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We.Tree – Connecting young individuals with Type 1 Diabetes Mellitus in rural areas through serious games

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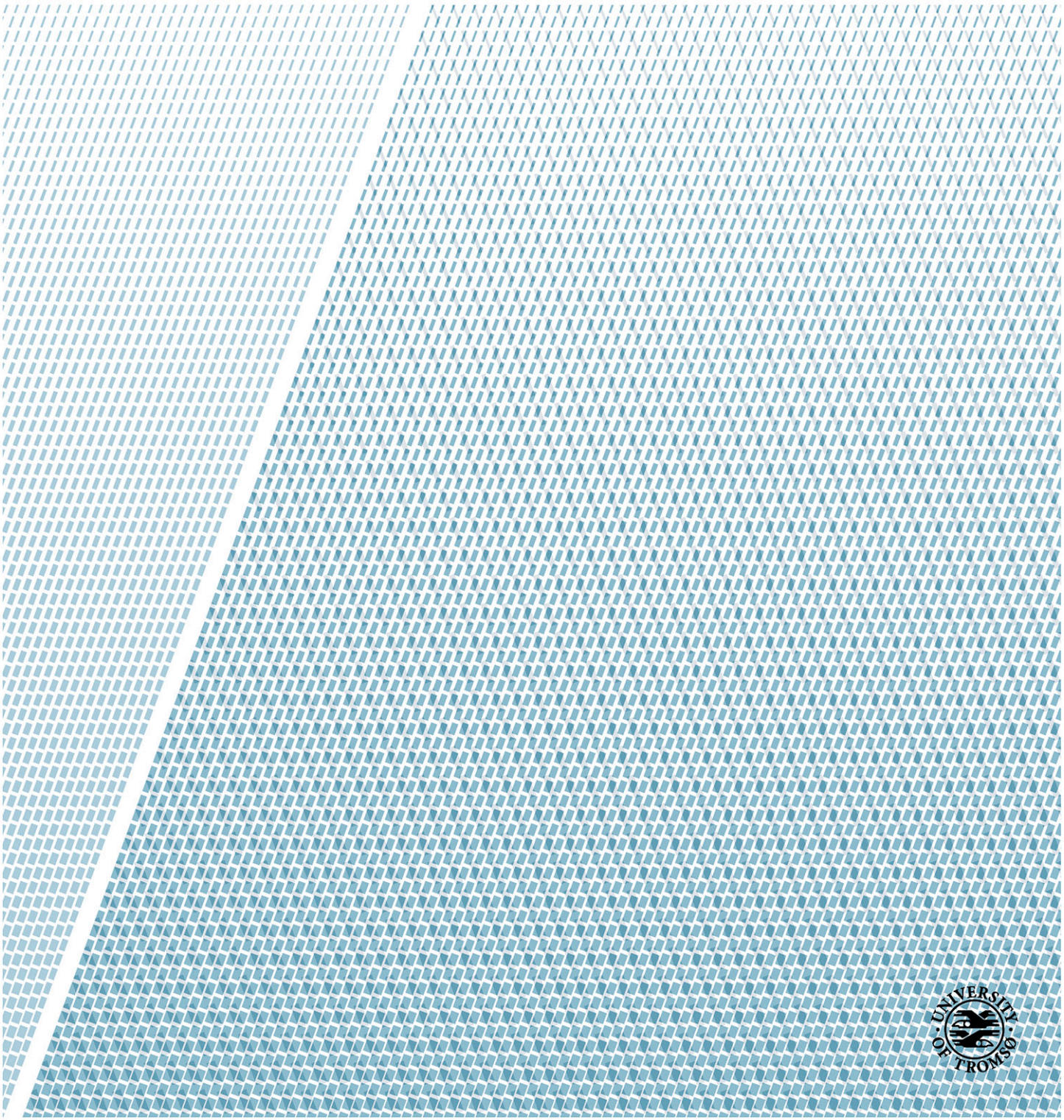

Preface

Gaming has been a huge part of my life, but even though it mostly has been for entertainment there have been some indirect elements that gave an educational effect throughout the years.

Apart from being a gamer, I got the interest in health science through the "Introduction to telemedicine" course at the university. It became clear to me the need for update in todays systems within the health sector, and how to simplify the situation for the many people living in rural areas in Northern Norway who has to spend several hours in travel to their General Practitioner or specialists at the hospitals.

Looking back at what gaming have ment to me, the presentation of a master thesis based on serious games for children with chronic diseases felt like an interesting task to do. The amount of games, the diversity of gaming platforms, and the increasing amount of children who play games, makes the serious games field a good way of connecting to almost everyone, both globally and people living in rural areas.

This master thesis for the degree of master of science in computer science is a cooperation between University of Tromsø - The Arctic University of Norway (UiT), Norwegian Centre for Integrated Care and Telemedicine (NST) and Plus Point AS, an interactive game studio in Tromsø. The thesis project' main goal is to develop a serious game based on the issue: "**Connecting young individuals with chronic diseases in rural areas through serious games**", where children with Type 1 Diabetes Mellitus (T1DM) is the main target group.

The end result: "We.Tree", a serious game developed for children with T1DM living in rural areas. This is a serious game which allows the user to connect with friends or other in the same situation, both for play and chat, but also to inform or educate the user about the importance of monitoring the diabetes

to stay healthy and avoid complications in the future.

As part of this project, there were an exchange program in cooperation with the University of Minnesota, Minneapolis (UMN) where I was supposed to be be grouped up with some of the students there and a game company in Minneapolis who focused on serious games. Sadly the host at UMN had some change of plans, which caused the exchange to not be realized. The extensive programming required to achieve multiplayer aspects, and also making design, would have benefitted of the group work at UMN, but unforeseen things happens so I had to manage with what I could handle by myself.

Since the UMN plans did not go as planned, I got the opportunity to travel to Utrecht, the Netherlands, to be present at the Games for Health Europe Conference in early November. This opportunity gave me insights to the state-of-the-art research within the field of serious games, where I could get first-hand experience of the current level of expertise within development of serious games. This conference had a lot of interesting presentations, but not as many as I hoped that was relevant for my case.

Tromsø, 15. December 2015
Mats Sørensen

Abstract

Young individuals with chronic diseases living in rural areas might face additional problems in their everyday life compared to those in the same position living closer to the cities. Living far away from friends, relatives, other in the same situation, or even general practitioners and specialists may act as an extra burden in their process through their situation. This project is meant to aid children who has Type 1 Diabetes and has to maintain healthy blood glucose levels by regularly physical activity, regulating their food plans and taking insulin.

Children might have difficulties accepting and adapting to the fact that they have a chronic illness which has to be managed daily for the rest of their lives. Since it is important to maintain a healthy and controlled lifestyle to avoid future complications, they have to be aware of their situation and perform the necessary actions.

In this project I have implemented "We.Tree", an early prototype version of a serious game which through gameplay will teach the users how to keep control of their daily situation through using an self-management application. By playing the game they will become aware of how food, exercise and insulin acts on the body, and what measures can be done to increase their wellness. Since the self-management part is built as a game it will be more motivating and fun to maintain the control of their illness, and the use of rewards and achievements will build up their self esteem and the feeling of being able to manage the situation.

As the project was regarding young individuals living in rural areas, where neighbours and friends may live far away, the game is also focusing on connecting the user to other children in the same situation. Together they can motivate each other in the diabetic situation and share knowledge and experience, but also just socializing and keeping in touch with others.

As a result of introducing self-management in fun and motivating education of how to properly use it, the children will become comfortable with monitoring their own situation at a earlier age. This will reduce the amount of work required by both the parents and the doctors which initially has to pay extra attention to the illness of their child. The parents can check on the progress by looking in the self-management application since all the registrations which the child inputs in the game is registered in the diary.

Acknowledgements

I would like to especially thank Ismet Bachtiar, Creative Director at Plus Point AS, for willingly being my co-supervisor in this project. Regardless for not being compensated, and no matter how packed his schedule was, he always managed to find time for a meeting and answering mails.

I would also like to thank Prof. Gunnar Hartvigsen (UiT/NST) for his role as supervisor, and my co-supervisors Prof. Eirik Årsand (NST/UiT) and Research Scholar Svein-Gunnar Johansen (NST/UiT) for their contribution and motivation to my master thesis. Thanks to Mirek at NST for much appreciated assistance, and thanks to all my fellow master students for sharing expertise in these desperate times.

Last but not least I would like to thank my girlfriend, Camilla Jenssen, for her continuous support, understanding and patience through the whole process.

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List of Abbreviations

ADB Android Debug Bridge.

API Application Programming Interface.

CPU Central Processing Unit.

GP General Practitioner.

GUI Graphical User Interface.

IPC Inter-Process Communication.

NFC Near Field Communication.

NST Norwegian Centre for Integrated Care and Telemedicine.

T1DM Type 1 Diabetes Mellitus.

T2DM Type 2 Diabetes Mellitus.

UiT University of Tromsø.

UMN University of Minnesota, Minneapolis.

UNN University Hospital of North Norway.

USB Universal Serial Bus.

Chapter 1

Introduction

Playing video games for pure entertainment may indirectly educate the player [55], depending of the type of game that is played. There may be history elements in war games, exposed for languages like english over time, simulation games where actual simulation of environments or objects is entertaining but also indirectly teaching the player how it works in reality, and so on. Some elements may of course include science-fiction, but in the end, being exposed for reality elements, history, languages, and similar, over time through games may have better effect than listening to the teacher or doing homework [67], [55], and also more motivating [70], [55].

With the possibilities of educational outcome through games, serious games is therefore a growing industry as it is starting to being acknowledged as a way of learning. The use of serious games could therefore be adapted into several fields of research or education, as a tool of educating and informing users for a given issue.

1.1 Background and Motivation

Children and adolescents with Type 1 Diabetes Mellitus (T1DM) living in rural areas with a scattered population have to face additional challenges in order to maintain optimal blood glucose regulation. Often, they dont have other kids in their neighbourhood with the same health problem, and it might take them hours to get to a doctor and days to get to a specialist hospital. This is the situation for many children with T1DM living in rural areas in

North Norway. In this project, I want to investigate if the use of smartphone based social game can help these kids to learn how to manage their blood glucose through playing a serious game, and to motivate and make it more fun by connecting them to other in the same situation through multiplayer functionality.

Today's children are growing up in an era where the technology and its use is increasing. Games and entertainment is becoming a bigger part of the children's daily life as the technology is being further developed, and the amount of different platforms and smart devices where this can be accessed is increasing.

With the technology it is possible to reach out to the users from wherever they are, so the concept of using games for a more educational or informal approach instead of purely entertaining purposes made the serious game project interesting.

By using serious games to educate within the health sector for instance, the time used on following up patients might be reduced as the patient themselves has an entertaining way of getting aware of their own situation through playing in the spare time [73]. This approach is especially interesting when it comes to children, as they might have difficulties understanding the importance of correct treatment to avoid complications for their situation, and not fully comprehending the information given from the doctors [44]. Therefore providing a game with simple and entertaining mechanics might aid the younger users in gaining knowledge of how to be aware and adapt to their situation.

1.2 Purpose and Goal

Proper diabetes self-management is one of the major health challenges due to the huge impact improved diabetes treatment has on our healthcare system and the patients themselves. Thus, this project is focusing on a very important and extremely challenging goal, both technically and medically to improve blood glucose management for children and adolescents with Type 1 diabetes through building a novel educational experience, spanning across different technologies and media.

The goal of this project is to benefit of todays technology and reach out to individuals living in the rural areas of Northern Norway that is affected by

the chronic disease T1DM, should it be parents of children with T1DM or the children themselves. This is done through developing a serious game that is used to make the user, the child, aware of the situation they are in and making the game a way of educating to proper precautions.

Patients living in rural areas often has to use a lot of time for traveling purposes to get to the closest hospital or General Practitioner (GP). Therefore the threshold for seeking medical assistance can be higher compared to those living in the cities [59]. This could have a bad effect, and specially for children which has to adapt to a new diabetic lifestyle.

By reaching out to patients living in rural areas I attempt to propose a solution that can educate and inform both the parents and the children about their situation in hope to let them control it. The earlier the child manages to adapt to the diabetic lifestyle, the earlier the whole family can be more comfortable.

> "...Diabetes is not an illness that should be equated with frequent hospital stays or emergency room visits. It is very manageable at home when done correctly..." [15]

Another issue with living in rural areas is differences in personal relations compared to living in larger cities, where the amount of close friends depends on the amount of population and acquaintances. Living in rural areas with, in this case, T1DM may therefore affect the children in a negative way since there might not be any friends within immediate reach, and specially other children in the same situation. To let the user connect to other despite the distances, the game allows for multiplayer connections where they can connect with other individuals in the same situation, or even friends, to let the user achieve a feeling of not being alone. Loneliness may increase the rates of seeking medical help as it is a way of socializing [65], so games and fun with others through technology may be a way of preventing loneliness for children living in rural areas.

In addition to loneliness, children may face other psychosocial[1] barriers due to their situation where they may feel "special" comparing themselves to their friends [15]. These barriers may be denial, embarrassment, anger, resentment, isolation, or depression should it continue for a longer period of time [15], [32]. Therefore it is important to include the social aspects within the development of the game.

[1] Psychological development in a social environment, Wiki

1.3 Methods

The development of this project was in close cooperation with a game company, and is therefore affected by their way of approaching a new game. Some of the methods used is based on how to approach the users, like what appeals to the target group and how can the game best be made to capture the essence of their expectations. Visual feedback is a great part of creating a game, where the user is satisfied by how information is presented and the usability is easily understandable.

Through this project it was focused on how to capture the focus of the user through graphics, and how this could be acquired and used to simplify the process of creating a game. It has also been focus on being able to describe the end result through documents which attempts to explain the core mechanics of the game, but also the sequential execution of the end product is created to explain the further outcome of the current prototype.

1.4 Major Contributions

This project presents a solution to help children with Type 1 Diabetes living in rural areas to better manage their diabetic condition through educating them to use self-management tools. This is done by developing a serious game that bases its gameplay around registering their diabetic values at several times a day. The game encourages them to keeping track of their condition and at the same time being a source for entertainment and socializing through friendly games with friends and other in the same situation.

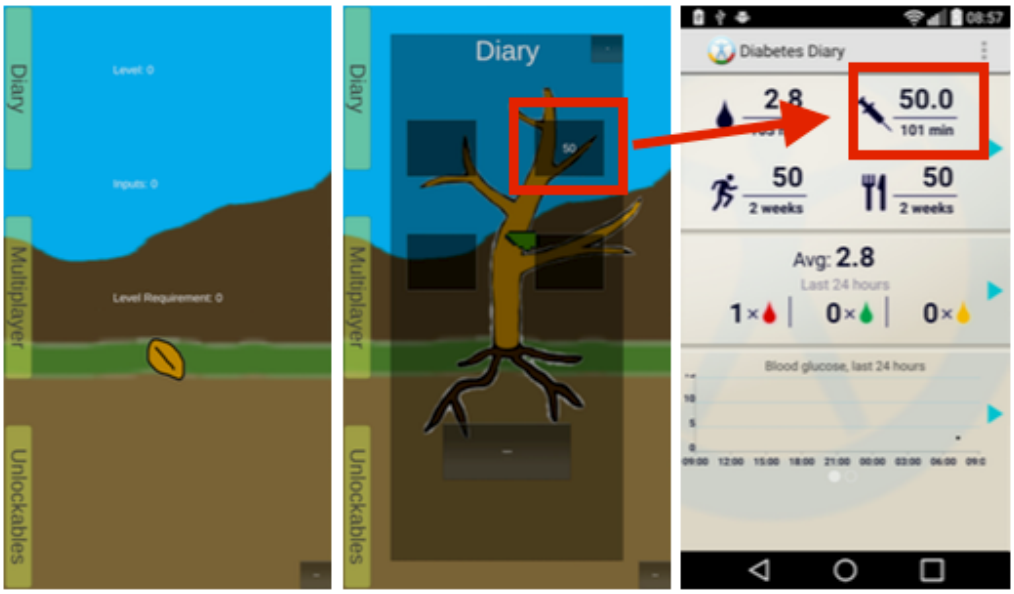


Figure 1.1: Example pictures of the prototype implemented in this game and how it passes values to the Diabetes Diary application.

In other words, this thesis makes the following contributions:

- The game educates the children to use self-management application at a young age. They are being encouraged to continuously register diabetic values, and are kept motivated through rewards that can be used to unlock more fun activities.
- The game registers diabetic input directly into the Diabetes Diary application, which is an self-management application. This allows parents and doctors to check the Diabetes Diary to ensure the child correctly manages their diabetes. This way the child will also become comfortable keeping track of their values at a younger age.
- The game presents the user with tips and information about diabetes, and educates the children in a fun and understandable way what their illness requires.
- The game connects the users to friends and other in similar situations. This way their friends can understand the situation and restrictions that has to be kept in mind as a diabetic. Since the users lives in rural areas of Northern Norway, they can connect to others in the same

situation playing the game. This way they can motivate and challenge each other to maintain a healthy lifestyle.

