Observing and recording each usability test may help the developers to analyze their system, and correct the flaws[54].

Before starting the usability tests, the developers should plan goals for what they want to know about the system[55]. This will ensure that the purpose of the test is fulfilled. The developers should then plan tasks according to the desired results. These tasks should allow the user to explore the system, or the parts the developers wish to test, giving the test person some time per task, in order not to stress the test person.

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

Nielsen states that after five user tests, 85% of the errors have been found[56]. Molich[57] states that six test persons is the ultimate number. Faulkner[58] states that while six test persons *may* find 85 % of the errors, they may also find considerably less. In Faulkner's research, a number of five test users found between 55 % and 100 % of the errors, while 20 test persons found between 95 % and 100 % of the errors.

In addition to the practical usability tests, we will use techniques such as background interviews, focus groups and on-site observations. The interviews will be performed in order to achieve a set of control data we can use for comparison when performing later usability test and codesign sessions. As mentioned in 4.7, we plan on arranging focus group sessions at an early and mid stage of the development of our TUI. These sessions will help us develop our TUI and eliminate usability issues at an early stage. We also plan on using the technique of on-site observation by letting children operate our TUI freely, in order to observe interaction between the children and the TUI.

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

Before the test persons arrive, a test leader should be chosen, to guide the test persons through the process. The test leader should be in charge of testing and act as an interviewer to help the participant to “think-aloud”^[59]. 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)^[60] 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.^[61] have made a scale based on the SUS-forms from different system usability tests, in order to make it possible to compare the mean score of a system with what is an acceptable level of usability. In our testing, we will make use of a Norwegian version, developed by Svanæs (see Appendix A), which will be answered by the test users or the parent of the test user.

5.3 How to test usability on children and toddlers

While usability testing on children and toddlers have the same basic approach as testing on adults, there are many more precautions to be followed. Hanna et. al.^[62] 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^[7], this may not be great of a concern.

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

Hanna et. al. also point out changes that should be made to the testing environment as mentioned in 5.2. They recommend making the testing environment more suitable for children by placing colourful posters on the walls. Children of young age may be afraid

of “the Doctor’s Office” and we will need to make adjustments to avoid frightening the children upon their arrival at the test lab.

As mentioned by Donker and Markopoulos[63] 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.

Zaman et. al. proposes a way to measure the likeability of tangible interaction with preschoolers[64]. They based their research on work done by Read, MacFarlane and Casey [65], 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 will use a similar approach to understand which forms of interaction children like most.

5.4 Usability testing on mobile devices

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

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

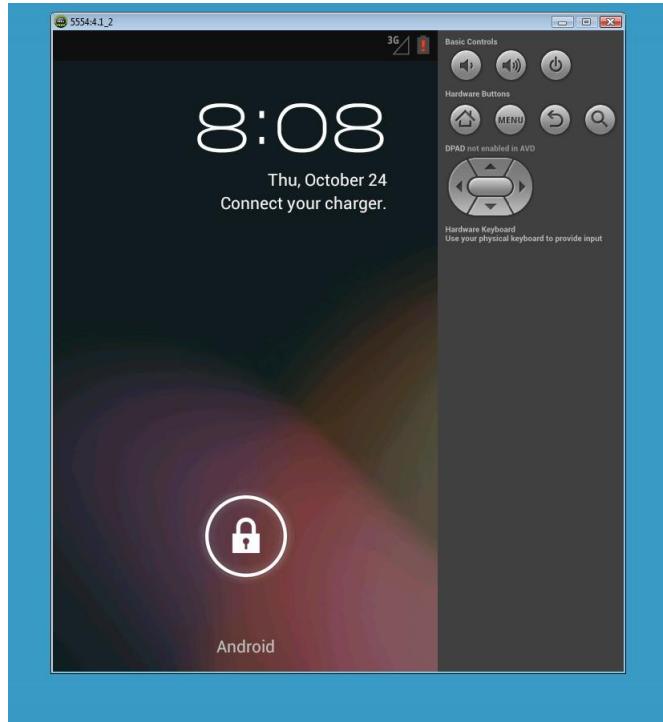


FIGURE 5.2: The Android Emulator running an emulation of Android 4.1

5.4.1 Emulator versus device

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

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

Using a real device has the benefit of being an actual device, and may lead to a more realistic interaction pattern when using the application. While a number of screen recorders for Android devices exist, these require that the device is rooted¹, which is

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

not an option for us. The use of a real device also allows the use of gestures, which is a benefit in contrast to the emulator which can simulate swiping.

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

5.5 Summary

The ISO-standards for usability and context of use[47] are well known and often mentioned, as they are in fact standards. We aim to achieve a usability as high as possible, through user-centered design and usability testing.

While we aim to follow Schneidermann's eight golden rules[48] when designing AsthmAPP, we focus more on the rules of consistency, informative feedback, reducing short-term memory load and designing dialog to yield closure, rather enabling shortcuts for frequent users (see Chapter 8.2 for an explanation).

Based on the research we read and the fact that NTNU has an excellent usability test lab at NSEP² we decided to do usability testing in doors, with smartphone devices.

²NSEP Usability lab - <http://www.ntnu.no/nsep/brukbarhetslaboratorium>

Chapter 6

Usability Tests

6.1 Purpose

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

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

6.2 Test Method

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

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

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

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

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

The results will later be analyzed to work out the improvements needed to be done to the system. The errors will be rated after level of severity[[54](#)].

- 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) - Have 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”.

6.2.1 Scenario and tasks given to the users

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

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

Chapter 7

AsthmaBuddy

7.1 Background

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

7.2 Technology

We have looked around for other options than Karotz to create our tangible user interface, i.e. Arduino and Raspberry Pi. Arduino is an open source electronics prototyping platform [69], which allows for many different combinations of configurations, while Raspberry Pi is a cheap computer on the size of a credit card. Arduino shields comes in many shapes and sizes and is built for modularity and extendability. A wide-range of components are available if you want to add technical functionality to an Arduino system, such as Bluetooth, WiFi or small motors. While Arduino allows complex hardware configurations, Raspberry Pi makes larger abstractions, which seemed like the better choice for us as developers. Arduino programs are normally written in C [70], and while there exists many tutorials and manuals for how to write Arduino code, we found the thought of writing in a programming language we had little prior knowledge of too

¹Karotz - www.karotz.com

challenging. 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 constraints on our system. Due to these facts, we choose to develop the system on a Raspberry Pi.

7.2.1 Raspberry Pi - Specifications overview

The Raspberry Pi was initially intended to teach British school children about computer programming [71]. Since its release, it took an unexpected turn when lots of computer enthusiasts bought the product to do their own mini projects for a cheap price.

The specification of a Raspberry Pi (Model B) is included in Table 7.1. Figure 7.1 shows an overview of the Raspberry Pi.