- Evaluates the current selection of serious games aimed for educating about self-management and compares to the proposed solution.

1.5 Scenario

To illustrate a scenario where this game comes in handy, we can imagine a family with a diabetic child living in the rural parts of northern Norway. Their 7 year old child just got diagnosed with Type 1 Diabetes and got their world turned upside down. Both the parents and the child has to learn how to adapt to the diabetic situation. They receive close follow-up on their progress through the early stages, but their diabetes consultant is located at The University Hospital of North Norway (UNN) which is a 3-hour drive away, each way. They frequently have to drive to UNN for regular controls on how they manage, resulting in a lot of hours traveling and hospital visits which is both tiresome for the child and the parents. The child misses a lot of school, activities and time with friends because of all the traveling, and starts to feel alone since he cannot play with his friends. If they just could get understandable information and a way of keeping track of their progress from home to not be insecure and anxious.

Their diabetic consultant suggests downloading "We.Tree" for their child and quickly introduces which values to register. A few weeks later they feel more comfortable as they can monitor the blood glucose values from the registrations done by the child, and can control the values of the day to see if there has been any situations where the child has been outside the recommended values. The child is happier since he can keep contact with his friends through the game and in a simple way illustrate how his condition affects his daily activities. He has also made new friends through connecting in the game, where they have play together and motivated each other to a healthy progression in the game.

Since the child has learned how to use the self-management aspect of the game, the family have become more comfortable controlling the situation and they have less frequently long trips to the hospital. However, when they are at the hospital the diabetic consultant can easily control the values that has been registered since the last time and give feedback on those.

1.6 Limitations

Since this is a one semester thesis, the time available limits the amount of development and testing possible since the process of creating a game, or a system in general, requires planning and preparations in advance of the developing itself, and the bureaucratic process of gaining access to patients with the relevant chronic disease long.

The aim of this game is to be of use for children around the age of 8-13 years old with T1DM. However, the amount of people in general in Norway with T1DM is quite low, and the amount of children within the targeted age-range with T1DM is even lower. According to DiabetesForbundet [19], there is around 28,000 Norwegians with T1DM, where around 2500 of these are children younger than 15 years old [7]. According to the Children's Department at UNN in 2013, there were only 18 children within the targeted age-group with T1DM spread around in Troms county [69].

Because of the limited time to develop, there was not enough time to implement several of the core mechanics which was big parts of the idea that was created "on-paper" in the pre-development phase. This is therefore described as future work. For the same reason, and because of the long process of getting through the hospital system, the possibility of including children with diabetes in the development of the game was unrealistic.

1.7 Structure

The rest of the thesis is built up as following:

Theoretical Background explains the theory behind this project, like Diabetes, the self-management application "Diabetes Diary" and how it may benefit diabetics in their everyday life, what is serious games and how may serious games aid diabetics, theory behind games and how game motivation is important to make users continue to play a given game, and finally some theory of the concept behind the game.

Related work presents the current state-of-the-art within related serious games which is published for smartphone platforms, some literature which presents solutions within the same genre, and related presentations from the Games for Health conference in November this year, before the findings is

compared to the result of this project.

Methods describes development decisions which was used during the development of this game, like agile development and the Scrum framework which was done together with my co-supervisor, Ismet at Plus Point, and benefits by using this approach, choices of development platforms, and how to properly create game documents and sequential game structure documents before starting the implementation to ensure good quality of the process and the end-result.

System Requirements and design which describes the requirements that was defined before the development of the game and which restrictions were set to ensure the correct outcome throughout the process, and also the design of the game.

Implementation explains the core mechanics and the elements that is implemented during this project.

Future Work explains elements which is part of the core mechanic of the developed game but which has not been implemented yet, but also elements which could be improved or added at a later point which seems like a good idea to be included in the game in the future.

Testing and Experimentation presents the result of the usability testing conducted on my classmates, where they gave feedback on usability of the current implementation and the concept ideas of the game, before some performance results of the game is discussed.

Discussion presents issues which could have been done differently or which caused a headache for some reason, or reasoning for why issues were solved the current way.

Conclusion summarizes the process and results found throughout this project.

Chapter 2

Theoretical Background

This chapter will explain more in detail of the theory behind the project.

2.1 Diabetes

Diabetes Mellitus is a group of metabolic diseases affecting blood sugar levels [18]. When you eat, your body turns food into sugars, or glucose, and at that point your pancreas is supposed to release insulin that regulates the blood sugar. Diabetes develops when glucose can't enter the body's cells to be used as energy, which occurs when either there is no insulin to "unlock" the cells so the glucose can enter, also known as Type 1 Diabetes, or if there is not enough insulin or the insulin is not working properly, Type 2 Diabetes [48]. According to World Health Organization, WHO, there are 380 million people worldwide with some type of Diabetes, but almost half of these are unaware of their situation and living with **undiagnosed diabetes**. They also estimate that by 2030 that number will be close to double [16].

Diabetes depends a lot on the behaviour of the patient and how they can accept the fact that they have to adjust their life and lifestyle maintain a healthy life and avoid future complications.

> "Diabetes is the model self-management disease. Its up to patients and their families to take care of diabetes, not the physician. Its a very unique situation where psychological, social, economic, and lifestyle factors really play a big role in how things

go." [9]

With control of their disease, f.ex. by using a self-management application, they can keep track of their glucose values through the day and do necessary precautions to avoid short- and long-term complications.

Type 1 and Type 2 Diabetes Mellitus:

Only 5-10% of diabetics has Type 1 Diabetes [63], but this type of diabetes is more common for children than adults, and is also known as Juvenile Diabetes [18]:

- Adults with Type 1: 10%
- Adults with Type 2: 90%
- Children with Type 1: 98%
- Children with Type 2: 2%

It may be difficult for young children to understand the changes T1DM requires them to do for the rest of their life, like measuring blood glucose several times a day [72], and it is therefore important for the parents to keep control and ensure that their child does as required. However, the technical advancements over the last decade has resulted in different equipment that can aid the parents and the child [53]. Technology like insulin pumps, continuous glucose meters, and self-management applications is examples of tools that can make the process easier for them.

During the last few decades Type 2 Diabetes Mellitus (T2DM) has increased at a particularly high rate and is now one of the world's most common long term health conditions [18]. This type of diabetes is related to that there is not enough insulin in the body, or that it is not working properly, which may be a result of obesity and lack of physical activity [18], [50].

Other types of diabetes gestational diabetes can be diagnosed on women late in the pregnancy as a result of high blood glucose levels during pregnancy [3]. If this goes untreated or is poorly controlled it will result in giving the baby high blood glucose level, which leads to the baby getting more energy than needed to grow and develop, causing the extra energy to be stored as fat. This will result in a "fat" baby with increased chances of health

problems, like low blood glucose levels are birth, risk of breathing problems, and the excess of insulin may lead to obesity as a children which develops into T2DM as adults [3].

2.1.1 Blood Glucose

People with diabetes has to regularly monitor and control their Blood Glucose levels and make sure it is within recommended values. But to do this, they would have to know which values to aim for. According to NICE - National Institute for Clinical Excellence (UK), the recommended values is as follows [8]:

NICE recommended target blood glucose level ranges

Target Levels by Type	Upon waking	Before meals (pre prandial)	At least 90 minutes after meals (post prandial)
Non-diabetic*		4.0 to 5.9 mmol/L	under 7.8 mmol/L
Type 2 diabetes		4 to 7 mmol/L	under 8.5 mmol/L
Type 1 diabetes	5 to 7 mmol/L	4 to 7 mmol/L	5 to 9 mmol/L
Children w/ type 1 diabetes	4 to 7 mmol/L	4 to 7 mmol/L	5 to 9 mmol/L

*The non-diabetic figures are provided for information but are not part of NICE guidelines.

Figure 2.1: NICE Recommended Blood Glucose Level ranged. Source[1]

However, these are general guidelines and each individual should consult their diabetic consultant or doctor to see if there are any personal issues which requires alteration.

To check the blood glucose levels the patients can use a **traditional glucometer**, where they prick their finger with a lancet and inserts a test strip with blood into the glucometer that returns the blood glucose value. Or they could have a **continuous glucose monitor** where a small probe is implanted under the skin and sends information to a receiver. This option provides glucose readings every few minutes, 24 hours a day, but requires that the receiver is within close range at all times which may be an obstacle for active children. This technology is increasingly advancing, and possible a good continuous solution will be available shortly.

The blood glucose should be controlled several times a day: First when they

[1] http://www.diabetes.co.uk

wake up, this is because of the "Dawn Phenomenon" where the body secrets hormones to begin waking up and causes a raise in the blood sugar [18]. 15-30 minutes before a meal to ensure that you don't eat too much and 1.5 - 2 hours after a meal to keep track of where your blood glucose ended up after eating. Before and after physical activity because this the decreases blood glucose levels and to avoid hypoglycemia from training. Lastly it should be checked when going to bed since the body will rest for several hours without any new supplies of carbohydrates.

Figure 2.2 is another illustration of how the blood glucose should be regulated.

Figure 2.2: Chart of blood glucose levels, Source[2]

2.1.2 Complications of Diabetes

Hypoglycemia: If the blood glucose levels gets too low, usually less than 70mg/dl (3.9 mmol/l), the diabetic may start to gain symptoms of Hypoglycemia, or insulin reaction [31]. Typical symptoms include clumsiness,

[2]http://www.oracldiabetes.com/controlyourhealth/graph/images/diabetes.png

confusion, sweating, and shakiness for instance, which may appear suddenly [34]. If the hypoglycemia is not treated and the blood glucose levels continue to fall it may cause unconsciousness, seizures, diabetic coma or in worst case, death [18].

Often, diabetics may experience hypoglycemia if they don't keep track of their food intake, exercise or alcohol consumption [18], and for instance eat less than usual or train more than usual which leads to imbalance in the daily plan for the glucose levels. Therefore it is important to maintain a healthy, well-planned diet together with an exercise plan build together with doctors or the diabetic consultant.

Hyperglycemia: Opposite to hypoglycemia, hyperglycemia is caused if the diabetic have too high blood glucose value, exceeding 200mg/dl (11.0 mmol/l) [18] . In this case the body does not have enough insulin, for T1DM, or the body is incapable of using the insulin in the body properly [18], for T2DM. Hyperglycemia may be a result of eating more than usual, or training less, and is in general treated by taking insulin (unless it is already done), exercising, or eating less.

In the short term hyperglycemia can be serious if the blood glucose levels rises very high, above 270mg/dl (15 mmol/l), which may cause Ketoacidosis, which is a state where the body burns fats for energy since the lack of insulin prevents the use of glucose. When the fats are broken down, they produce ketones in the blood, and large amounts of ketones can cause severe illness [30].

If high blood glucose values persists over long time, it may result in complications like organ damage which then leads to additional health problems. It is therefore important to maintain a healthy lifestyle when it comes to food and exercise, but also with correct use of insulin.

Diabetes is the leading cause of blindness, kidney failure, amputations, heart failure and stroke, which may be caused by high blood glucose over long time. Annually, diabetes costs the American public more than $245 billion because of incorrect self-management of their situation [16].

2.2 Diabetes Diary

Norwegian Centre for Integrated Care and Telemedicine (NST) has developed a self-management application, Diabetes diary, for people with diabetes. In this application the user is supposed to input registrations like food (carbohydrates), activity, insulin and blood glucose levels. By doing this, the user will have a overview of the current blood glucose levels and be able to see the effects of training and food, and take the necessary precautions to stay within the recommended blood glucose values [51], [52].

In Figure 2.3 the main screen of the Diabetes Diary is presented and looks to be separated into three different parts. The top section shows the four input values which is registered in the diary. By interacting with any of the four values you can register a input of that type. The four different input types are:

- Top left - Droplet: Blood Glucose measurement, in this case 122 mg/dl 48 minutes ago.
- Top Right - Syringe: Insulin Units, in this case 4.5 units 4 hours ago.
- Bottom Left - Running Man: Physical activity counted in steps, here 66 steps 2 hours ago.
- Bottom Right - Cutlery: Grams of Carbohydrates, 20 grams 40 minutes ago.

The middle section of the main screen contains the average blood glucose values from the last 24 hours, but also shows if any of the registrations deviated from the normal values. In this case there has been three registrations when the blood glucose was below recommended values(the red droplet), five registrations within recommended values(the green droplet), and 3 registrations with too high blood glucose values(the yellow droplet).

At the bottom you can see a graph-like figure where each of the registrations of the day is plotted depending on time and value.

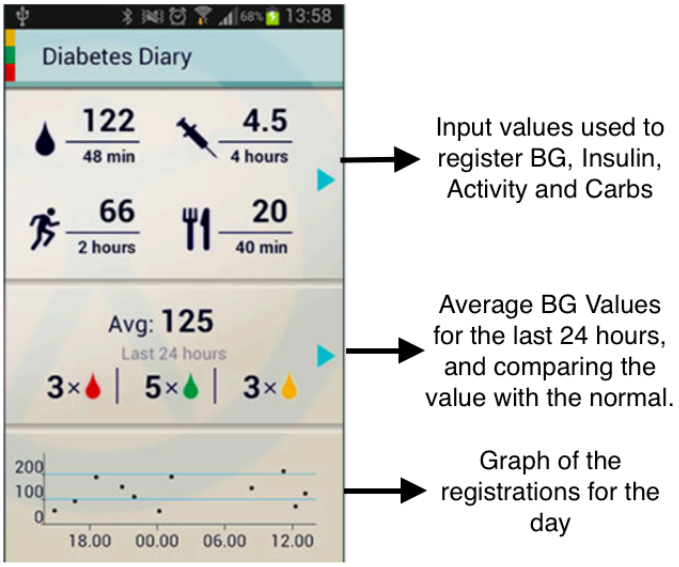


Figure 2.3: Screenshot of Diabetes Diary main screen, Photo: NST[3]

All these can be viewed in a more detailed approach with more accurate plotting of the last registrations, a log of what has been registered, which food was eaten and the carb values and so on.

However, the diary requires insight and discipline for regular use and might therefore be hard to make younger individuals keep using the diary. This is one of the reasons I decided to build the game based on the Diabetes Diary, to simplify the use of Diabetes Diary for younger persons. The game should act as a way of making them indirectly use the diary through the game to keep track of their disease. Figure 2.4 illustrates how the game acts as a shell above the diabetes diary, and by using the game the registrations are handled by the diary in the background. Since this is a early prototype version the registrations is done in the same way as in the diary as a proof-of-concept to show that registrations are passed from the game to the diary.

[3]Source: http://telemed.custompublish.com/better-quality-of-life-for-patients-with-diabetes.5208977-287081.html

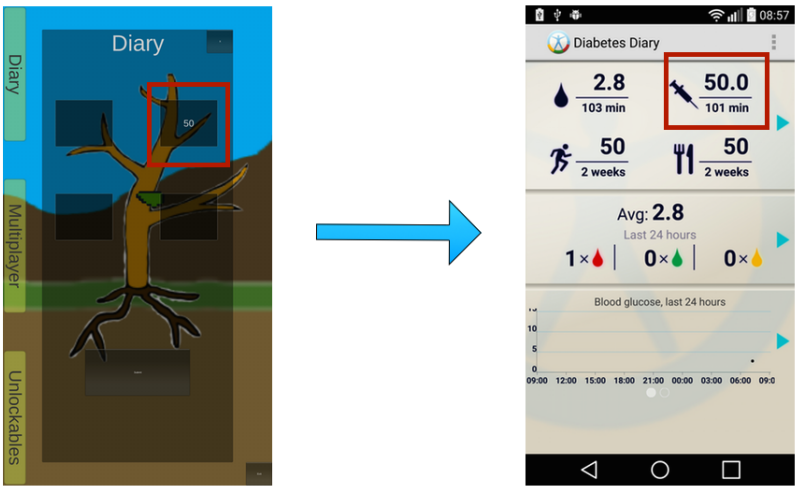


Figure 2.4: The game acts as a shell above the Diabetes diary. By playing the game, registrations is done in the Diabetes diary.

When the child plays and inserts the values to progress in the game, all they see is what happens in-game. The values are passed from the game and into the Diabetes Diary application, which has to be located on the same device. Diabetes Diary does not require to be active while the game is played to receive the registrations. By playing the game correctly, all the relevant values will then be available for control in the Diabetes Diary. This way the parents, doctor, or even the child themselves can keep track of the values through the diary.

2.3 Serious Games

Todays children are growing up with technology, which is used both for entertainment and problem solving [27]. Digital entertainment is easy accessible, and increasingly used among children. Games tend to consume a lot of the users time by having a fun and understandable gameplay, which motivates the user to keep playing it for good entertainment. Therefore with the rise of the game industry, the use of games as a tool of education and information is starting to become something of value. Instead to take away the element of entertainment to force boring education on the children, they insert the education into the entertainment. With that, Serious Games was created.

The definition of serious games first arrived in 1970, even before the game

industry had started to grow, where Clark Abt [49] presents simulations and games to improve education, both in and outside of the classroom [64]. Later this definition was redefined by Ben Sawyer in 2002, where he based his definition on "connecting a serious purpose to knowledge and technologies from the video game industry" [76]. In other words, a Serious Game is a game which is created for an educational or informal purpose, and not purely for entertainment [39].

Almost any field can use serious games to educate users in a possible benefitting and entertaining way [81]. As long as there are subjects to inform or educate about, it would most likely be possible to tailor a serious game for that use.

Serious games allows the creation of fictional situations which could be a reflection of a real situation, allowing the user to gain experience of how to handle a situation which would be tough to gain knowledge of from the real world. "You would not let your new management trainees run your business but you would like them to fully understand every facet of your business as early as possible." [62]

> "It is the attributes of games, such as compelling storylines, attainable challenges, rewards, recognition and control that make them so powerful for learning. This is why serious game are replacing the longstanding but outdated traditional learning environment (e- learning or classroom)." [36]

Another strength with serious game based learning, is the repeatability. A game can be played over and over, testing knowledge and experience. Should an answer be wrong, the user could just try again at a different approach [62]. The possibility of testing different approaches in a repetitive gameplay allows the user to test their problem solving abilities to gain additional knowledge.

2.4 Serious Games for Diabetes

Children may have difficulties adjusting to their disease at a young age, since it requires a lot of information and insight to maintain a healthy lifestyle. In addition to that children children often compare themselves to friends, and if they then have a chronic condition, like diabetes, they might feel "different" than their friends [10].

With self-management being a big part of having diabetes, where the person has to manage their everyday life by measuring blood glucose, taking insulin, physical activity and maintaining a healthy diet. Keeping control of everything can be tough without good management, and specially knowing the blood glucose values. Self-management applications simplifies keeping control of the everyday health status, and benefits the user and possibly the GP which then can get a clear view of how the patient has been doing and feeling.

Most of the serious games related to diabetes explained throughout this thesis attempts to highlight the importance of keeping self-management to control the daily health status. There are much focus around logging daily activities, blood glucose levels, carbohydrates and insulin, both on applications designed for adults, but also for applications for children. Making the children early comfortable with self-management is a preventive step in the right direction to ensure good health quality regarding their disease in the future [9].

There will also be explained some related games which were focusing on how it is to live with diabetes, where the importance of keeping the blood glucose levels optimal at all times, and the effects it has on the body should it enter the "danger zones".

2.5 Game Motivation

- Why would you open that game?
- Why do you keep playing that game?
- What do you gain by playing that game?

This is issues game developers faces as they attempt to create a good game. How can they create a game that makes the users keep opening the game and use their time on playing it. The same counts for serious games, as they have to motivate users to keep playing to be able to learn anything from the game.

In the serious game setting for this project, if the user is not motivated to play the game for the self-management purpose they will receive less out of it compared to those who are motivated to learn. But motivation is a difficult factor to account for. Some might be motivated by graphics, others by the

storyline of the game, functionality, purpose, and so on. It is impossible to create a game which would motivate everyone to play it.

However, this project only attempts to motivate young children with T1DM which narrows down the requirements to satisfy. F.ex. the concept and visuals has to appeal to 8-14 year old children, perhaps through known elements they have a relation to, like popular cartoons or heroes in their perspective.

To make people want to play a game, there has to be certain elements which makes the user want to play the game. Figure 2.5 shows the 11 basic needs that people seeks to achieve through gaming: Perseverance, Competence, Knowledge, Creation, Skills, Competition, Caring, Cooperation, Danger Management, Optimal Choice and Emotional Regulation. All these needs are achieved through the three big rewards: Achievement, Satisfaction and Recognition [42].

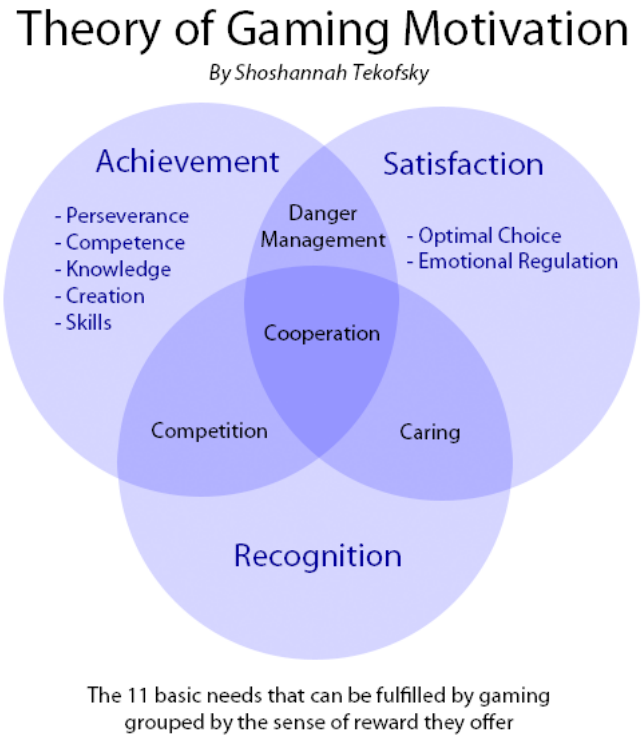


Figure 2.5: Theory of Gaming Motivation, Image: Think Feel Play[4]

[4]Think Feel Play - The psychology of Video Games: http://www.thinkfeelplay.com/theory-of-gaming-motivation/

F.ex. A survival simulation game requires the user to start from the most primitive tools that can be found in the nature and build his way towards a goal while surviving the harsh wilderness. He starts off with a rock and hammers loose on trees to acquire wood. He then discovers the possibility to use wood and build a shelter which can keep him safe during the nights. Further on he manages to create tools of iron and creates a sharp spear which he can use to hunt bigger animals. In reality the user gains basic knowledge of how to survive out in the wild, at least in a virtual reality, but he also can play with his imagination to create new items and set his skills to a test. He is satisfied that he has managed to survive for seven nights in the game, but he is getting thirsty for more. He runs out to fight a bear. He dies (in-game of course). He has to start over. At this point he has gained a lot of knowledge, and he enjoyed the game since he could play with his creative ideas and skills to survive. Perhaps he is motivated to beat his record because of the satisfaction achieved through creativity and fun. But of course, for this to be a reality, the game has to be of interest for the player.

Given that the player in the example above was really motivated to learn about surviving in the wild and the game managed to live up to his expectations, the outcome of playing the game would be increased compared to a person who was forced to test the game and did without being interested in it [60].

2.6 We.Tree, the Tamagotchi approach

The We.Tree gameplay is based on the Tamagotchi [41], which is a handheld minicomputer from the late 90's. The tamagotchi is a simple virtual pet which could be carried around, for example on a keychain, so that the user could play and nurture the pet at all times. Figure 2.6 shows an example of a pet in a fancy yellow egg-shape container, where the three buttons on the bottom is all the interaction with the pet. The point of the tamagotchi is to play with it, feed it and let it rest to keep it healthy and happy.

We.Tree implemented in this project is based on the tamagotchi behaviour, where nurturing the tree to keep it healthy and growing is the main objective, and is based on the use of the Diabetes diary, connecting to friends and having fun, and keeping the tree clear of weeds and harmful growth.

Figure 2.6: Gameplay based on a Tamagotchi, Photo: Popsugar.com

Chapter 3

Related Work

This chapter presents related work, and the current "state-of-the-art", within the genre of serious games for individuals with diabetes. The purpose is to get an overview of the published literature and the released games within the same genre as this project, and then compare the findings with the outcome of this project.

Literature might explain ideas or solutions which could be in development or at a planning stage, and could possibly be released in the future. Through thorough research of literature within the same field of research, in this case serious games for children with diabetes, one might find possible options of how to approach the problem, but also possible experiences of how not to. Therefore early literature research could give pointers to do's and don'ts for the further process.

This project presents a serious game for smartphones where the user group are children around the age 8-13 with T1DM living in rural areas. The aim of the game is to educate/inform how to live with T1DM to avoid future complications, and at the same time connecting them with other individuals in the same situation through multiplayer options. This is done by making the user aware of how to use self-management applications to keep an overview of the daily values, and adapting by considering the blood glucose levels. The self-management point of view is built into the game, with a Tamagotchi-like gameplay where the user has to input its real-time values into the game to make progress, including gamified elements to avoid making the game all about the disease.

With the increase in popularity of serious games, and the many tools for

creating games and applications, it is important to look at the available applications in addition to the research literature. Many of the developed applications might not have its origin from a research project, where articles are written about the problem and proposing a solution for it.

If there already exists literature and applications that attempts to solve the same problems, then you know you have to look at other possibilities for creating a more unique solution.

Research for related work has been done for this project, where the findings will be compared to the end result throughout this chapter.

3.1 Serious diabetes games - Literature

During the development of this project I noticed the lack of scientific papers presenting similar solutions with serious games for children with T1DM. When searching for related literature, there exists several papers which attempts to analyze available serious games and present design principles and find the "best" approach at tailoring a serious game [58], [57], [79].

F.ex. [58] presents design principles of serious games based on behavioural models, where they develop a educational game used as a pilot study for adolescent drivers with diabetes. This study attempts to highlight the reality of experiencing hypoglycemia during driving, and attempts to educate the adolescents based on decisions they take during driving in a game. The authors of [57] attempted to present design principles for serious games that works, but concluded with that there is not enough evidence of working serious games to define game design methodologies that works.

On the other hand [66] briefly describes 14 serious games with the purpose of making the users aware of self-management, and presents their approach of creating a serious game. It is concluded with that the serious games "typically" is based on the user attempting to control a diabetes simulation through problem-solving and decision-making, based on issues like balancing food and insulin to maintain blood glucose at a safe level.

The author of [69] has done a systematic review of diabetes related serious games from 2012 to 2014, which is presented in [68]. Here she presents results from 3 systematic reviews during the years 2012-2014 and then compares them against each other.

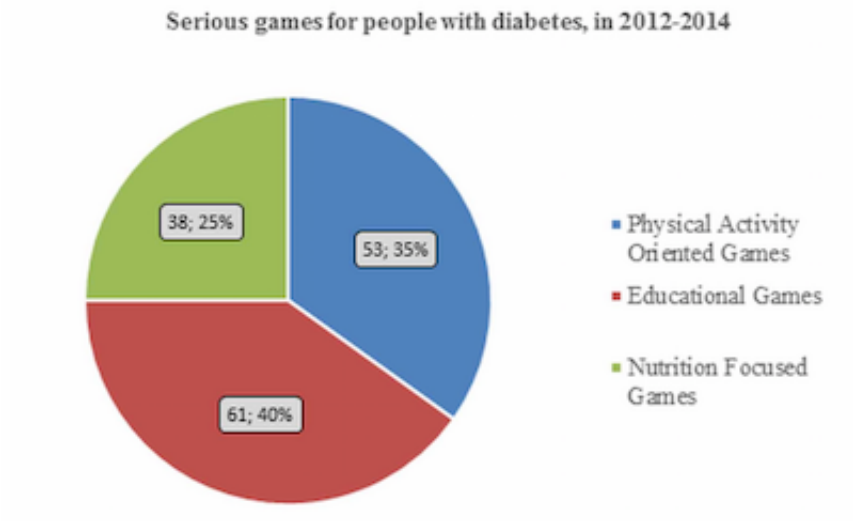


Figure 3.1: Serious games for people with diabetes, categorized, 2012-2014. Source: [68]

Her findings concludes among other things that the amount of new games for health literatures identified in 2014 went down to 16 new games, from 48 in 2013 and 65 in 2012, which might indicate an decline in the popularity of serious games [68].

In Figure 3.1 you can see a categorization of the diabetes-related serious games identified in the reviews from 2012-2014, where "Educational Games" refers to "Self-management skills promoting games" [68] which is the same genre as the proposed serious game in this project.

3.2 Serious diabetes games - Published games

The solution in this thesis is at this stage based on smartphone devices to be usable in a more handheld manner, compared to bigger tablets and computers which mainly is at home and often shared between multiple people. Therefore the related work is mostly restricted to applications for similar devices, mobile smartphones, except for a few relevant projects which was presented at the Games for Health conference and is explained in the end of this section.

Also since there exists multiple platforms to publish games, depending on different operating systems for the smartphones, related work within Android

applications are explained more in detail than iOS applications since the We.Tree solution is developed for Android.

3.2.1 iOS Applications

The simplest way I found to browse available iOS applications, where I could set restrictions to iPhone applications but also being able to do specific searches, was through iTunes App Store on Mac because the web solution[1] did not have a search function available.

The search queries[2] used to find related games, and their results will be explained below:

"Serious Games Diabetes": Table 3.1 shows the result of "Serious Games Diabetes", which only gave on result:

Table 3.1: Search result of "Serious games diabetes"

#	Application	Description
1	Helbred på Spil	Danish game to highlight good choice of habits and activities. An Avatar is created with a chronic disease and a life-goal, and by playing mini-games and activities you try to keep the avatar alive by finding the balance between activities and habits. [28]

"Diabetes Games": Searching on "diabetes games" gave 19 results. Most of these games were purely informational or not too related, like explaining how to get a healthy life without too much sugar [2], quizzes to test your knowledge of Diabetic health issues [17], [29], cooking applications to understand food which is good for diabetics [20], and weight loss applications [21]. However, there was one application which turned out to be closely related, Dex: Your Virtual Pet.

Dex: Your Virtual Pet: Dex is a virtual pet with diabetes, and like a tamagotchi the user has to play with, pet and feed him to keep him healthy. Since Dex has diabetes the type of food which is given to him affects the

[1] iTunes iPhone application front page: `https://itunes.apple.com/no/genre/ios/id36?mt=8`

[2] Search phrases

gameplay. By feeding him with too much unhealthy food, Dex will respond as in Figure 3.2(b), where the user receives feedback that the choice of food was not too good for Dex and a button to "Learn healthy food choices" appears. Dex also has to exerice to maintain the good mood, and to have enough energy to do fun and educational mini-games. Dex tries to educate the user that exercise is important to control the blood sugar, and healthy food is required to have enough energy and feeling good.

(a) Feeding Dex (b) Dex feeling bad

Figure 3.2: Dex, virtual pet with Diabetes, Photo: iTunes App Store

Another gamified approach among the available applications:

Complication Combat: How long can you manage type 2 diabetes and its complications

> "...is a fun interactive game intended to educate about the complications associated with type 2 diabetes and to inform users that type 2 diabetes and its complications can be challenging to manage and treat..."

Even though this game focuses on type 2 diabetes, there are similarities in what the user has to avoid to ensure good health. This game is based on

a quick gameplay, where a timer counts down and the user has to act on objects depending if it is good or bad for the health. The longer the player stays healthy, the higher score. This game informs the user of what is good and bad for a healthy life, the possible complications associated with type 2 diabetes, and lifestyle choices that can help progressing the disease.

Search queries gave in general a low amount of relevant hits of applications, which perhaps could be caused by a search-engine not handled to look for results based on tags, like "diabetes", "serious",etc, or it could just be a result of a generally lack of related applications.

Other queries with low amount of results:

Table 3.2: Query results when looking for relevant games on iTunes

#	Query	Result
1	Diabetes games children	Nothing
2	serious games children	Numbers and Letters educational application
3	Diabetes children	UpBete - mobile app linked with the UpBete web system, displaying information from the website and allows for submitting blood glucose readings to the web.

UpBete [46]: Web solution to support Children and Young people with T1DM and engage them to learn how to use self-management solutions to have control of their disease and reduce the chances of future complications. The online solution provides a community where children and parents can find information about diabetes, food and tips for good health.

In general it was not the greatest selection of serious games on iTunes which were related to serious games within diabetes management for children. One application built on the tamagotchi concept, to keep a creature with diabetes alive and highlighting the effects of the choices the user chose throughout the process.

3.2.2 Android Applications

Further research of published applications is done for the android applications. Where Google Play Store is used to browse the applications... bla bla bla search queries etc.

"Diabetes children": As seen in Figure 3.3, which just displays some of the most popular results, there are more applications published on the android platform compared to the iOS platform within this field.