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

TABLE 7.1: Raspberry Pi specifications

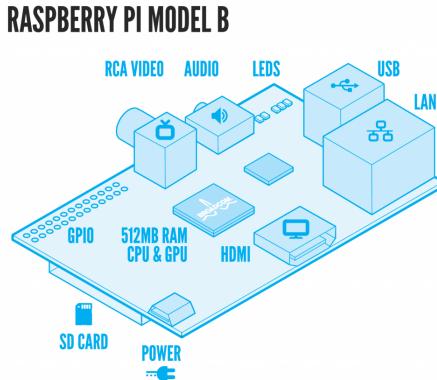


FIGURE 7.1: Raspberry Pi Model B architecture. *Image source:* <http://raspberrypi.org/faqs>

7.2.2 Additional Components

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

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

The RFID reader we used was a Sparkfun ID-12LA². One of the requirements of the USB reader was that it should be able to connect through an USB-port.

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

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

²Sparkfun ID-12LA documentation - [http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Sensors/ID/ID-2LA,%20ID-12LA,%20ID-20LA\(2013-4-10\).pdf](http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Sensors/ID/ID-2LA,%20ID-12LA,%20ID-20LA(2013-4-10).pdf)

to what action(s) is expected from the user during a treatment (see more in INSERT REFERENCE TO PROTOTYPE 1).

Pi4j Pi4j³ is a Java framework that allows development for Raspberry Pi in Java, without having to write anything in C.

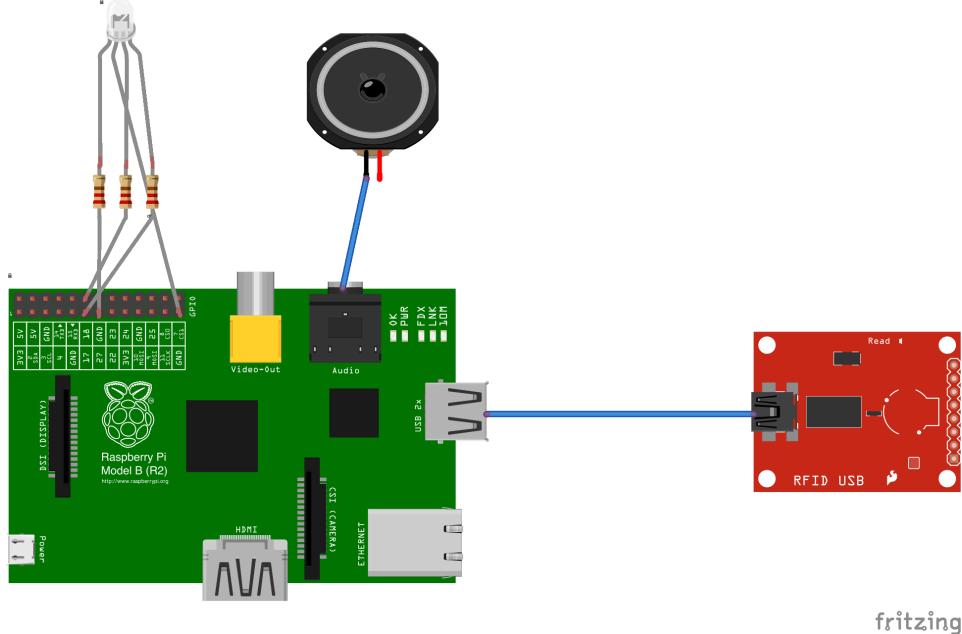


FIGURE 7.2: CaptionBot

7.3 System Overview

7.3.1 Use Cases

Figure 7.3 shows a general overview of the use cases we have included in our prototype. A medication process can be started in one out of two ways. A parent can register an alarm by using AsthmAPP. This alarm is then triggered by AsthmaBuddy, giving the child a notification that it is time to take their medicine.

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

³Pi4j - <http://pi4j.com>

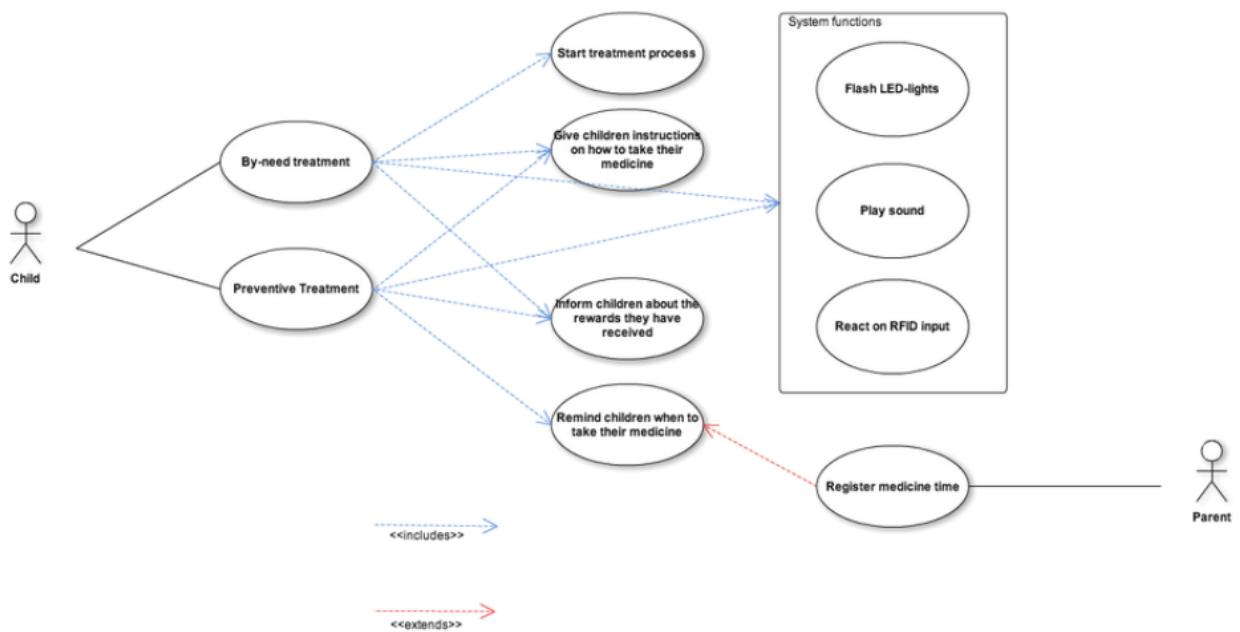


FIGURE 7.3: AsthmaBuddy Use Cases

7.3.2 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 amount of stars 10. System plays sound to tell the user how many stars he/she has collected totally
Extensions	x.a User aborts treatment by not continuing the sequence

TABLE 7.2: 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 registers interacts with AsthmaBuddy, to notify that he/she is ready for the treatment 4. Start instructions by playing sound, telling the user to find a grown-up that can keep watch 5. System waits for interaction to make sure the user is ready 6. System tells the user to mount the medicine on the mask and put the medicine towards AsthmaBuddy's face 7. System plays sound to simulate breathing 8. System plays sound to tell the user how easy it was to take medicines and that it is the user's turn 9. System plays sound to instruct user, telling the user to shake the medicine 10. System waits for interaction to make sure the user is ready 11. System plays sound to instruct user to put the mask on his/her face 12. System plays sound counting to 10. 13. System plays sound to tell the user he/she has done a good job 14. System calculates reward based on health state 15. System plays sound to award user with the calculated amount of stars 16. System makes a HTTPGet call to the server to find the total amount of stars collected 17. System plays sound to inform the user about how many stars the user has collected totally
Extensions	x.a Child does not interact with AsthmaBuddy when prompted

TABLE 7.3: Textual use case: By need treatment

7.3.3 State Diagram

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

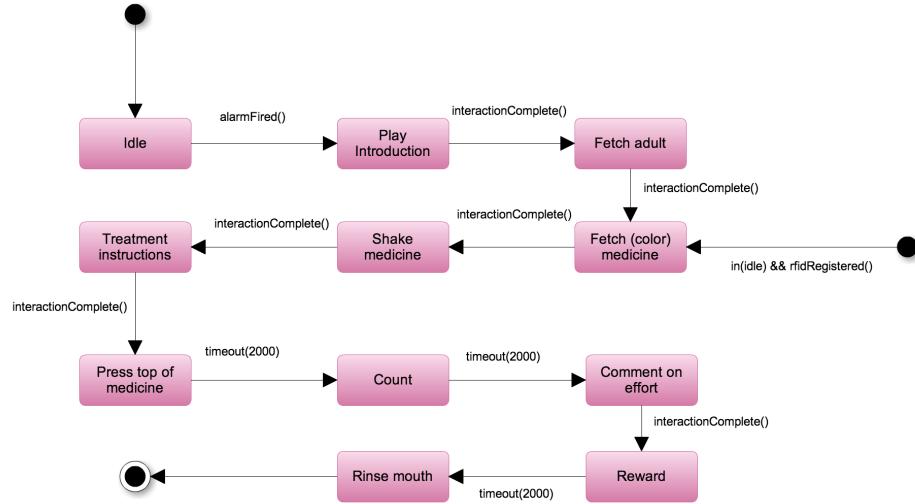


FIGURE 7.4: AsthmaBuddy State Diagram.

7.3.4 Sequence Diagram

Figures 7.5 - 7.8 shows sequence diagrams of how the system works internally. Some abstractions have been made, in order to reduce the cluster of arrows.

7.3.4.1 By Need Treatment

7.3.4.2 Planned Treatment

7.3.4.3 Playing Instructions

7.3.4.4 Finishing a Treatment

7.3.5 Node Server

In addition to the Java application running on the Raspberry Pi, we developed a Node.js server⁴. This backend system was developed in order to easily visualize the rewards given to a child. The initial problem is that AsthmAPP stores data to a MySQL