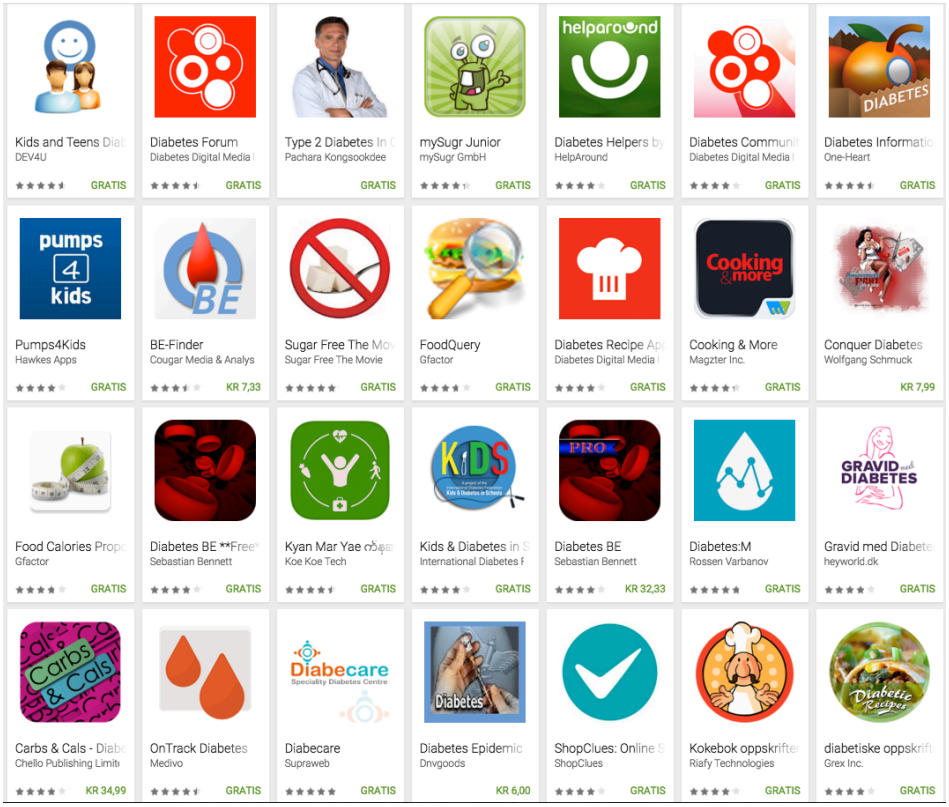


Figure 3.3: "Diabetes Children" result on Google Play

Although the selection of apps on Android is greater than on iOS, there are a lot of the same. Applications which offers communities and information around diabetes, cooking applications to make the users aware of healthy food, complicated self-management applications, fitness applications and so on. The selection of serious games for diabetic children seems to be just as small as on iOS. The 4th top result here, mySugr Junior, is a good solution for a self-management application for children with diabetes. mySugr Junior

will be explained more in detail later.

"Children diabetes games": This query resulted in a few more games compared to the previous, see Figure 3.4, but most of them just belonged in the game section without actually being related to diabetes or serious games. mySugr Junior is present here as well, representing a game and not just a self-management application for children. Cooking and food applications are still highly represented in this section, understandingly.

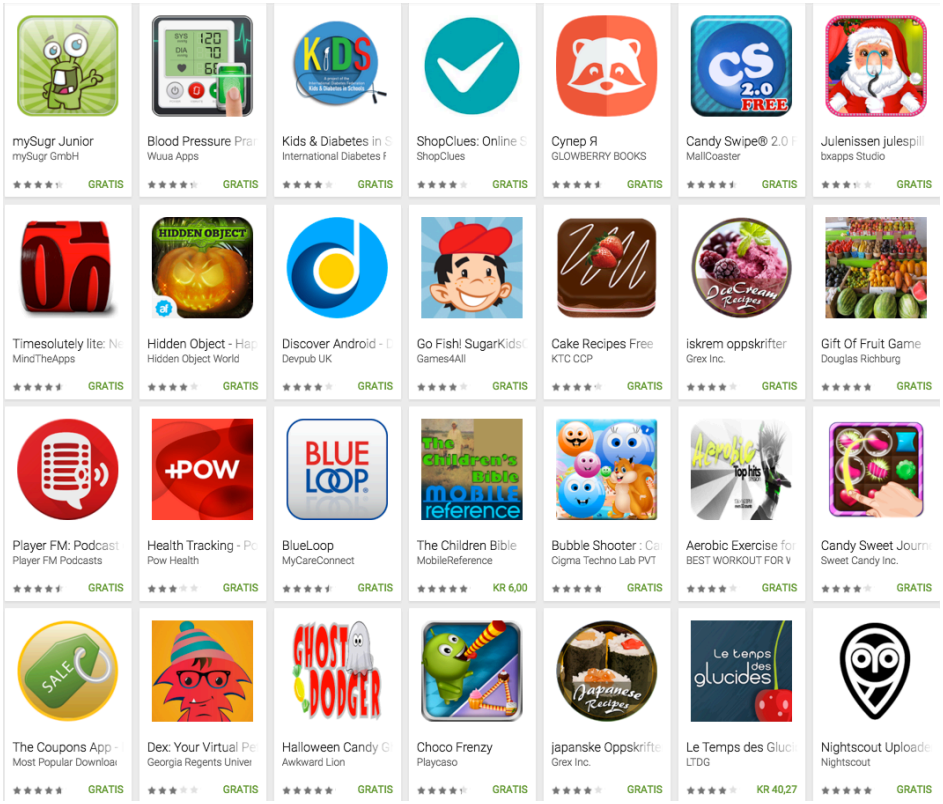


Figure 3.4: "Children Diabetes Games" result on Google Play

The top 5th application from left, "Cynep R[3]" [12], is a russian food application for children with T1DM with the purpose of teaching the children self-discipline, healthy habits and good nutrition insights. By using the application all input is registered as a blog, where the parents can get an overview of how well their child is progressing, or to help if necessary. This application, however, is currently only available in Russian, which makes it hard to use

[3]Supposed to be russian, but had issues with Russian letters in the document. See reference for link to correct name

for Norwegians. Among the results you even find “Dex: Your Virtual Pet”, which was one of the more related applications found when looking at iOS applications.

3.2.3 GlucoZor

When looking for relevant serious games in the masses of applications available I came across GlucoZor [24] when searching for “diabetes game”. GlucoZor is a game for young individuals, where the user (cares for)(tar hånd om) a dinosaur with diabetes in a tamagotchi fashion. By creating and giving balanced meals, fun activities, controlling the blood glucose levels, and cuddling with the dinosaur, it attempts to educate the children how to face the challenges as diabetics and living a healthy life. In Figure 3.5 you can see how GlucoZor reacts when his blood glucose levels are getting too low, indicating that he needs insulin to feel better again, which the user is about to give 10 doses of.

Figure 3.5: GlucoZor getting insulin, Photo: Google Play

GlucoZor has a rewarding system where the user is rewarded in-game coins for good progress. These coins can be used to purchase new activities or upgrading the playground with GlucoZor lives in. Figure 3.6 shows the playground while GlucoZor is in the half-pipe on skateboard. This gives the game a big potential for fun elements, and not just the tamagotchi gameplay.

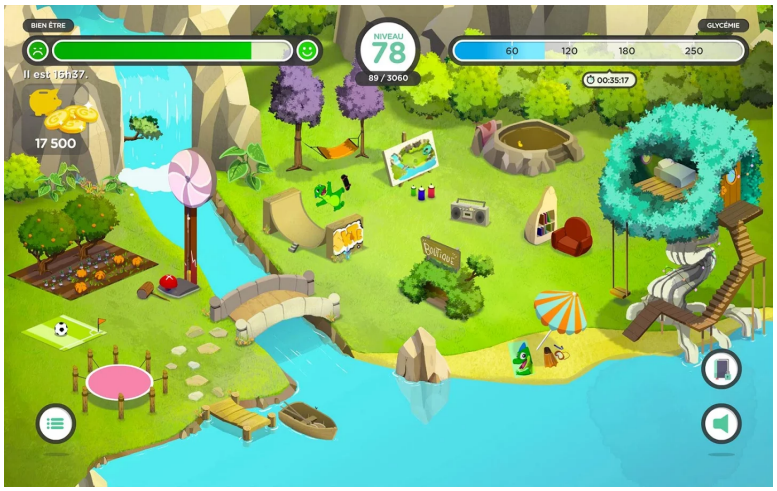


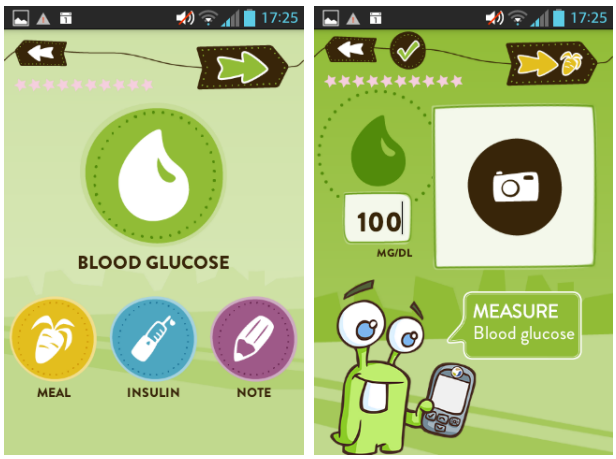
Figure 3.6: GlucoZor in his playground, Photo: Google Play

3.2.4 mySugr Junior

As mentioned earlier, mySugr Junior [33] is a self-management application which is created for children use. Many of the self-management applications that is available on the market has complicated interfaces and functionality, and no elements that attempts to motivate young people to continuous use. To motivate younger people there has to be some fun elements, so that it is not all about the disease.

In Figure 3.7(a) you see the menu where the type of input is chosen in a understandable manner for children. Big, simple, and colorful illustrations. In Figure 3.7(b) the blood glucose registration is chosen, and the mySugr mascot is illustrated with a (blood glucose meter) in a childish way. There are just two elements to care about: The blood glucose value, and taking a picture of the meter. The picture is included upon registration, and is displayed in the daily overview.

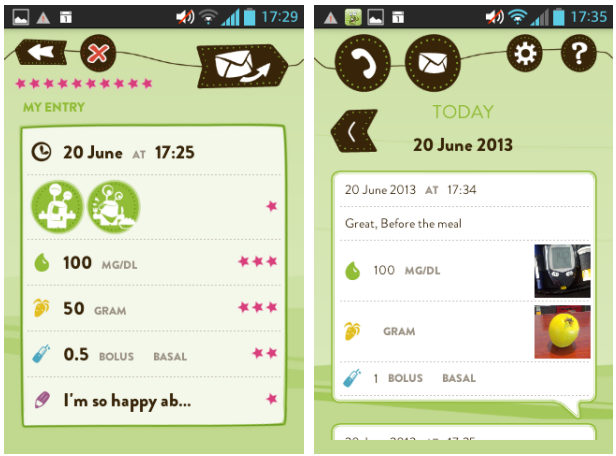
> "... The mySugr Junior App is a diabetes logbook app specially made for children. It makes it possible for children to learn to manage their diabetes in a playful way. At the same time, it helps parents to feel confident and gives them control over the therapy..." [33]



(a) Menu (b) Blood Glucose menu

Figure 3.7: mySugr Junior menu and BG input, Photo: Google Play

mySugr Junior therefore is a more child-friendly self-management application, where the process of registering inputs throughout the day is more understandable for children, but also with some fun elements as a motivational factor. The daily overview, seen in Figure 3.8, where the child can see the given scores for the registrations, Figure 3.8(a), but also have a different perspective for the parents where they can control the given input through images taken during registrations, Figure 3.8(b).



(a) Kids overview (b) Parents overview

Figure 3.8: mySugr Junior kids and parents overview, Photo: Google Play

3.3 Games for Health Europe, 2015

I was present at the Games for Health Conference 2015 in hope to see some related work and gain insight into the level of expertise within the current research of serious games for diabetics.

In general, the choice of platform were based on PC and tablet solutions because of sensor integrations or similar. Solutions targeting elderly people were mostly for PC, as web cameras or similar equipment was included to simplify online communication between health care personal and the elders, while much of the games designed for younger persons included sensors that did not require a keyboard or such controllers to play. Types of sensors or equipment varied from the Microsofts kinect[4] to breathing sensors for children with breathing impairments, and VR[5] googles to let the users experience other environments, among other.

There were two presentations which dealt with serious games for diabetics, the PERGAMON project, and SugarVita. The images from the conference is taken during live presentation, and may vary in quality.

3.3.1 PERGAMON

PERGAMON: Pervasive Serious Games Supported by Virtual Coaching. The PERGAMON project provides a technology framework for the creation of pervasive serious games, with the possibility of integrating sensor devices and supported by a personalized user coaching experience [35]. This project is about creating a framework which other enterprises can take in use when creating serious games. This framework consists of sensors, virtual coaching, and context-sensitive support within the game, which is tailored for the use of each individual enterprise.

> "... PERGAMON is developing a new pervasive serious game that promotes the management of diabetes, as an example of addressing cronic disease through the PERGAMON framework. The game will:-Provide feedback from a network of sensor devices -A personal coach that guides and supports players in daily activities both within and outside of the game...." [35]

[4]Motion sensing input device for Xbox and Windows PCs
[5]Virtual Reality googles

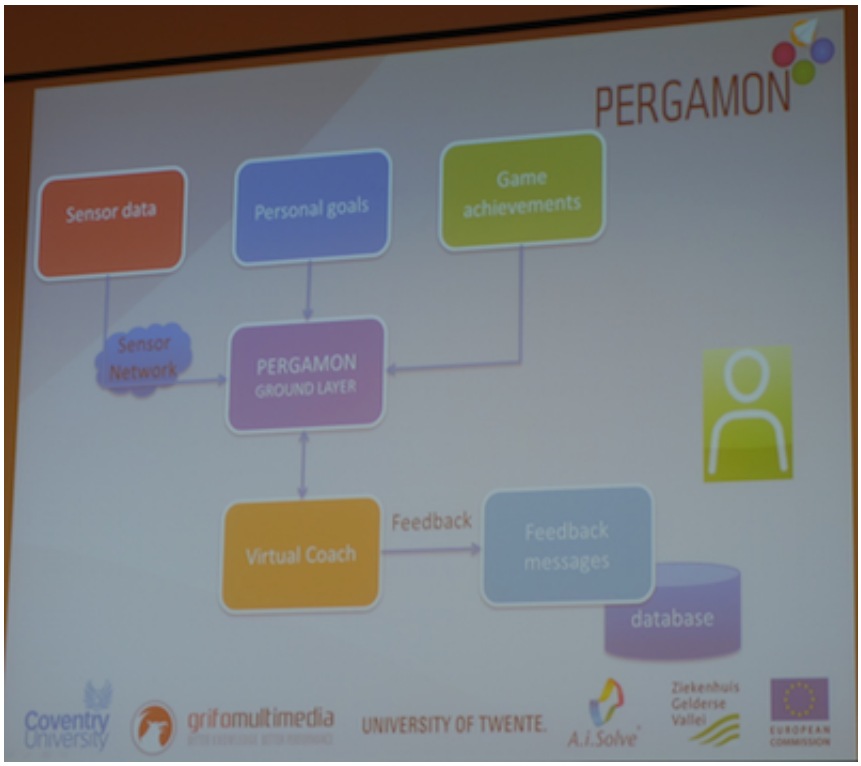
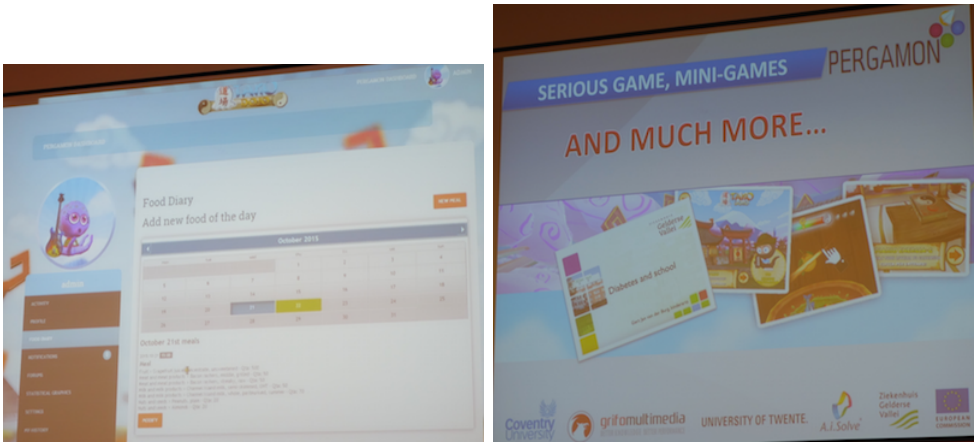


Figure 3.9: PERGAMON Framework Architecture

In Figure 3.9 you see the PERGAMON Framework, and how they intend to build in sensors and a virtual coach to create a tailored background layer which other enterprises can use as a foundation for their serious game development.