⁴Node.js - <http://nodejs.org/>

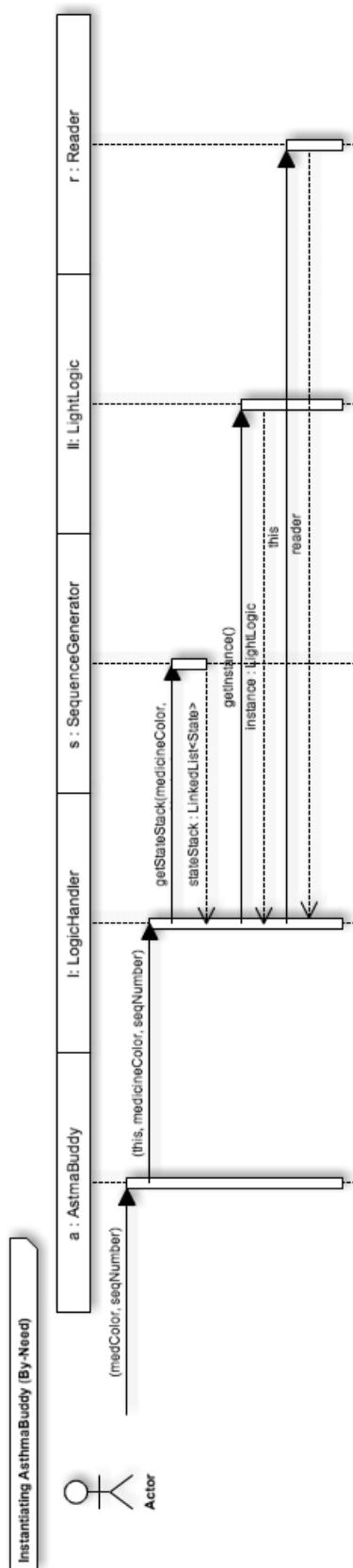


FIGURE 7.5: By Need Treatment - Sequence Diagram

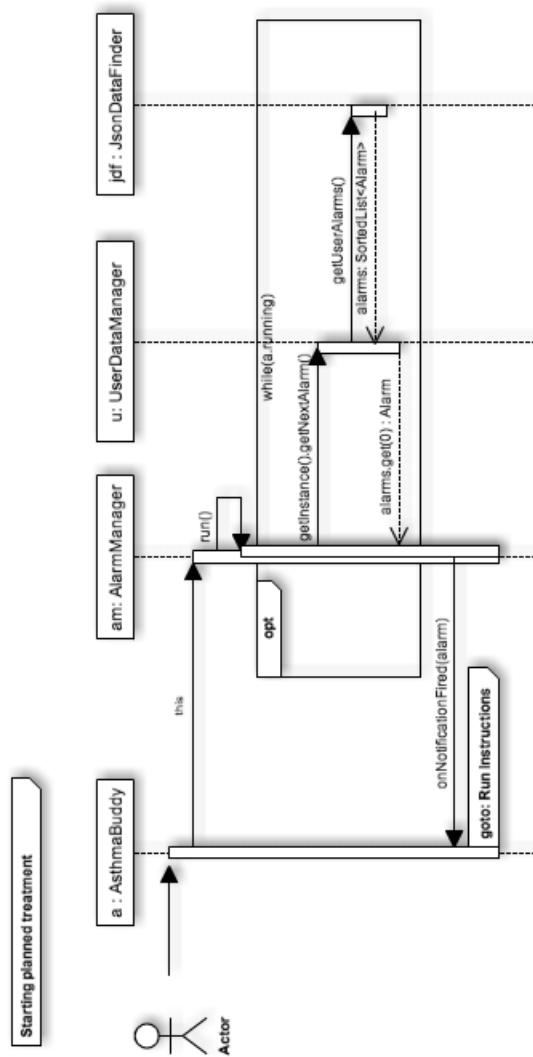


FIGURE 7.6: Planned Treatment - Sequence Diagram

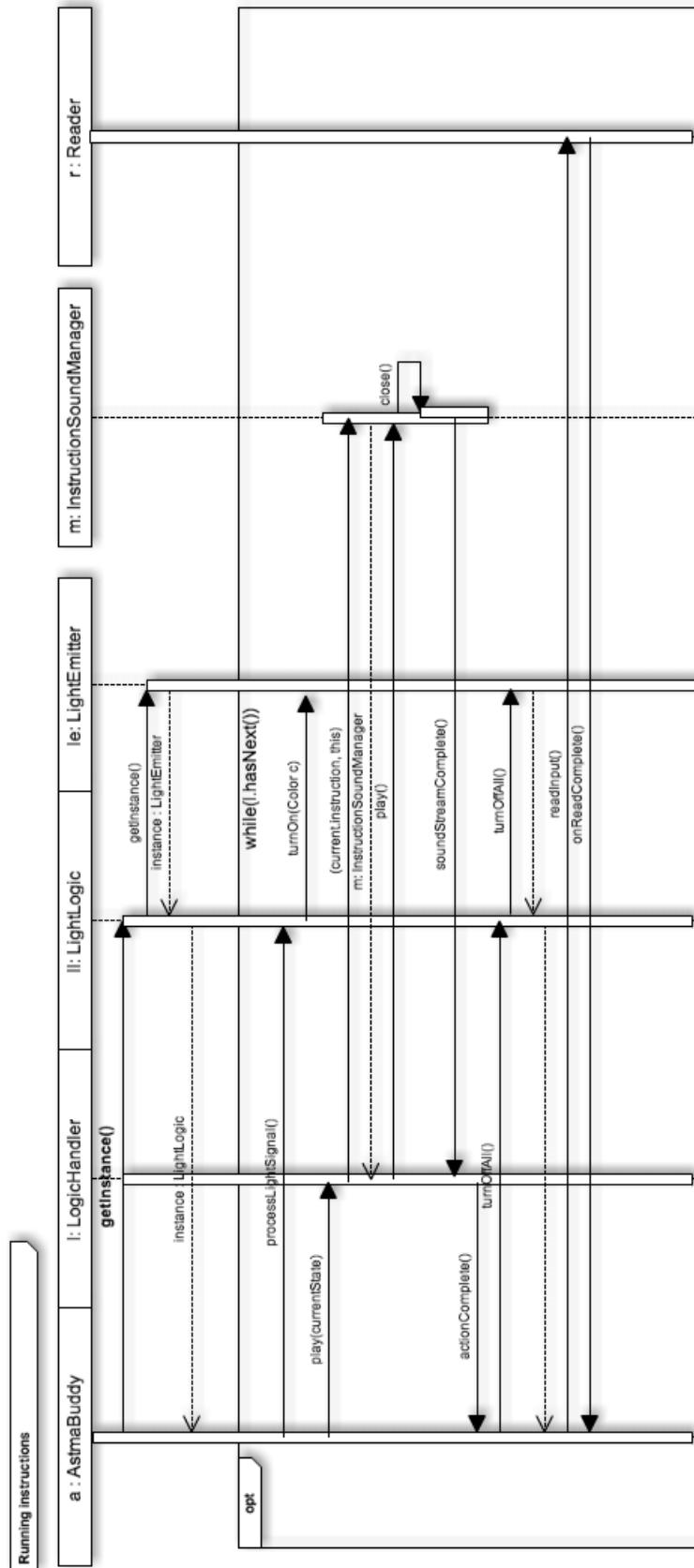


FIGURE 7.7: Playing Instructions - Sequence Diagram

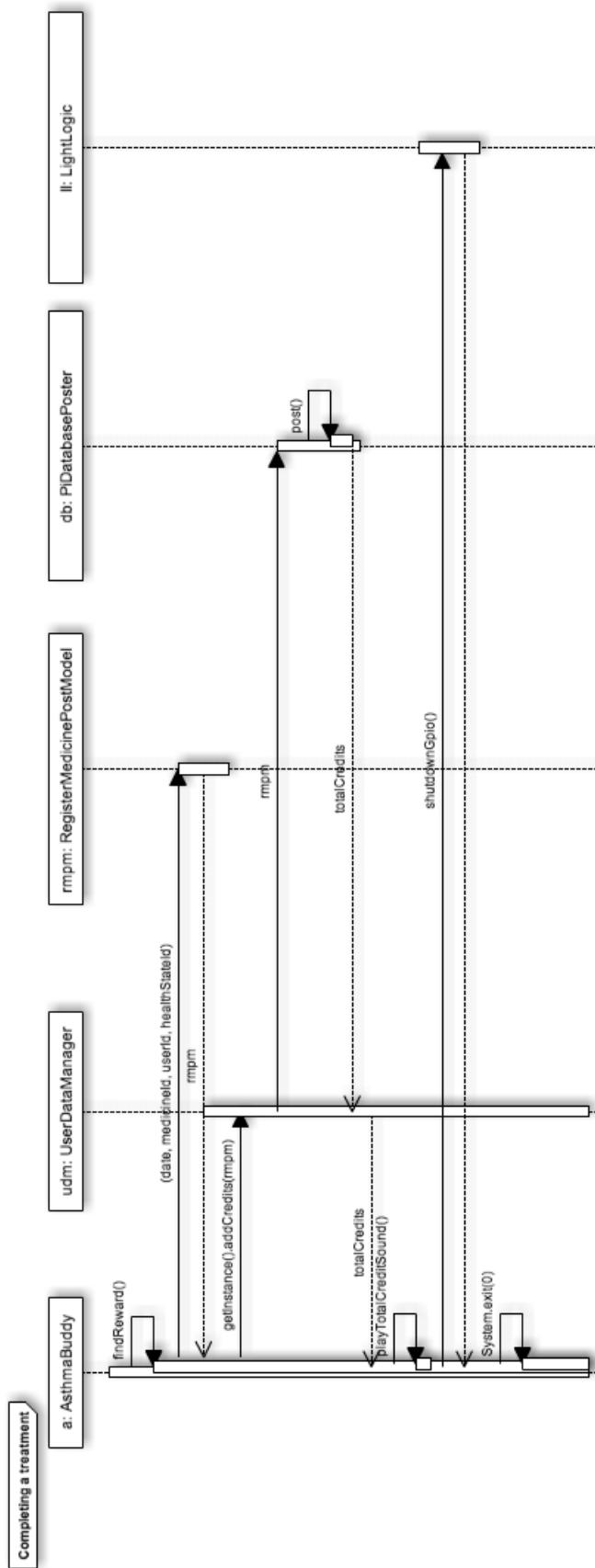


FIGURE 7.8: Finishing a treatment - Sequence Diagram

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 a webservice, which includes the rewards a child has been given until now (for instance, by use of the smartphone), and the alarms set for this user. When AsthmaBuddy starts running, it checks for alarms to be fired every 60 seconds. When a child has finished a treatment, AsthmaBuddy updates the database, with the childId previously retrieved, and the amount of stars a child gathered during his or her treatment. Additionally, with the data retrieved from the database, AsthmaBuddy has the capability to tell the user how many stars a child has gathered⁵.

7.4 Design Rationale

When designing AsthmaBuddy we choose to use a teddy bear as an avator for our system. There are several reasons as to why we think this is an appropriate avatar. Teddy bears are well known toys, and has been loved for a long time. They are considered gender-neutral [72] [73] and in our subjective opinion it is a toy that could be discretely placed in a children's room. With the look of a teddy bear, AsthmaBuddy can easily be placed among other toys and not be too visible. It was also important for us to choose a teddy bear of some size. A too thin bear could lead to problems with fitting the system inside the bear, and could in order lead to scepticism from the children. AsthmaBuddy will bear resemblance to Tamagotchi [74] and Furby [75], but AsthmaBuddy's purpose is to motivate, instruct and learn children about asthma, not being a toy meant purely for play.

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

Norwegian fire fighters have used a teddy bear in order to calm down children who find themselves in dramatic situations ⁶. The fire fighters state that the children respond

⁵Since this is a prototype, this functionality only works until a child has gathered 20 stars. It became cumbersome to handle rewards totalling more than 20 stars

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

positively to the teddy bear. While we were not able to find scientific research done on the use of teddy bears in dramatic situations, we found this news article interesting and a relevant mention to our research.

[Pictures of the bear we chose?]

7.5 Prototype version 1

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

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

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

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

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

7.6 Evaluation of prototype version 1

Interaction Method	Comments	Will it be in version 2?
Give AsthmaBuddy a “High Five”		
Hold AsthmaBuddy’s hand		
Hold smartphone close to AsthmaBuddy’s belly		
Press AsthmaBuddy’s nose		
Press AsthmaBuddy’s belly		
Hold medicine close to AsthmaBuddy’s mouth		
Hold RFID-chip close to AsthmaBuddy’s nose		
Hold RFID-chip close to AsthmaBuddy’s belly		
Clap your hands		
A variation of the above interactions		

TABLE 7.4: Evaluation of interaction methods for AsthmaBuddy

7.7 Prototype version 2

7.8 Further improvements

Chapter 8

AsthmAPP

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

8.1 Basic System Architecture

Figure [MAKE NEW PICTURE OF ARCHITECTURE] shows an overview of the architecture we intend to use for our solution. We will build upon the architecture used by Aaberg et. al.[\[1\]](#).

We have access to a MySQL-server hosted at NTNU, which we will access by a PHP-server hosted at NTNU. The main reason we have to access the database through a server layer, is that it is quite cumbersome to connect to the database if a device is not connected at NTNU's network. In addition, by having a webservice do some of the work for us, it becomes easier to parse results from the database through JSON.

The downside by having this approach is that scalability suffers from this architectural choice. However, we consider these problems as outside the scope of our thesis, and will continue using this approach.

8.2 How Usability Research has Affected our Design

While designing AsthmAPP, we strive for a easy-to-use design with a good overview. In chapter [5](#) we described usability and general terms a designer should consider. We have especially taken Shneidermann's eight golden rules into consideration when designing[\[48\]](#)

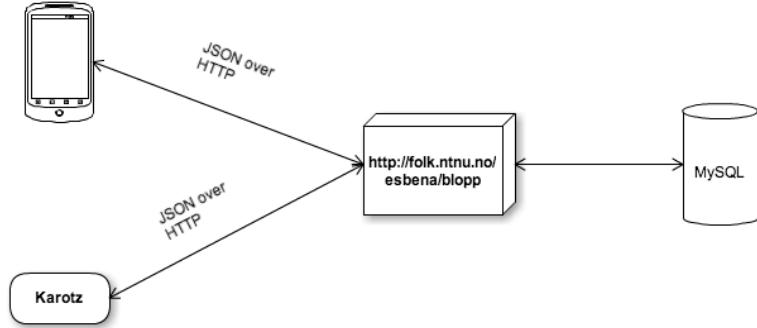


FIGURE 8.1: Basic architecture of our system

in addition to the Android Design Principles [76]. We have tried to lighten the short-term memory load by using a combination of sounds, pictures and text to tell the user what options are available or what is expected from the user. During a treatment the user is prompted to take active action in order to continue through the process, giving the user a locus of control. The layout for both partitions of AsthmAPP give a general overview, and has few shortcuts between the different elements. To navigate from one element to another the user will have to go via main menu. While this breaks with Shneidermann's rules and the Android design principles, we believe that the solution we have found is the best solution.

8.3 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].

8.3.1 Treatment

Figure 8.3 shows a screenshot for the application when the child starts their treatment. Starting this sequence can come from one out of two events: (i) *The child reacts to an alarm set in the parent partition*, and (ii) *The child needs to take their medicine by need*. If (ii) is the case, the child is instructed to pick the medicine from a list shown by the application. If (i) is the case, the medicine is chosen beforehand. When a child has started their treatment, they are taken through an animated sequence, which reacts when a child interacts with the device. In addition, they are being told what to do through the comforting voice of Andreas Ystmark.

8.3.2 Showing rewards

Figure 2.4 shows a screenshot for the application when the child wants to review how many stars he/she has received, based on the amount of treatments completed. We have made two design decisions for our reward system. First, we never want stars to be removed. We don't want children to feel that credits are being removed from them. Second, we can't assume children are able to read, and thus we have made it countable, and hopefully they can comprehend how many stars they've actually got. In addition, we provide some help to those who are able to read numbers, by showing the amount of stars a child has on the top. The downside here comes when a child has been completed a huge number of treatments, as this will obscure the view.

8.3.3 Shop

In the shop, children are allowed to buy rewards from parents. Figure 8.4 shows a inside-view of our shop. Children can buy a reward by pressing the selected reward in the menu. Due to time constraints and lack of good software solutions, we have not been able to implement voice over, so the children might need help with reading the name of the rewards. The possibility of adding pictures to represent the reward should make it easier for children to understand.