The diabetic example consisted of a dashboard which gave a monthly log of activity, food diary, statistical graphics and so on, where the user could register and look at daily food and activity information, as seen in Figure 3.10(a). Together with the self-management part, they also had mini-games with the purpose of informing or education about diabetes for the users. Figure 3.10(b) shows different examples of mini-games and information which could be included.



(a) Diabetic dashboard (b) Activities example

Figure 3.10: PERGAMON diabetes management

3.3.2 SugarVita

SugarVita is a project by Maxima Medical Center in Eindhoven, Eindhoven University of Technology, and Fontys School of Applied Sciences in Eindhoven, where they have developed a digital board game for young seniors to gain knowledge about factors that influence their glucose level [40]. To achieve realistic functionality of the game behaviour they have both developed a physiological model to predict blood glucose and insulin levels, but also user research and concept development to ensure educational output of playing.

The goal of the SugarVita project: "Design a digital application to educate people about their diabetes in a personal and playful manner, which fits the lifestyle and needs of our target audience." with the current conclusions:

- SugarVita, a digital multi-player board game
- Traditional concept, modernized through technology & style
- Includes a physiological model to predict glucose levels
- Playful education for patients and beloved ones
- Next goal: motivational and educational effect

(a) SugarVita Digital Boardgame (b) SugarVita Gameplay

Figure 3.11: SugarVita Digital Boardgame

In Figure 3.11(a) you can see the overview of the board that is used in the game, where the light-purple fields with a "?" is a "take-chances" similar to other board games, and the dark-purple fields is one of the diabetic fields like physical activity, food, or insulin. When the player rolls the dice in-game and lands on a diabetic field, the player is affected by a health status which impacts the blood glucose level for a given amount of turns. As seen in Figure 3.11(b) in the top of the screen from the left, the user is affected by 3 health statues. The blue one is Insulin and lowers the blood glucose level, while the two red ones represents an action which increases the blood glucose level, like a snack or a small meal. Next there is the colorful bar which represents how healthy the blood glucose levels are, which the user has to attempt to keep around the green area, followed by the numeric value of the blood glucose level.

The board is based on a daily cycle, where they start from waking up and then traversing through three food or activity periods. On the board it looks like the first cluster of steps could be the breakfast time, before the midday cluster and then the late evening cluster before they end up at the bed and start area. As the user traverses the day on the board, they have to balance their food, activity and medication values, and when the game is over it is displayed a daily overview of their blood glucose value, as seen in Figure 3.12.

The person which managed to control their values best is the winner.

Figure 3.12: SugarVita Daily Overview of the Blood Glucose values.

3.3.3 Games for Health EU Proceedings 2013 and 2014

When looking at the available proceedings from the earlier Games for Health conferences, currently 2013 [77] and 2014 [78], there is only one peer-reviewed paper that is related to diabetics:

Game Design of a Health Game for Supporting the Compliance of Adolescents with Diabetes:

> "... The main objective of the game would be to promote the compliance of the affected person with diabetes treatment. It is meant to raise the awareness of the adolescents regarding the need to accept the disease and to face life with the sense of responsibility that the situation requires..." [78]

The game which will be developed is based on a simple "Jump and Run" genre, where the hero controlled by the player has a handicap and has to fulfil

tasks that "may get him/her into a tangle or further into mortal danger" [78]. The diabetic metaphor in the game is to achieve balance of the hero's danger level through the game. They also present the social issue of having diabetes, where they introduce a sidekick[6] which represents the social environment and helps the hero in difficult situations which can not be handled alone.

It has not been the greatest presence of serious games for children with diabetes presented in the 2013-2015 Games for Health conferences and proceedings, which could be an indication that it is a field with great potential. There are also commonalities within choices of device for the solutions being presented. There is a high focus on tablet and bigger devices with more gaming possibilities compared to smaller devices, like handheld smartphones, which can be carried more easily around and therefore more available at times.

3.4 Comparison Conclusion

Throughout this chapter I have identified serious games which is released in application stores for smartphones which is related to the approach of the serious game developed in this project. I have also checked available literature on google scholar[7] for related literature which may present a non-developed solution similar to this project. At the end I presented relevant presentations from when I attended the Games for Health conference in November 2015.

Most of my own findings from the literature searches concluded in articles attempting to find a global design method for how to design serious games, before presenting some of the findings from [68] and the total amount of relevant diabetes games were identified.

When searching for related published applications I found a few which was closely related to my approach in different ways. F.ex. GlucoZor [24] had gameplay based on a tamagotchi approach and the user had to manage a virtual pet with diabetes, mySugr Junior [33] presented a compelling approach to a child-friendly self-management application. Dex [14] also presented a virtual pet with diabetes where the user has to balance food and activity to maintain good energy and health. If the player eats too much sweets and bad food, the game presents the user with some information and recipes to healthy food and tips to maintain the correct food plan.

[6] Friendly helper
[7] scholar.google.no

A combination of GlucoZor and mySugr Junior is kind of how I imagined the end-result of this project to end up. The tree represents the virtual pet, which has to be nurtured and taken care of by inserting diabetic information through a child-friendly approach to the Diabetes Diary registrations, but also has fun elements and multiplayer features where the user can extend their tree into a eco-system-like forest as the amount of friends and animals increases.

Lastly i presented the relevant presentations from attending the Games for Health Conference, but also from the Games for Health proceedings of 2013 and 2014. From the earlier proceedings there were only one peer-reviewed paper regarding diabetics, which appealed to adolescents to gain balance in their lives and the importance of keeping social contact to avoid psychological barriers regarding the illness. During the 2015 conference there were presented a digital boardgame, SugarVita, for seniors, which would benefit both the diabetics and their life partners at understanding how diabetes affected their lifestyle and how to adapt. The PERGAMON project presented a framework for pervasive serious games, where they had created an example game for people with diabetes with a dashboard and log for self-management purposes, and minigames for education about diabetes.

Chapter 4

Methods

This chapter contains the methods that has been used throughout development to ensure the quality of the outcome. The process of developing any system, or in this case game, consists of several steps from the beginning to the end, where planning is extensive and execution is repeatedly thought through.

Quoted from a report published in 1989:

> "... The third paradigm, *design*, is rooted in engineering and consists of four steps followed in the construction of a system(or device) to solve a given problem:
>
> - state requirements;
> - state specifications;
> - design and implement the system;
> - test the system.
>
> An engineer expects to iterate these steps (e.g., when tests reveal that the lates version of the system does not satisfactorily meet the requirements) ... " [61]

The above quote shows that the definition of an engineer is just as accurate at present times. Game development shares a lot of the software engineering methodologies, but with perhaps a few differences in the including roles that is needed to ensure the outcome of a worthy game. Similar to the

way of developing systems, developing games that have a poor development methodology, or none at all, often take much longer than they should, run over budget, and tend to be unreasonably buggy[1] [56]. Therefore, planning the game details as an early process to achieve a overview of all the components that has to be implemented is used as a tool to help the developer(s) focus on the core components. This way the main functionality is kept in focus, and not spending too much time on objectives which may not be relevant for the final outcome.

Planning the development process is just one of many methods of ensuring quality and correct focus through the entire development, specially where there are several instances and stakeholders involved in the project where each has their ideas and opinions of the development. To ensure all involved parts were kept up to date on the progress, and satisfied with how it was developed, the agile development methodology was used.

4.1 Agile Development

During the development phase of a game or a system, it is important to include stakeholders in the creation process and to make sure to elicit each individual stakeholder requirements and needs [71]. The requirements and needs for the project must then be developed into well documented, detailed, agreed requirements which will be the fundament of the given system. The requirements will act as a specification of how and what the end result should satisfy, based on the needs of all the involved stakeholders.

Typical situations during badly documented development phases could be when stakeholders wants drastic changes of the functionality mid-development, which could result in a lot of wasted time of the current implementation, or changes close to due-delivery causing it to be postponed to a later date. A possibility to meet changes during development, for example if stakeholders experiences shifting business demands, is to include stakeholders regularly in the development process [74]. This is called Agile Methodology [1], and it is increasingly used in todays development processes [80].

A known agile methodology for this is called Scrum Development Process [1], [38], [74], which is an incremental, iterative way of working compared to the traditional sequential development, where the development is divided

[1] Faulty, contains errors.

into sprints ranging from 1-4 weeks, where the developers and possibly stakeholders meet at the start and the end of the sprint for continuous updates or feedback. See Fig 4.1 for the process of Scrum.

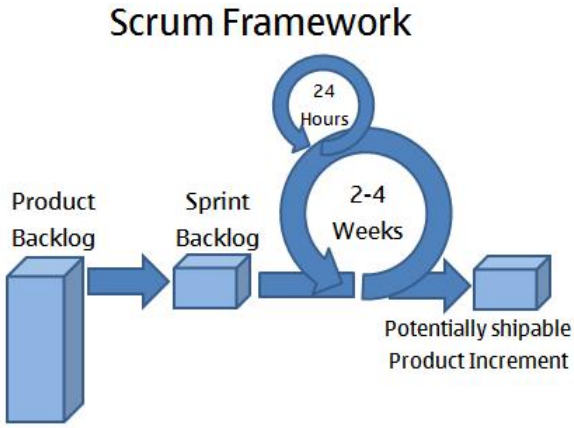


Figure 4.1: Scrum Framework, Image: expertprogrammanagement.com, [74]

Starting from the "Product Backlog", which is all the tasks that has to be done during the development process, a small sample of the tasks is then picked, the "Sprint Backlog". The sprint is an iterative period of 2-4 weeks where the sprint backlog tasks are done. When one sprint is done, a new one is started with new tasks from the product backlog, unless there are unfinished tasks from the last sprint. Sprints are repeated for the whole duration of the project. The purpose of a sprint is to involve all the stakeholders and interests in the start and the end of a sprint, where all involved parts is updated on the progress for that period. In these meetings possible issues which were discovered during the time is brought up and figured out together.

While the stakeholders are involved in the sprint phases, the developers of the project often has daily stand-ups together to bring the other developers up-to-date. In these short daily meetings, could be just five minutes before they start working in the morning, they report their progress to the other developers which then can give feedback if they feel the progress is heading in a wrong direction, or possible improvements or other options. This is done frequently through the whole development process.

For each completed sprint: the stakeholders are involved and kept up to date, the developers have regularly kept each other up-to-date, and in the end a small part of the tasks has been completed. The process is then repeated with a new sprint, until the product backlog is empty, or until the product from the sprints satisfies the requirements for the end result.

The scrum process has been used throughout this project, where stakeholders have been spread across corporations. Together with my co-supervisor at Plus Point I've had meetings each second week where the graphic and game development has been discussed, and attempting to finding the best solutions for the visual end-result. On the other hand I've had weekly meetings with my supervisor and co-supervisors at UiT/NST, where it has been more focus on the ideas behind the game. Therefore it has been important to keep both sides updated on the progress in the other part as those weekly meetings were separated.

4.2 Development Platform

The game development was done in a game engine, which gave easy access to powerful tools to simplify creation of functionality, behaviour and the integration and use of graphics. This could have been done by using different approaches, like implementing everything from scratch, including different types of engines and tools required in the end result. Or by using an already existing game engine where you also start from scratch, but has the option to simply add tools or elements which is supported within the game engine. These elements or tools could be things like physics, collision detection, easy creation of the game world, real-time display of the images and their location on the screen, and so on.

The choice of game development platform for this project is Unity[2] [43],but there exists other solutions which could have been used to solve the given problem, like Unreal Engine [45], CryEngine3 [11], GameMaker:Studio [23], and several others. Each of the different game engines has their pro's and con's, like Unity currently has the best licensing terms but can be time-consuming for making games with complex and diverse effects, while Unreal Engine has the largest community support but higher learning curve on the tools to use, and CryEngine offers an amazing graphic output and the most powerful audio tool but is relatively new on the market and therefore a small community support and a steep learning curve [22].

The chosen development platform for this project was actually set as a requirement beforehand, possibly to achieve greater insights or experience with the use of it for future projects within the research group.

[2] `http://unity3d.com`

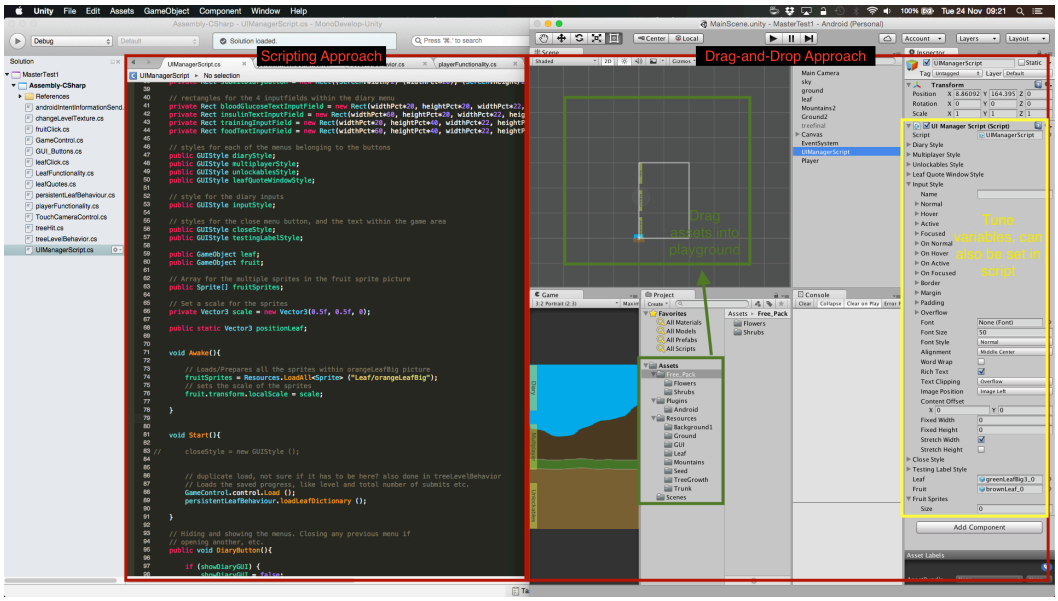


Figure 4.2: Scripting vs. Drag-and-drop

Unity is a powerful game-making engine which allows the programmer to use a variety of tools [43] for both a drag-and-drop approach, where you simply drag elements into the environment and use tools to manipulate their functionality, or a scripting approach, where pure programming can be used. No matter which is preferred, they can be used interchangeable at all times, so the approach is not a set decision which has to be taken into consideration. Figure 4.2 shows some example of the scripting approach on the left side, versus the drag-and-drop environment on the right side. On the right side you can see the playground where all the game objects can be places and moved into the correct possition, both in 2D or 3D, and below to the left you can see how it would look on the device screen. When the implementation is executed, the game will be playable in the editor through the device screen simulator as if it was done through a real device. For testing on real device just plug in and connect the device to the computer via a Universal Serial Bus (USB) cable, and the game can be built and deployed to the device.

The great variety of tools makes it easy to create and see the progress during development and without any third-party[3] systems to run it. Other built-in features in Unity are easy 2D or 3D manipulation, animation of sprites[4],

[3]A program or system which is not related to the used system, but built as an extension to solve a issue not provided by the original system

[4]Image or animation that is integrated into a larger scene

physics, collision detection between objects, and more.

In Figure 4.3 you see a tree which is added to the game scene. To the tree there has been added a "Polygon Collision" feature, which basically defines the area of the picture by placing several small areas of collision detection areas. This gives a much more accurate collision detection that using more primitive figures when it is used on figures with complicated shape. There are several different types of collision features to chose between, like box, edge, circle colliders, but it all depends on the object it should be used on. Is it 2D or 3D, how many edges, the figure of the object and so on. Complicated figures with a lot of curves, edges, nooks and crannies benefits best from the "Polygon Collision" used in this example.