8.3.4 Treatment instructions

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

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

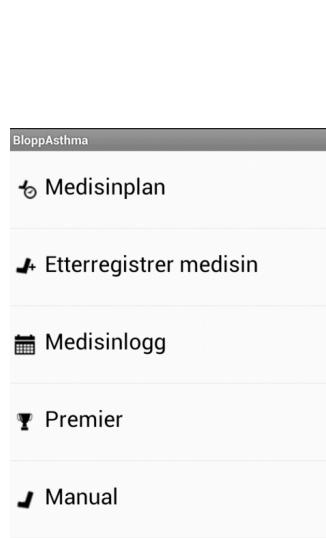


FIGURE 8.2: Main menu of partent partition

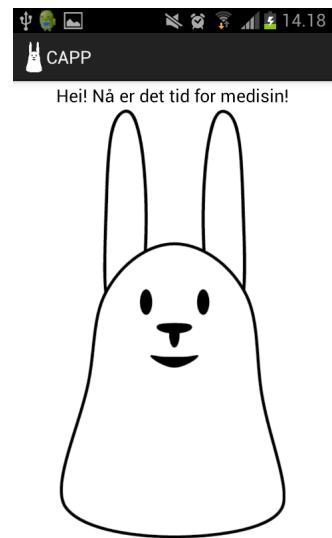


FIGURE 8.3: Starting a treatment

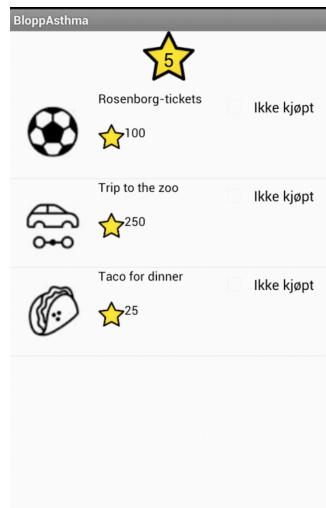


FIGURE 8.4: The shop

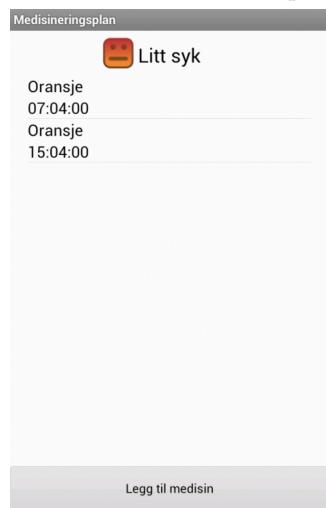


FIGURE 8.6: Edit medicine plan

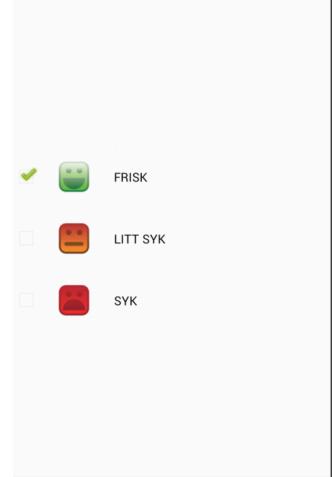


FIGURE 8.5: List of medicine plans

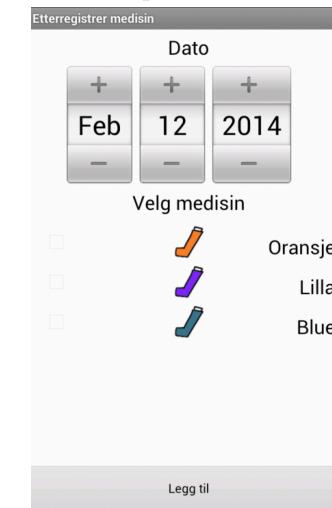


FIGURE 8.7: Register treatment

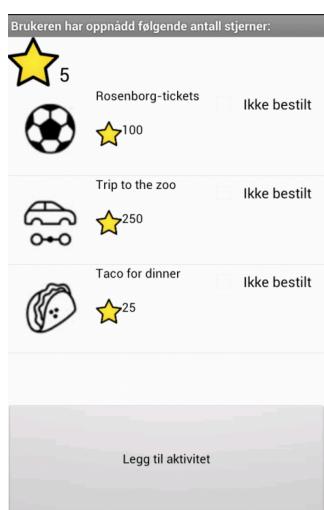


FIGURE 8.8: List of rewards

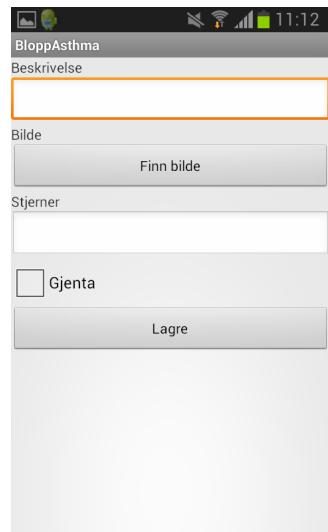


FIGURE 8.9: List of rewards

8.4 Parent Partition

8.4.1 Menu

Figure 8.2 shows the main menu of the parent partition. It has six options (Norwegian translation in parenthesis):

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

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

8.4.2 Medicine plan

Creating a medicine plan for asthma treatment is highly connected to the Traffic Light System explained in Appendix H. 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 2.16 and 8.6 shows the view in which one may change medicine plan their child are currently on, in addition to setting alarms where

appropriate. For instance, one might set an alarm at 07:00, which makes the user aware before it is time to leave for school. Changing medicine plan is done by selecting the checkbox at the left side of the panel.

8.4.3 Register Treatment

What happens if a child need their medicine, but the application or our TUI is not nearby? They would probably be disappointed because they did not get their star, and did not get any rewards. Fortunately, it is possible to register a medicine that has been taken afterwards, which entitle the child the amount of stars they should have gotten. *Register Treatment* allows parents to register the medicine, at any given day prior to current time (See Figure 8.7).

8.4.4 Medicine log

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

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

8.4.5 Manual

The manual contains exactly the same information as shown in Section 8.3.4. The manual is added to both the parent partition and the child partition of the application.

¹Measured by NILU - [www.http://luftkvalitet.info/](http://luftkvalitet.info/)

²Measured by NAAF - [www.http://www.pollenvarslingen.no/](http://www.pollenvarslingen.no/)

This is done because it is important for both the children and the parents to know how to use the medicine correctly.

8.4.6 Reward

Figure 8.8 shows the list of possible rewards a child might receive. They are added by parents through *Add reward*. The idea of having parents set their children’s rewards is to specify rewards according to children’s interest (see Section 3.4). Figure 8.9 shows how one may add a reward. Users inserts a description, then either take a photo or select one out of our standard images. It is possible to set a reward on “Repeat”, which will make the reward appear multiple times, each time with an increased cost. When the user press *Save* (Lagre), the reward is added and children have the possibility to buy it.

Chapter 9

Results

Chapter 10

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.

Chapter 11

Conclusion

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

11.1 Research Questions

The research questions presented in Chapter 1.3 provides a basis for summarization of results discussed in Chapter 9 Results and Chapter 10.

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

RQ2 What is the ideal design for a TUI in order to motivate children to take their asthma medicine?

11.2 Process Evaluation

Chapter 12

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.

Appendix A

Norwegian SUS form

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

Noen spørsmål om systemet du har brukt.

Vennligst sett kryss i kun en rute pr. spørsmål.

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

|

SUS
Norsk versjon ved Dag Svanæs
NTNU 2006

FIGURE A.1: Norwegian SUS form

Appendix B

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 [1]

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.

B.1 Improvements

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

B.1.1 Rewardsystem

The children's application (CAPP) is all about changing the children's view of medication to something positive. It shall be a motivation for the children to take their

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.

B.1.2 Distraction sequence for children

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

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

B.1.3 User testing of the guardian application

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

B.1.4 Web application

There is a possibility of making this application as a web application, as a whole. By extracting the functionality and running it on a web service it would make it easier for

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

B.1.5 Support for more children

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

B.2 Ideas and minor improvements

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

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

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

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

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

Appendix C

Questionnaire. Demographics

Vennligst besvar spørsmålne under, før vi begynner testen.

Kjønn
Alder
Utdanning
Yrke

Appendix D

Interview conducted before usability testing

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

Appendix E

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 F

Scenario and tasks

Du er verge til et barn på 4 år. Dere har nylig vært hos en lege med spesialkompetanse på barnesykdommer. Barnet har fått diagnostisert astma. For å enklere holde orden på at medisinene blir tatt til riktig tid, på riktig måte, har du lastet ned applikasjonen 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 1: Du skal sette opp en medisineringsplan i henhold til anbefaling fra legen. For enkelhets skyld skal du kun endre medisineringsplanen for barnet når det er helt friskt. Legg til en varsel for “Flutide” kl 13:37 og en varsel for “Seretide” kl 18:30. Velg deretter å følge denne medisineringsplanen.

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

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

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

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

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

Appendix G

AsthmaBuddy Manual

The following Appendix works as a user manual for AsthmaBuddy.

Appendix H

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.

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

Want to take an Asthma Class: Call 983-6336

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

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 I

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.

I.1 AsthmaBuddy

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

I.1.1 Instructions

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

I.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.*

I.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 J

Constraints

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

J.1 The Health Register Act

Norway has specific laws for storing of medical information. The most significant law is “The Health Register Act¹”[77]. 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. If the application were ever to be deployed to Google Play, we would need permission from *The Data Protection Authority*, but it not required if the application is just for research purposes. Our application is still pending.

J.2 Measures for Anonymization

Pursuant to section 16 of the Health Register Act [77] 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

²<https://helseforskning.etikkom.no/> - i

Bibliography

- [1] Dale Gisvold Svalestuen Aaberg, Aarseth. Blopp - development of a prototype for treatment of asthmatic children, using android and karotz. 2012.
- [2] Norges astma- og allergiforbund. URL <http://www.naaf.no/>.
- [3] Jonas Asheim. Konsept for forbedret behandling av barn rammet av astma/rs-virus, 2012.
- [4] Nasjonal strategi for forebygging og behandling av astma- og allergisykdommer. URL <http://www.regjeringen.no/upload/hoD/Dokumenter%20fha/astmastrategi.pdf>.
- [5] Jacob Anhøj and Claus Møldrup. Feasibility of collecting diary data from asthma patients through mobile phones and sms (short message service): response rate analysis and focus group evaluation from a pilot study. *Journal of Medical Internet Research*, 6(4), 2004.
- [6] Toddlers use tablets often, 2011. URL <http://www.nrk.no/nyheter/norge/1.7921036>.
- [7] Babies using smartphones. URL <http://www.babies.co.uk/blog/babies-using-smartphones/>.
- [8] Nor Azah Abdul Aziz. Childrens interaction with tablet applications: Gestures and interface design. *Children*, 2(03), 2013.
- [9] Kit Huckvale, Mate Car, Cecily Morrison, and Josip Car. Apps for asthma self-management: a systematic assessment of content and tools. *BMC medicine*, 10(1):144, 2012.
- [10] Andrea Leal Penados, Mathieu Gielen, Pieter-Jan Stappers, and Tinus Jongert. Get up and move: An interactive toy that measures (in) activity and stimulates physical activity.

- [11] Communication of illness related experiences of chronically ill children and the effect of sisom, a computerized symptom assessment tool. URL <http://www.communicaretools.org/sisom/research/the-effect-of-sisom.aspx>.
- [12] James Currier. Gamification: Game mechanics is the new marketing, 2008. URL <http://blog.oogalabs.com/2008/11/05/gamification-game-mechanics-is-the-new-marketing/>.
- [13] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: defining "gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, MindTrek '11, pages 9–15, New York, NY, USA, 2011. ACM. ISBN 978-1-4503-0816-8. doi: 10.1145/2181037.2181040. URL <http://doi.acm.org/10.1145/2181037.2181040>.
- [14] Kai Huotari and Juho Hamari. Defining gamification: a service marketing perspective. In *Proceeding of the 16th International Academic MindTrek Conference*, pages 17–22. ACM, 2012.
- [15] Serious games initiatve, 2013. URL <http://http://www.seriousgames.org/>.
- [16] Alf Inge Wang, OK Mørch-Storstein, and T Øfsdahl. Lecture quiz-a mobile game concept for lectures. In *Proceedings of the 11th IASTED International Conference on Software Engineering and Application (SEA07)*, pages 305–310, 2007.
- [17] Mikael Lebram, Per Backlund, Henrik Engström, and Mikael Johannesson. Design and architecture of sidh—a cave based firefighter training game. In *Design and Use of Serious Games*, pages 19–31. Springer, 2009.
- [18] Seth Cooper, Firas Khatib, Adrien Treuille, Janos Barbero, Jeehyung Lee, Michael Beenen, Andrew Leaver-Fay, David Baker, Zoran Popović, et al. Predicting protein structures with a multiplayer online game. *Nature*, 466(7307):756–760, 2010.
- [19] Firas Khatib, Frank DiMaio, Seth Cooper, Maciej Kazmierczyk, Miroslaw Gilski, Szymon Krzywda, Helena Zabranska, Iva Pichova, James Thompson, Zoran Popović, et al. Crystal structure of a monomeric retroviral protease solved by protein folding game players. *Nature structural & molecular biology*, 18(10):1175–1177, 2011.
- [20] Judd Antin and Elizabeth F Churchill. Badges in social media: A social psychological perspective. In *CHI 2011 Gamification Workshop Proceedings (Vancouver, BC, Canada, 2011)*, 2011.

- [21] Kimberly Ling, Gerard Been, Pamela Ludford, Xiaoqing Wang, Klarissa Chang, Xin Li, Dan Cosley, Dan Frankowski, Loren Terveen, Al Mamanur Rashid, et al. Using social psychology to motivate contributions to online communities. *Journal of Computer-Mediated Communication*, 10(4):00–00, 2005.
- [22] Ian Bogost. Gamification is bullshit, 2011. URL http://www.bogost.com/blog/gamification_is_bullshit.shtml.
- [23] Paul Ekman. *Emotions revealed: Recognizing faces and feelings to improve communication and emotional life*. Macmillan, 2007.
- [24] McGonigal Jane. Reality is broken, why games make us better and how they can change the world, 2011.
- [25] Truls Steinung. Interessante utfordringer: En studie av gamification og belønningsstrukturer i et spillperspektiv. 2012.
- [26] Gabe Zichermann and Christopher Cunningham. *Gamification by Design: Implementing game mechanics in web and mobile apps*. O'Reilly Media, Inc., 2011.
- [27] Scott Nicholson. A user-centered theoretical framework for meaningful gamification. *Proceedings GLS*, 8, 2012.
- [28] Theodore W Frick Michael D. Corry and Lisa Hansen. User-centered design and usability testing of a web site: An illustrative case study. *Educational Technology Research and Development*, 45:65–76, 1997. URL <http://www.jstor.org/stable/30221343>.
- [29] Andrew J Stapleton. Serious games: Serious opportunities. In *Australian Game Developers Conference, Academic Summit, Melbourne*, 2004.
- [30] Hiroshi Ishii and Brygg Ullmer. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, pages 234–241. ACM, 1997.
- [31] John Underkoffler and Hiroshi Ishii. Urp: a luminous-tangible workbench for urban planning and design. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, pages 386–393. ACM, 1999.
- [32] Hiroshi Ishii, Carlo Ratti, Ben Piper, Yao Wang, Assaf Biderman, and E Ben-Joseph. Bringing clay and sand into digital designcontinuous tangible user interfaces. *BT technology journal*, 22(4):287–299, 2004.
- [33] Lucia Terrenghi, Matthias Kranz, Paul Holleis, and Albrecht Schmidt. A cube to learn: a tangible user interface for the design of a learning appliance. *Personal and Ubiquitous Computing*, 10(2-3):153–158, 2006.