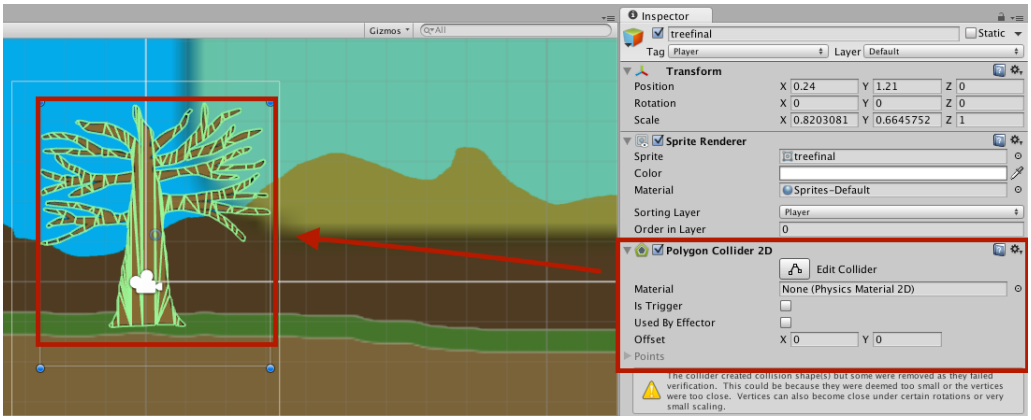


Figure 4.3: Simple feature to detect collision on complex figures with several edges

This is just one of many helpful tools within the Unity game engine. Another great feature is the multiplatform support, where the end product can simply be converted to work on almost any type of platform or device[5], in addition to extensive animation possibilities, graphics like lighting and shading, real-time mixing and mastering of audio, and advanced optimization options, like memory profiling.

[5]Slight modifications or adjustments might be necessary to achieve the best outcome

4.3 Unity on Android Platform

Unity projects can be deployed to multiple platforms, which makes it useful for multi-platform compatibility like Android and iOS smartphones. However, if any platform-dependant implementations are used, like Google's Play Store [25] and its Application Programming Interface (API) [26] for Android [5] or Apple's App Store [6] for Apple devices[6], this has to be changed between platform deployments.

For simplicity this project is currently based on Android smartphones, but the multi-platform deployment gives the possibility to port[7] the game to other platforms, like iOS, as future work.

At the time this project was chosen, the Diabetes Diary application, which the game of this project builds upon, only had released an Android version for use but were in the process of creating an iOS version. Since the game communicates with the Diabetes Diary application on the same Android device, it is required certain Android implementation within the Unity project to make it work. This is explained more in detail in Section 2.2, but should the game be ported to iOS this would have to be modified to the equivalent iOS implementation.

4.4 Game document

The Game Document is a descriptive text of the game which explains all the parts which makes the game, where each part is narrowed down to the smallest detail, explaining its use and purpose. Since the document is created early in the game development process, the content may be changed or parts may be added or removed as the game is being created and each part is being realized.

During the development process of this project, a game document were created in cooperation with one of my co-supervisors, Ismet Bachtiar. This document explains all the planned parts that the game should consist of, their parameters, and their functionality. By creating this document early in the process, figuring out how the result and functionality could be, the development of the game itself was a lot clearer since all the elements were

[6] iPhone, iPad, Mac, iMac, etc

[7] Adapting the software to a different environment than originally designed for

defined on paper and just had to be implemented in code.

Since the game document explains all the elements in the game, it is included as the design of this project in Chapter 5.2.

4.5 Sequential Game Structure

The Sequential Game Structure document has the same purpose as the previously mentioned Game Document, but from another aspect. While the Game Document explains all the elements at detail and their purpose, the Sequential Game Structure has the purpose of explaining the step-by-step interaction with the game. What happens when the game is opened, what does the user have to do or click on, how does the user gain feedback on his actions, are there difference between the first-time use and repeating steps, etc. By explaining all the steps, and what happens when something is interacted with, what does the next step present, and so on, the document acts as a text-based version of the game or system, and by reading the sequential steps it is gained an understanding of how the game works and what it ideally wants to present.

The Sequential Game Structure explanation is benefitting for my project, as only the core functionality has been implemented, while graphical or visual feedback like text boxes or game replies is not present. By reading the sequential game structure it would give explanation to elements within the game that is not currently available, but would be in a eventual end-result.

The full Sequential Game Structure is included as Appendix B.

Chapter 5

Requirements and Design

I this chapter I will attempt at presenting the requirements and design which were developed during the planning phase of this project, but since the planning was done together with Ismet at Plus Point the requirements and design was somewhat done together and resulting in the Design section. Throughout the planning process all the elements of the game was thought out, where the functionality and design of each element that built the game was documented. This was done in the "Game Document", which is included in the Design section and describes each of the mechanics the game should consist of. After this document was finished, I could start implementing the game based on the document.

In requirements I mention among other things requirements which were set when the project was chosen, but also attempting to write down requirements that was shaped during the "game documentation process".

The process of creating a game has similarities with traditional software development, where games are software with art, audio, and gameplay. However, there are difference in the development process between these categories. There are elements required in creating games which does not build upon the software engineering methodology, but more in the creative, visual and storyline methodology. A system may achieve its purpose based on good usability [54], while a game continuously need to motivate the player for continuous use to be attractive [13], and the aspects of keeping players motivated includes several parts. The same purpose counts for the serious games genre, as they are built to inform or educate the players there has to be elements which motivates the user to want to continue playing the game at later occasions.

Game development include large parts of arts, audio and gameplay [56], and the same counts for the serious games. The process of creating a game therefore builds on methods that differ from the software engineering approach. For example, the gameplay should be based on a storyline which would keep the player interested in the outcome of continuing the progress, while the art and audio presents the gameplay in a satisfactory way.

The development of the We.Tree game has its roots from software engineering, but solo developing a game from scratch has differences compared to the traditional software engineering approaches. Implementing gameplay based on the growth of a tree, acquiring graphics or assets or make own to benefit the visual part, visual feedback to motivate the user, are some examples of the varying elements to take in consideration.

To achieve the best result as possible, game requirements and the general outcome specifications was documented as a pre-development process to get an overview of elements and requirements that had to be focused through the game development phases.

5.1 Requirements

As quoted by Denning [61] in Chapter 4 on the steps to follow in the construction of a system, the creation of a game follows the same steps. In the beginning there has to be stated requirements for the game, both to what the game must do and qualities that it must have. This is to ensure that the stakeholders, users and developers all agree on how the outcome should be. Incase of bad documentation and communication between the involved parts, the outcome might not end up as they expected which could end up with extra costs to get it fixed, or a delay in the delivery of the product. Therefore all the stakeholders should create a well-documented requirement specification in cooperation with the developers, where all agree on how it should be solved.

When I chose this project, there were certain requirements which I had to adapt to regarding what I was supposed to develop and how. Based on requirements like, creating a serious game, for smartphones, use Unity, is some examples of requirements that I as a developer got from the stakeholders of the project.

Further i will explain the requirements that was set for the project, but also

mention constraints and project drivers through the development process.

Functional Requirements: "Things the product must do." [75]. With the given topic of this project, there are a some requirements the functionality of the game should satisfy. See Table 5.1 for an overview of what the game should accomplish during use, where "Description" states the requirement, "Purpose" explains the requirement, while "Source" is who set the requirement.

Table 5.1: Functional Requirements

#	Description	Purpose	Source
1	Educate	The game shall educate the user about diabetes, how to maintain a healthy lifestyle to avoid complication, and how to use self-management applications to make the process easier to control. A design suggestion is to present information through interacting with the leaves.	Project
2	Social	The game shall have the possibility of connecting the user with friends and other in the same situation to increase the social aspects. A design suggestion was to present connections as roots.	Project
3	Diabetes Diary communication	The game builds on the use of the self-management application Diabetes Diary, and shall in this implementation communicate with the separate application on the same device.	Mats

Non-functional Requirements: "Qualities the product must have to be acceptable to the stakeholders and operators such as performance, look and feel, usability" [75]. Since this project spans over a short period of time there are few non-functional requirements as the development will not get to that

stage of implementation. The only non-functional requirement I can come up with is that the game is based for young persons, and therefore the usability must be understandable for their age.

Other than the functional and non-functional requirements, the project constraints also defines requirements which affects the development process of the project. Project constraints is more global requirements, which might not directly affect the functionality, but limitations or restrictions which then affects the outcome.

Project constraints: "Global issues that shape the requirements." [75]. See Table 5.2.

Table 5.2: Project Constraints

#	Description	Purpose	Source
1	Smartphones	Smartphone based game, not tablets or bigger devices. This to make it a more portable and lightweight game that can be brought and used anywhere, and not just in the couch where the tablet is.	Project
2	Android platform	Android based implementation, as time-limitations does not allow for multi-platform focus throughout the project.	Project
3	Serious Game	The genre for the project was Serious games, since it is a game ment for educating users, and not purely for entertainment	Project
4	Children	Young Individuals to limit the targeted age-group, focusing on creating a game for a given age-group instead of everyone.	Project
5	Diabetes	A cooperation with the Diabetes-group at NST, and to limit the educational part for a single disease	Project
6	Unity	Project has to be developed by using the development platform Unity3D	Project

With the given Non-functional and Functional requirements and project constraints for the project, I could start planning the game based on the plan for the outcome. In cooperation with my co-supervisor we came up with a fitting concept of gameplay and elements which together resulted in a worthy plan.

The core mechanics which were thought of in the beginning is presented in Table 5.3, and all game elements is explained in detail in Chapter 6.

Table 5.3: Game Development Planning

#	Description	Purpose	Source
1	Tamagotchi gameplay	Growing tree as a virtual "pet" which grew as the progress increased	Ismet
2	Leaf Growth	Continuous reward for submitting Diabetes Diary inputs. The leaves should also act as the source for information regarding the diabetic situation.	Ismet / Mats
3	Fruits	A rare reward, which could be used to boost the users own progress, or it could be passed to a friend as a token of help.	Ismet / Mats
4	Animals	Fun element, different animals unlocks different mini-games which can be played against friends or fun singleplayer activities.	Ismet / Mats
5	Roots	Using the roots as a metaphor of multiplayer connections, where the user grows their tree and the roots spread out in the world connecting to either friends or other in the same situation.	Ismet / Mats

Project driver: "Business-related forces." [75]. The project drivers represents what lies behind the creation of the game: like who is the owner of the project and how they want it to be realized, the users and what they may gain out of the result, and so on. See Table 5.4 for all the project drivers.

Table 5.4: Project drivers

#	Description	Purpose	Source
1	Cooperation	Cooperation between the University in Tromsø and Plus Point in Tromsø, which results in more stakeholders and seriousness. The chances of the project to be continued in the future is bigger as there are different types of stakeholders which may see the potential.	Project
2	Research	The project is a part of the diabetes research group at NST, where the group is included and knows about progress and can give feedback and inputs to the process. Since the result builds on an application closely related to the diabetes group it may be possible to include the end result in the diabetes applications portfolio.	Supervisors
3	Serious games	Serious games is a genre in big growth, where the possibilities of using serious games is starting to become clear, and more attempts of creating serious games to a given issue is increasing.	Mats
4	Global Market	Creating games today can reach out to a global market and cam be deployed on several platforms. This gives the opportunity to release the game in such a way that it can be instantly reached from all over the world, get a huge community and a lot of users.	Mats

Project Issues: "Define the conditions of which the project will be done." [75]. Project issues gives a picture of the factors involved in the development process and that could have affected the end-result, either in a good or bad way. See Table 5.5 for most critic issues.

Table 5.5: Project issues

#	Description	Purpose	Pro / Con
1	Short time	Short semester, less time to put some effort in the programming part since writing counts most	Con
2	Exchange program	Initially supposed to be a exchange program with the possibility of group work with students at UMN, but did not happen so the amount of implementation was reduced as it had to be done solo	Con
3	Games for Health	Attended Games for Health Europe, seeing state-of-the-art solutions and presentations which could possibly provide input for my work. This has been explained more in detail in Chapter 3	Pro
4	Game Environment	Game implemented in Unity, a development platform made for building 2D and 3D games easily. Great selection of tools which might enhance the user experience, and simplify the tasks for the programmer	Pro

Discarded ideas, or possible future work. Elements that has been mentioned throughout the implementation period as possible things to add to the gameplay, or ideas which could improve the overall feeling of the end result. Many of the ideas are possible future works, which could be implemented should the project be continued at another time, but many ideas are also just general thoughts which might not be necessary but fun to have included. See Table 5.6 for more information.

Table 5.6: Possible Ideas

#	Description	Purpose	Wh0
1	Tree sicknesses	Add sickness elements to the tree, to make the user adapt to the gameplay situation, trying to make the tree healthy again	Possible future work - Gunnar/Svein-Gunnar
2	Tree sickness behaviour	A tree sickness to motivate the user not to eat for example candy for a whole week. Trust based, no ways to make sure that the user maintains the task. Tasks may be changed to other types of food, or do motivate to more training for a period for example.	Possible future work - Gunnar/Svein-Gunnar
3	Parental Control	Having a parental control, or a way for parents to monitor or alter the gameplay or requirements and be able to give rewards	Possible future work - Gunnar/Svein-Gunnar
4	Weekly game report	Through the parental control, give the parents a weekly report of the game progress for that week	Possible future work - Gunnar/Svein-Gunnar
5	Forest representation	Making friends and connections appear as a forrest in the background, where each friend represent a tree (or multiple, to avoid the feeling of less friends). Possibility to interact with trees.	Possible future work - Ismet/Mats

6	Ecosystem	Let the animals and forest representation be like a ecosystem which gives the user increasing amount of objects to interact with, make it more fun and a more visual feeling of achieving growth and progress	Presentation feedback - Possible future work

5.2 Design

As mentioned in Section 4.4 a Game Document were created in cooperation with my co-supervisor, Ismet, in the development process of the game before I started on the implementations. This document explained all the elements which was planned to be included into the game, what they were supposed to do and how they worked. Since this document explains the structure and all the elements it fits good as a Design description.

Since the Game Document was created in advance of the implementation itself, elements or their impact may be different compared to the implementation, but mostly the game document is equivalent to the current implementation.

The design of the game is as follows:

Player, The tree managed by the user

- Upwards Growth
  - Increase size of the tree - Taller, thicker, more branches
    - Stages
      - Initial Seed
      - Little twig
      - Branching out
      - Multiple branches
      - Increasingly taller, more branches - Continuous growth

            - "Final stage" - Ideally a generic growing tree which can grow "forever"
        - Growth increased by:
            - Diabetes Diary application input - Gameplay mostly based on Diabetes Diary inputs
            - Nutrition / Daily interaction with the tree or its surroundings - Gamification elements for some progress functionality other than Diabetes Diary inputs

- Downwards growth, Roots for multiplayer connections
    - Roots grows underground
        - Stages
            - Initial, seed with no root
            - 1 small root
            - Roots branching out
            - Multiple branches of roots
            - Bigger root, with increasing number of branched roots
            - "Final Stage" - Ideally a generic growing tree, with roots following the growth "forever"
        - Grows / Increases as the tree grows. Roots is a part of the tree
    - Roots allows for more connections / multiplayer possibilities
        - Each root represents a connection possibility, friend or random

- Leaf amount
    - A sign of progress / status
        - Healthy Tree
            - More leaves
            - Color of the leaves, green
            - Increasing amount of animals at/in the tree
        - Unhealthy tree
            - Decreasing amount of leaves / Leaves may start to fall off
            - Slow progress on tree growth, caused by few diary inputs
            - Color of the leaves, orange/red/brown, depending on inactivity

            - Residing animals starts to evacuate

- Fruits
    - A rare version of the leaf, a fruit might spawn instead of a leaf. Functionality which boosts the progress of some type
        - Apple
            - Increases growth rate of tree
        - Banana
            - Increases chances for additional fruits
        - Coconut
            - Increases the effects of environmental elements, like weeds and weather effects
        - Grapes
            - Increases the amount of leaves generated per Diabetes Diary input
        - Orange
            - Increases the chances of animal visits
        - Pear
            - Reduces the growth rate of weed
        - Can easily add more fruits or change their property.
    - Fruits harvested from the tree when they spawn
        - Can be used by the player
        - The player could gift it to a friend instead

Environment, Environmental elements that benefits the player progress

- Critters / Animals
    - Moose
    - Fox
    - Monkey in the tree
    - Birds
    - ...
    - Each animal represents a different mini-game /fun feature
        - Single player game

        * Multiplayer game, can invite friends or connections
        * Fun activities
    - Seeks the tree at different occasion
        * Short visit, timed event
        * Permanent home, taking residence in or around the tree
        * Collectable, added to the collectables tab which is an overview
- Weather, game elements to increase growth other than diary input
    - Less effect than Diabetes Diary inputs
    - Rain to water the tree, increases growth
    - Weeds, Fallen leaves, threats like snails, leaf worms...
        * Clean away to stop them from stealing nutrition
    - Cloudy
        * Swipe away clouds to let the sun shine on the tree

Social

- Roots connects to other players
    - Fun
        * Asynchronous mini-games with friends / connections
        * Leaderboards between friends
    - Communication
        * Chat, socializing
    - Helping out
        * Visit a connections tree, aid in nutrition / growth
        * Send boosts to connections
- Unlocked by progression
    - Roots allows for connections, more roots = more connections
    - Achievements, Eco-system: gardens, forest
        * Friends / Connections can be represented by trees in the background, eventually creating a forest

Graphical User Interface

- Buttons
  - Diabetes Diary input
    - Tab where the user inputs Diabetes Diary information, like Blood glucose values, carbs, physical activity and insulin units, which is then passed on to the Diabetes Diary application
  - Unlockables
    - A log of unlocked elements, and what has been achieved per day
      - Animals residing in/at the tree
      - Leaf information
      - Fruit boosts
  - Multiplayer
    - Show root connections / Friends
      - Able to interact with / visit their tree
    - Communication tool, chatting with connections

Numbers, The impact and values of the elements

- Growth
  - Tree
    - Gradually increased growth requirement
    - 8 + (level of tree), for levels above level 3. Simple algorithm
      - level 0 -> level 1 -> level 2, 4 inputs
      - level 2 -> level 3, 6 inputs
      - level 3 -> level 4, 8 inputs
      - Next levels defined by (8+(level of tree)
  - Roots
    - Follows the stages of the tree
  - Leaves
    - N leaf spawns a day, based on the max amount of inputs possible for a day

  - Fruits
    - Rare version of the leaf, 1/20 chance for fruit instead of leaf
      - A fruit may appear from a random Diabetes Diary input even after the daily leaf has been achieved
      - Up to a maximum of 1 fruit per day
    - Boost types:
      - Apple: 1 input = counts as 2
      - Banana: Increase chance for fruits by 30% for N inputs
      - Coconut: Increases environmental values by 30% for N hours
      - Grapes: Increases leaf rate by 50%, f.ex. 3 leafs per 2
      - Orange: Increases chances for animals by 30%
      - Pear: Reduce weeds / threat growth by 30%
  - Animals
    - Rare occasions, max once every 2-3 days-ish

- Decay
  - Does not reduce level of the tree / roots, but withering the leaves
  - Tree
    - Starts to wither after 3 days
    - Significant withering after 5-7 days
    - "Dead" after 10 days, leaves falls off but trunk remains the same level
  - Roots
    - Follows tree, but is not affected by the withering in the same way
  - Leaves
    - Start to wither after 3 days
    - Lose 10% of max every consecutive inactive day
      - Yellow, Red, Brown color
      - Fall on the ground
  - Animals
    - No new animals if three is in withering stage
    - 1 Residing animal evacuates each cinsecutive day after withering stage is reached

- Notifications
  - Tied to optimal usage of the Diabetes Diary, remind the user to use the diary
  - Type of messages:
    - <Utilarian>
      - "Have you eaten your breakfast?"
      - "Your blood glucose levels are high / low, remember insulin / eat food" - Requires reading of Diabetes Diary information, currently only writing to Diabetes Diary
      - Other types of comments regarding the everyday life
    - <Game Voice>
      - "Live life, get a leaf! Record you readings"
      - "Weeds steals nutrition from the tree, remember to clear them out"
      - Other types of in-game comments regarding the gameplay, try to get the attention and make the user open the game

Chapter 6

Implementation

Throughout this chapter all the elements the game consists of will be presented and their functionality will be explained.

We.Tree has two types of play modes: Single player and Multiplayer. The main purpose of the game is raising awareness of self-management applications and to teach the users to register daily diabetic information, which is focused on through single player. The multiplayer mode is to allow the user to connect with other in the same situation as them; living in rural areas, medications and restrictions, frequent hospital visits and long travelling distances, and so on. By connecting to other, they can share experiences, have fun together and perhaps make the diabetes situation into something more positive.

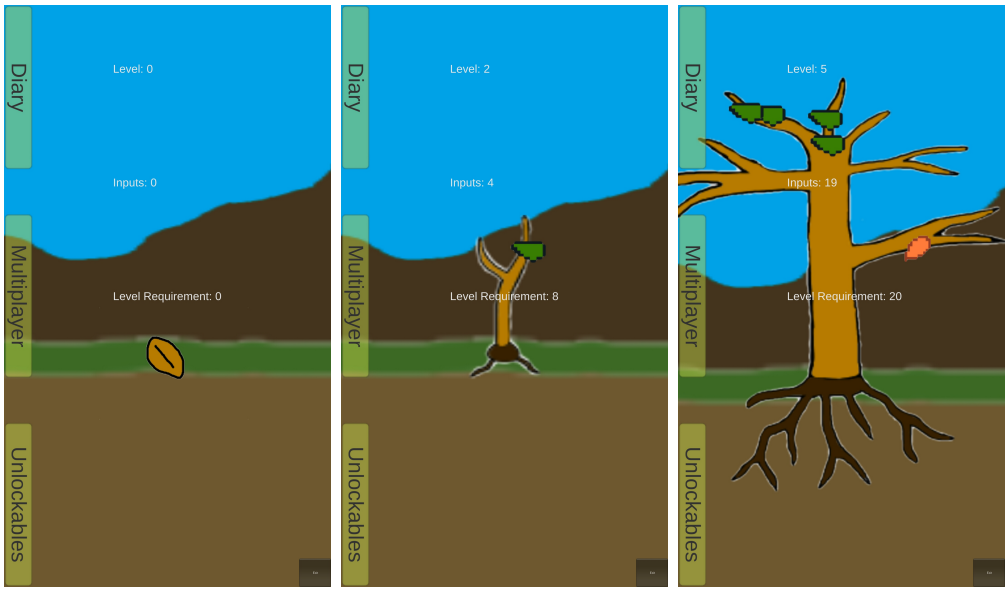
6.1 Core Mechanics

The single player aspect is the core functionality of We.Tree, where the user is encouraged to input food, physical, insulin and blood glucose values to achieve progress within the game. To avoid too much focus on the disease being the main type of progress, there is also included gamified elements which achieves the same progress, but at a reduced rate. The gamified elements is also a way of motivation to continuous use, and not making the game all about entering diabetics data and then done. It should encourage to keep visiting the game as a fun way to gain knowledge of how to live with, and handle the diabetic situation.

6.1.1 Growth of the tree

When the user first starts the game, they are presented with a seed that is planted in the ground. This seed represents the tamagotchi-element, the virtual pet, which has to be taken care of through gameplay.

As the user is introduced to the Diabetes diary functionality, they will learn that by using the diary for the correct purpose achieves progress in the growth of their seed. In the early stages the seed will turn into a spire, and then further on evolve into a taller tree as progress continues. Each time the user registers one of the four types of values into the Diabetes diary they will see the tree growing, either by reaching a new level, or by obtaining a new element on the tree, like a leaf, a fruit, or an animal.



(a) Seed, first level (b) Starting to grow (c) Higher level tree

Figure 6.1: Different stages of tree growth

In Figure 6.1 you can see three examples of growth progress, where 6.1(a) is the starting seed level, which eventually will turn into the two consecutive tree examples. As the tree grows, the requirements to grow to the next stage increases. The tree will therefore grow fast in the early stages, but then take longer time as the level increases. Growth of the tree is represented as the trunk and branches, where the leafs are a separate mechanic.

6.1.2 Roots

As the tree grows upwards against the sky, the tree also grows downwards into the ground. The roots represents connections, and is to be used as the multiplayer functionality where the user connects to friends. As seen in Figure 6.1(b) the tree has two small roots, which could be used to connect to friends. Each root represents separate connection, so as the tree grows and the amount of roots increases, which can be seen in Figure 6.1(c), the player can increase the amount of friends connected to.

As the multiplayer functionality is not implemented at this stage, roots will be explained more in detail in the future work section.

6.1.3 Leaf

Leaves is a way of rewarding the user for the Diabetes diary registrations. For every registration the user performs, there spawns a new leaf on the tree. The leaves represents partly the process of growing the tree as the amount of leaves increases as the tree grows. The point of the leaves is to act as the informational or educational part around diabetes, where the leaf contains a quote, information or some educational fact related to diabetes. By interacting with the leaf the content of that leaf is displayed in a text-box for the user.

Some examples of possible leaf information:

- Shakiness, Sweating, chills and clamminess are signs for low blood sugar, eat some carbohydrates to feel better.
- Recommended Blood Glucose values ranges between 4-10, but consult your doctor for personalized values.
- Too low blood glucose is dangerous, but too high is also dangerous.

There are many possibilities for what information to present to the user, like those above, general information about diabetes, how to adjust to food and exercise, and whichever information that could be use to inform or educate the user about T1DM.

When the information is presented in a leaf, it will continue to be on the tree with the same information, unless it falls off because of inactivity, and could be interacted with at any time, presenting the same information repeatedly to the user. The possibility of remembering the information when being exposed by it over several times is therefore a reality.

6.1.4 Fruits

Fruits is a rare version of the leaf, and has a chance to spawn instead of a leaf each time a Diabetes diary registration is done. The fruit can be used to boost progress, where each fruit boost affects different functionality.

For example, current boost functionality of the different types of fruits is as follows:

- Apple - Increases growth rate of the tree
- Banana - Increases the chances for additional fruits
- Coconut - Increases the effect of environmental elements, like weeds
- Grapes - Increases the amount of leaves generated per Diabetes diary input
- Orange - Increases chances of animal visits
- Pear - Reduces the growth rate of weeds

Currently the fruits are build for the user only, but the plan is to be able to share the fruits with friends to give a helping hand on their progress. More in the future work section.

6.1.5 Animals

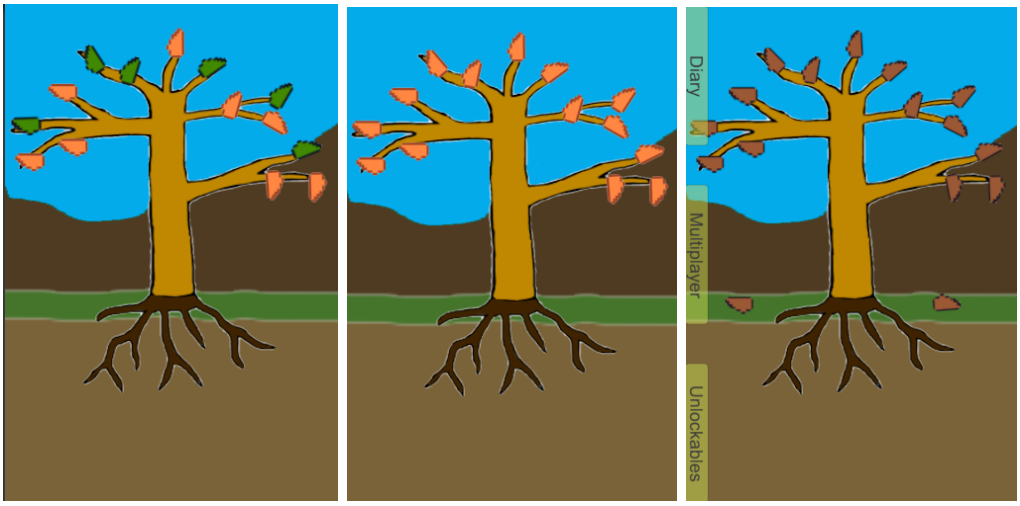
Different animals may seek refugee at or around the tree at random occasions, either temporarily or permanently. The animals represents a different mini-game which then is unlocked when they arrive at the tree. The unlocked mini-games could both be a single player game for the user to play and have fun with, or be a multiplayer game which could be played in cooperations with one or more of the connections of the user.

The concept of animals is present, but there is not implemented any different mini-games which is ready for use and is therefore a future work implementation.

6.1.6 Inactivity

The tamagotchi concept of a virtual pet requires constant attention to keep it alive. Should the user be inactive, the tree will start to wither after a few days until it dies and the leaves will start to fall off after too long inactivity.

Figure 6.2 shows three different stages of withering, where in 6.2(a) it is represented by a few leaves which starts to turn orange to indicate that the tree is starting to become malnourished, until all of the leaves eventually turns orange before they then start to become brown. Should all the leaves become brown, as in Figure 6.2(c), which indicates that the tree is at its final withering-stage, the leaves would start to fall off and lay dead on the ground.



(a) Starts to wither (b) Half-dead (c) Final withering stage

Figure 6.2: Withering stages of the tree

At this stage of implementation, the tree itself does not die after longer inactivity but all the leaves will fall off. Should the user become active again they would just have to start over with the leaves and not the growth progress and at this point it would help with friends that gave fruit boosts to help on the progress and made it fun again.

6.1.7 Gamification elements

To avoid that the game is all about registering diabetic inputs to achieve progress, there is also game elements which benefits the nourish of the tree and that is not related to the Diabetes diary inputs. For example the user has to clear away weeds which grows around the tree to avoid that the weeds steals some of the nutrition of the tree.

Other examples, which is possible future work, is to let the tree get enough sunshine which is done by swiping away clouds on the sky which blocks for the sun, remove rotten fruits or leaves of the tree, keep leaf worms away and so on.

These elements should be a way of keeping the user active for a short time, to let them care for the tree and at the same time gain some growth progress.

6.2 Multiplayer

Multiplayer functionality is to let the user connect to other users in the same users, either other friends which is added to their list of friends and connected to a given root, or perhaps to a random user which eventually could become a good friend through the game. The multiplayer functionality allows the user to invite friends to play mini-games together, where they can have fun and chat together, and also to motivate the other and help in the growth process of their tree. By giving fruit boosts and interacting with their friends tree they can give a hand in the growth process of the tree.

Multiplayer requires heavy implementation to work properly, and has not been done for this project. Multiplayer functionality is therefore a major future work issue, but the social part is an important aspect for the children and is therefore a core functionality of the project. It will be explained more in detail in future work.

Chapter 7

Future Work

This chapter will address the issues of the implementation which did not become a reality, but which was included in the planning phase and considered a core mechanic. It will also explain possible future extensions or solutions which has been discovered during development which could be an improvement to the game.

7.1 Single player functionality

Single player future work presents ideas that has to be included or added in the game to enhance the feeling of the game as it is played by the user only, and where the progress is mostly based on growing the tree through using the Diabetes Diary inputs. It is though the single player functionality the user will gain most of the diabetes information, while multiplayer addresses more the socializing issues.

7.1.1 Present diabetes information in Leaves

The main issue of this project is to educate the users about their situation with diabetes, and provide information and help at trying to achieve control of their daily situation through the game. The information is achieved through the leaves which is generated when a diary input is registered, where each leaf has a new quote or informational text which will aid the user.

Currently there is only made a few test leaves with information which presents basic general information as mentioned in Section 6.1.3. This would be required to both increase the amount of possible information, but also to present it in an understandable matter for the children.

In a extreme situation where the user manages to register the maximum amount of inputs, possibly up to 24 times a day as mentioned in 7.5, through a whole year would require 8760 different leaf information presentations.

No matter the number, there should be a vast amount of different information with the goal of influencing the user and making them aware of things to take into consideration as a diabetic.

7.1.2 Fun elements

Since it will not be so much fun by just reading information from the leaves, there has to be some elements which represents fun and that acts as an entertainment motivation to keep playing the game.

One option is the possibility of growing the tree through environmental effects, such as removing clouds that blocks the sun from shining on the tree but also to balance this with rain that waters the tree, remove weeds and threats that may steal nutrition from the tree, like leaf worms and so on. This will take away the feeling that the growth progress is all about the diary inputs, and encourage the user to also play a few minutes after a registration has been done.

Another idea is games which is unlocked through the animals which is based for single player, where the user does not play together with someone else, but plays it alone with the possibility of competing versus a leaderboard of scores.

7.1.3 Motivate to grow

Some motivational reward for progressing further in the game is needed to make the users want to keep using the game. Currently there are only leaves which is awarded to the user for progressing, and this is not enough motivational reward to ensure continuous use.

An example is the GlucoZor application mentioned in Chapter 3, where the user is awarded coins that is used to built up a playground of different activities. This way the user will keep playing to earn more coins and be able to equip the playground with more fun elements. By introducing a in-game currency which the user will endeavour to keep earning, the game has a fun and motivational aspect of continuation. If the player is just rewarded with a informational leaf they will quickly get bored of it and stop using it.

With the new currency to strive for, there also has to be something to spend that currency on. The playground from GlucoZor is one great example, which in this case is represented by the eco-system idea explained in Section 7.2.3.

Another motivating feature is Achievements. These are unlocked by progress, and represents a feat of progression. By reaching a certain milestone, f.ex. spawn 10 leaves, spawn 50 leaves, spawn 100 leaves, reach level 5, reach level 10, unlock 5 animals, and so on, the player is awarded a achievement with a point based value depending on how tough it is to achieve it. This allows for a certain competition between friends, where they can compete on achieving the highest achievement score, "fighting" each other and attempting to outdo the others.