- [34] Lori L Scarlatos, Yuliya Dushkina, and Shalva Landy. Ticle: a tangible interface for collaborative learning environments. In *CHI'99 Extended Abstracts on Human Factors in Computing Systems*, pages 260–261. ACM, 1999.
- [35] Zhiying Zhou, Adrian David Cheok, JiunHorng Pan, and Yu Li. Magic story cube: an interactive tangible interface for storytelling. In *Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology*, pages 364–365. ACM, 2004.
- [36] Danae Stanton, Victor Bayon, Helen Neale, Ahmed Ghali, Steve Benford, Sue Cobb, Rob Ingram, Claire O’Malley, John Wilson, and Tony Pridmore. Classroom collaboration in the design of tangible interfaces for storytelling. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 482–489. ACM, 2001.
- [37] Gillian Crampton Smith. The hand that rocks the cradle. *ID magazine*, pages 60–65, 1995.
- [38] Kazuyoshi Wada, Takanori Shibata, Tomoko Saito, and Kazuo Tanie. Effects of robot-assisted activity for elderly people and nurses at a day service center. *Proceedings of the IEEE*, 92(11):1780–1788, 2004.
- [39] William Farr, Nicola Yuill, and Hayes Raffle. Social benefits of a tangible user interface for children with autistic spectrum conditions. *Autism*, 14(3):237–252, 2010.
- [40] Lesley Xie, Alissa N Antle, and Nima Motamedi. Are tangibles more fun?: comparing children’s enjoyment and engagement using physical, graphical and tangible user interfaces. In *Proceedings of the 2nd international conference on Tangible and embedded interaction*, pages 191–198. ACM, 2008.
- [41] Brygg Anders Ullmer. *Tangible interfaces for manipulating aggregates of digital information*. PhD thesis, Massachusetts Institute of Technology, 2002.
- [42] Sriram Subramanian and Bernard Champoux. A design approach for tangible user interfaces.
- [43] Victoria Bellotti, Maribeth Back, W Keith Edwards, Rebecca E Grinter, Austin Henderson, and Cristina Lopes. Making sense of sensing systems: five questions for designers and researchers. In *Proceedings of the SIGCHI conference on Human factors in computing systems: Changing our world, changing ourselves*, pages 415–422. ACM, 2002.

- [44] Elizabeth B-N Sanders and Pieter Jan Stappers. Co-creation and the new landscapes of design. *Co-design*, 4(1):5–18, 2008.
- [45] Lars Albinsson, Mikael Lind, and Olov Forsgren. Co-design: an approach to border crossing, network innovation. *Expanding the knowledge economy: issues, applications, case studies*, 4(Part 2):977–983, 2007.
- [46] Donald A Norman and Stephen W Draper. *User centered system design; new perspectives on human-computer interaction*. L. Erlbaum Associates Inc., 1986.
- [47] International Organization for Standardization (ISO). Ergonomics of human system interaction-part 210: Human-centred design for interactive systems (formerly known as 13407). 9241-210, 2010. URL http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52075.
- [48] Ben Shneiderman and Shneiderman Ben. *Designing The User Interface: Strategies for Effective Human-Computer Interaction*, 4/e (New Edition). Pearson Education India, 2003.
- [49] Eelke Folmer and Jan Bosch. Architecting for usability: a survey. *Journal of systems and software*, 70(1):61–78, 2004.
- [50] Jakob Nielsen. *Usability engineering*. Access Online via Elsevier, 1994.
- [51] Jeffrey Rubin and Dana Chisnell. *Handbook of usability testing: howto plan, design, and conduct effective tests*. Wiley. com, 2008.
- [52] Maloney-Krichmar D. Preece J Abras, C. User-centered design. *Encyclopedia of Human-Computer Interaction*, 2004.
- [53] Plaisant-C. Cohen M. Jacobs S. Schneiderman, B. Designing the user interface: Strategies for effective human-computer interaction - 5th edition. 2009.
- [54] Joseph S Dumas, Janice C Redish, and KA Schriver. A practical guide to usability testing. *IEEE Transactions on Professional Communications*, 38(1):45–45, 1995.
- [55] International Organization for Standardization (ISO). Iso/iec 25062:2006 software engineering – software product quality requirements and evaluation (square) – common industry format (cif) for usability test reports. 25062, 2006. URL http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=43046.
- [56] J. Nielsen. Why you only need to test with 5 users. 2000. URL <http://www.useit.com/alertbox/20000319.html>.
- [57] Rolf Molich and Henrik Larsen. *Usable web design*. Nyt Teknisk Forlag, 2008.

- [58] Laura Faulkner. Beyond the five-user assumption: Benefits of increased sample sizes in usability testing. *Behavior Research Methods, Instruments, & Computers*, 35(3):379–383, 2003.
- [59] Clayton Lewis. *Using the "thinking-aloud" method in cognitive interface design*. IBM TJ Watson Research Center, 1982.
- [60] J. Brooke. Sus- a quick and dirty usability scale. pages 189–194, 1996.
- [61] Kortum P. Bangor, A. and J. Miller. Determining what individual sus scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, 4:114–123, May 2009.
- [62] Risden Hanna and Alexander. Guidelines for usability testing with children. pages 9–14, September + October 1997.
- [63] A Donker and P Markopoulos. A comparison of think-aloud, questionnaires and interviews for testing usability with children. *People and Computers XVI-Memorable Yet Invisible, Proceedings of HCI*, pages 305–316, 2002.
- [64] Bieke Zaman and VV Abeele. How to measure the likeability of tangible interaction with preschoolers. *Proc. CHI Nederland*, 5, 2007.
- [65] JC Read, SJ MacFarlane, and Chris Casey. Endurability, engagement and expectations: Measuring children’s fun. In *Interaction Design and Children*, volume 2, pages 1–23. Shaker Publishing Eindhoven, 2002.
- [66] Elena T Beck, Morten K Christiansen, Jesper Kjeldskov, Nikolaj Kolbe, and Jan Stage. Experimental evaluation of techniques for usability testing of mobile systems in a laboratory setting. In *proceedings of Ozchi*, pages 106–115, 2003.
- [67] Rudy Schusteritsch, Carolyn Y Wei, and Mark LaRosa. Towards the perfect infrastructure for usability testing on mobile devices. In *CHI’07 extended abstracts on Human factors in computing systems*, pages 1839–1844. ACM, 2007.
- [68] Adriana Holtz Betiol and Walter de Abreu Cybis. Usability testing of mobile devices: A comparison of three approaches. In *Human-Computer Interaction-INTERACT 2005*, pages 470–481. Springer, 2005.
- [69] Arduino. URL <http://www.arduino.cc/>.
- [70] Brian D Strahl and C David Allis. The language of covalent histone modifications. *Nature*, 403(6765):41–45, 2000.
- [71] About the raspberry pi foundation. URL <http://raspberrypi.org/about>.

- [72] Karen Stagnitti, Sylvia Rodger, and John Clarke. Determining gender-neutral toys for assessment of preschool children's imaginative play. *Australian Occupational Therapy Journal*, 44(3):119–131, 1997.
- [73] Isabelle D Cherney and Kamala London. Gender-linked differences in the toys, television shows, computer games, and outdoor activities of 5-to 13-year-old children. *Sex Roles*, 54(9-10):717–726, 2006.
- [74] Tamagotchi. URL <http://www.tamagotchi.com>.
- [75] Electronic furby - the furbsters guide to all things furbish. URL <http://www.mimitchi.com/html/furby.htm>.
- [76] Android design principles. URL <https://developer.android.com/design/get-started/principles.html>.
- [77] Lov om heleseregistre og behandling av helseopplysninger, May 2001. LOV-2001-05-18-24.