7.2 Multiplayer functionality

Being able to socialize and play together with friends and connections was a huge part of the planned game. Through multiplayer functionality the user will be able to connect to friends without distance being an issue. With distance being one of the main criteria for this project, multiplayer connections solves this issue by easing the social barriers the user can experience from living in rural areas by connecting them to others through online gaming.

Features which is represented through the multiplayer functionality is: Connecting to friends and connections and the possibility of chatting, inviting them to play fun minigames, and motivate for good and healthy progress through giving boosts and help at taking care of the tree.

7.2.1 Root Connections

The multiplayer aspects of the game is represented through the roots of the tree. As the tree grows the roots expands and reaches out to new places. This can be seen in Figure 6.1, where the tree starts as a seed, and as the tree grows and level increases, the roots expands.

Initially each of the roots branches was supposed to represent an open slot for a connection, so the same root represented the same connection at all times. However, by assigning a connection slot for each branch of the root would result in a limited amount of possible connections. In Figure 7.1 you see an example of where each root contains a friend, and when interacting with one of the connections you are brought to a friend-page where you can f.ex. pass a fruit boost to them, view their tree and give a helping hand, or chat with them.

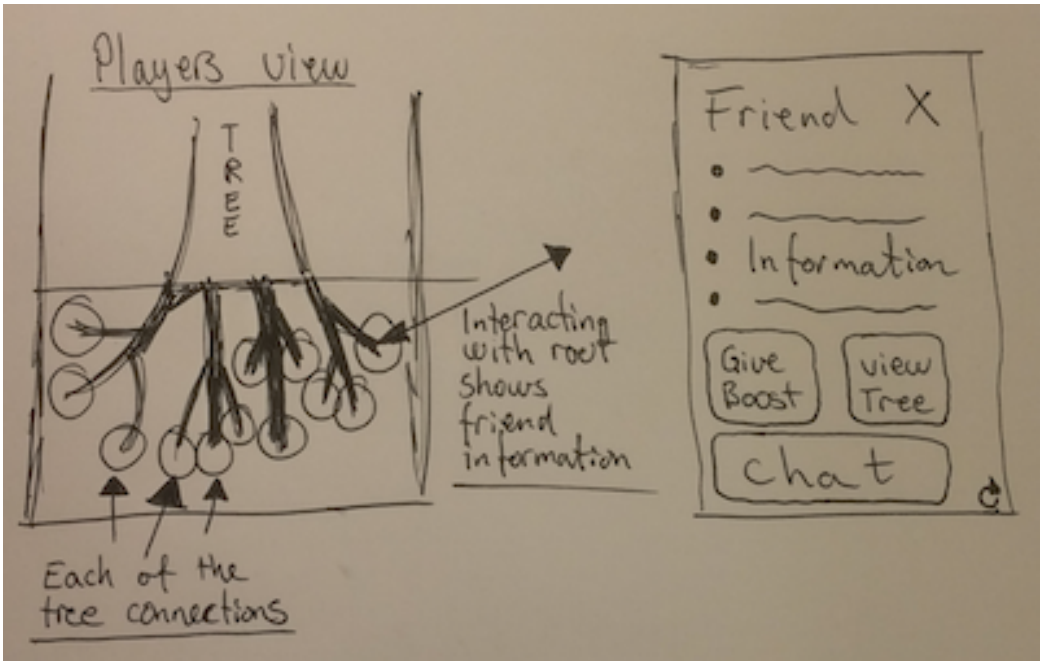


Figure 7.1: Root connection navigates to friend

7.2.2 Multiplayer games

Eventually the player will unlock different animals which takes residence in or around the tree. These animals represents minigames which the user can invite friends to play together. F.ex. a fox takes residence at the tree, and when the user interacts with it he gets the option to invite friends to play chess together. Or a eagle lands in the tree and unlocks a turn-based angry birds like game, where they have each turn to launch a bird into a building a compete to do most damage on the building gaining most score.

Since the game is designed for being played in short intervals each time, the minigames has to be designed for asynchronous use as the users will often not be online at the same time for a longer time. And because of the asynchronous turn based games they have another motivation to open up the game at a later time both for registering input, but also to play together with their friends.

7.2.3 Creating an eco-system

As the user increases the amount of connections, and as animal takes residence at the tree, an idea is to create a eco-system where trees are represented in the background as friends, and animals running around. This offers the same possibilities as mentioned in the GlucoZor playground in Section 3.2.3, where the user can use acquired in-game currency to buy items and place them into the eco-system. This could make the user feel more motivated to play and acquire currency, and to create a zoo-like environment for the animals.

Figure 7.2 attempts to illustrate how friends is represented in the background as other trees, and as the amount of friends increases this eventually grows to become a forrest.

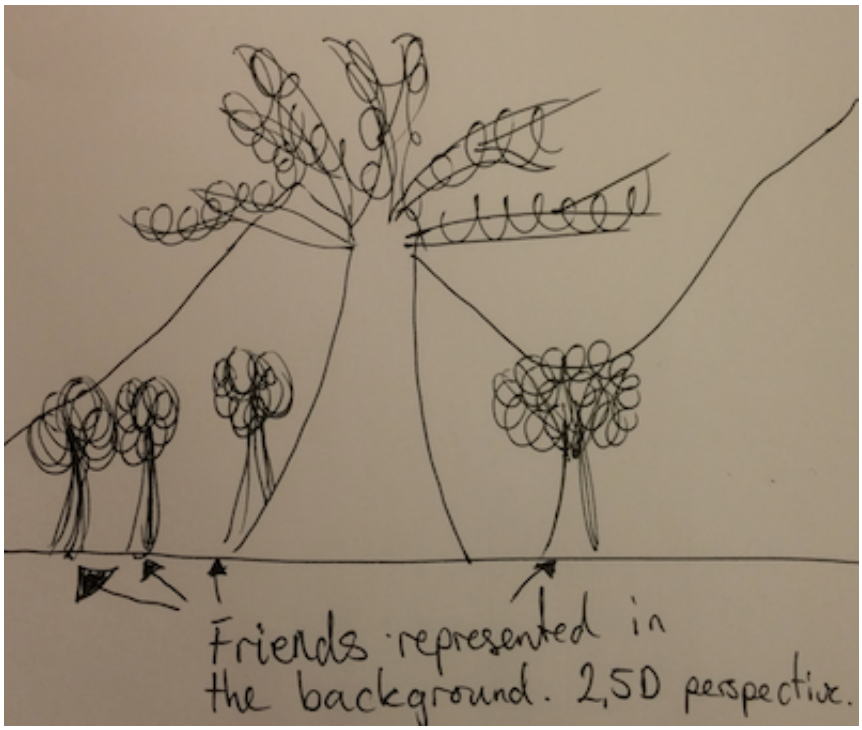


Figure 7.2: Friends represented in the background

7.3 Graphics and Animation

I basically have zero graphical skills, which shows in the graphics of this game. During the development of this game, Ismet, my co-supervisor, made me focus a lot on looking for suitable graphics which could be found for free on the internett, but I found none which suited my needs so I had to create my own for the current use. Creating graphics is one thing, another is to create graphics for animation. When the tree levels up now, it just changes from one image to another without any animation of growth or good looking effects to enhance the visual feeling. The visual feeling is a huge part of the game experience, where good looking graphics appeal to the player.

Figure 7.3 is an example of a graphic file which satisfies the animation creation of an in-game object. This example shows one image that contains drawings of a character at different stages of running to the right and to the left. In Unity this one image will be separated into several small images containing each state of the running, which then can be used in the animation

creation tool to create a fully functional animated figure. When the character is running to one direction, the images will loop and create the illusion of running.

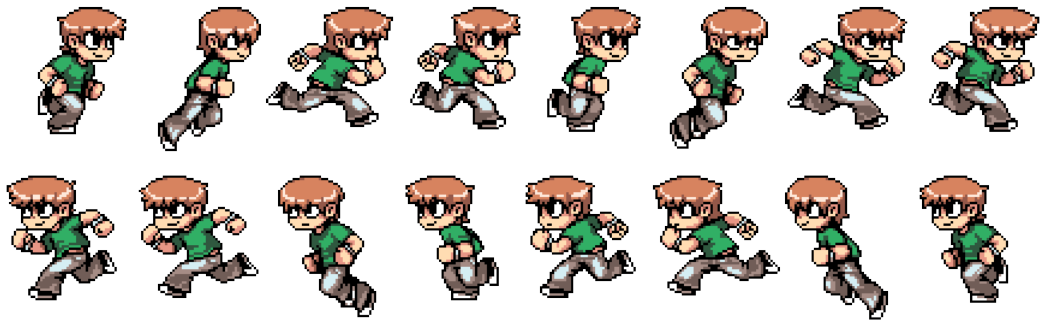


Figure 7.3: Multiple sprite image example, Source: [1]

For the best quality of the end result of this project, it is needed to be created several "multiple sprite" images like Figure 7.3. This would be a job for a designer which has experience in creating animations, since this would be required for all of the animals, the full growth process of the tree, animation of a spawning leaf. Not to mention all the graphic which has to be included during implementation of all the possible minigames.

7.4 Integration possibilities

There exists several tools or applications which could be integrated into the game and make some of the tasks simpler for the user. For example, currently the user has to manually input the diabetic values, this could be simplified by extracting relevant data from other applications which records exactly what is needed.

7.4.1 Choice of Food

When the user registers the amount of carbohydrates through the game, they have to manually insert the correct number of carbs[2]. This could be tricky

[1] http://blaiprat.github.io/jquery.animateSprite/
[2] Carbohydrates

for a child to know the amount of, but could be simplified by using the same approach as is done in the Diabetes Diary application.

In Figure 7.4 you see an example from the Diabetes Diary where the user has eaten pork. The user then insert pork into the input field which then presents the user with a selection of different pork menus, where he then picks the correct type of pork menu and the carbs for that menu is chosen.

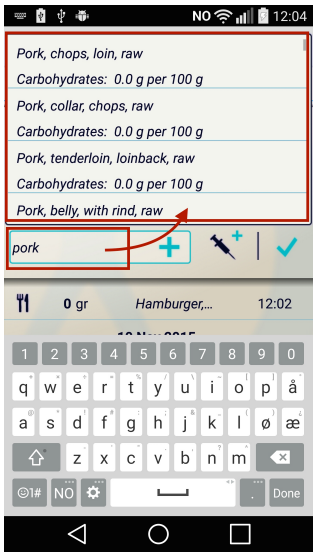


Figure 7.4: Food menu from Diabetes diary

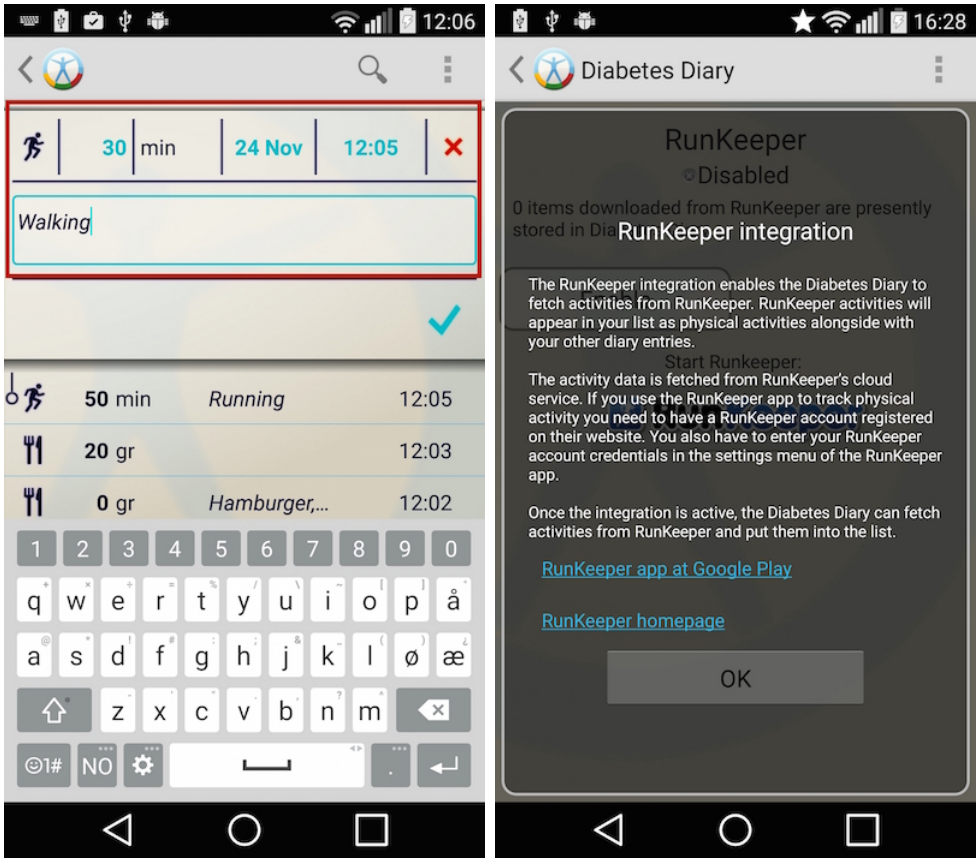
Being able to simply search for the correct meal or snack that has been eaten to find the correct amount of carbs, the children will easily be able to submit more correct values into the diary. This could indirectly also make the user aware of the carb differences to meals depending on how it is cooked, f.ex. butter vs. oil.

Implementing a similar feature, where children can pick their food form a simple list is of great necessity to make the diabetic registration process for the children as simple as possible, and therefore avoids that they will find it too difficult to play the game.

7.4.2 Physical Activities

With the possibilities of todays smartphone technologies and the included sensors, smartphones can be used to record the physical activity throughout

the day. There exists several applications which can record steps and motion, and then present the results in clear way with map information, distance, time, and so on. Examples for application in the genre: RunKeeper[3] and Endomondo[4]. As these applications are launched on the smartphone they will count steps through the day, and can be used to register a given type of activity for a more precise counter.



(a) Activity Menu Diabetes Diary (b) RunKeeper Integration

Figure 7.5: Activity Registrations in Diabetes Diary

The current state of the game is just passing a numerical value from the game to the Diabetes Diary. This value represents physical activity in minutes, and does not differ between types of activity. In Figure 7.5(a) you can see the user inserting 30 minutes of activity into the diary, however in Figure

[3]https://runkeeper.com
[4]https://www.endomondo.com

7.5(b) the user has the option of integrating RunKeeper and connect it to the Diabetes Diary application. RunKeeper is an application which tracks activity of the user. The user starts the application when starting on an activity, f.ex. running, and then keeps the smartphone in the pocket until done with the activity. When done running, RunKeeper is stopped and then displays results like time used, map with the route information, calories burned and similar. At that point the RunKeeper information is registered in the RunKeeper cloud, which allows Diabetes Diary to fetch the activity information and put it into the diary.

Integration of an application which can track physical activities and make the information simply available is a great option to both make the registrations more accurate, but also easier to keep track of for the user. F.ex. RunKeeper has a simple API which can easily be integrated into own applications and receive the information gathered through the RunKeeper application itself [37].

7.4.3 Glucometers

There are two types of glucometers which helps the diabetic keep track of their blood glucose levels. The **traditional meter** includes pricking your finger with a needle-like object which then reads your blood glucose levels. This may be a traumatic experience for the children in the beginning, as it is not pain free and therefore does not really help on adapting to the diabetic situation.

Another type is the **continuous glucose monitors** which can provide glucose readings every few minutes, 24 hours per day. This technology uses a tiny probe which is implanted under the skin that sends the information to a receiver through bluetooth, Near Field Communication (NFC) or similar transferring technology.

It would be possible to integrate this type on technology so that the values could be directly inserted into the game. So when a child opens the game to register a blood glucose value, he simply presses a button in-game and the information is passed on from the receiver to the game. The same procedure would be through the traditional glucometer, when the user pricks his finger and reads the value, the glucometer sends the information to the smartphone and could be registered into the game.

This way the child would not have to read the value first, and then manually insert it into the game, but automate the process slightly.

7.4.4 Reading from the Diabetes Diary

Currently the users registers diabetes inputs through playing the game which are registered in the Diabetes Diary application. At a later stage it will be possible to make the game also read from the Diabetes Diary, and present feedback of how well the blood glucose values are. F.ex. if the diary shows a glucose level within the danger zones, the game can present the tree as sick or feeling ill and encourage to the necessary action.

7.5 Diary Input Restrictions and Balancing

Currently there are no restrictions for how often the user can submit an input to the diary and progress within the game. This will obviously be a todo for the end result to avoid misuse of submissions for progress purposes within the game.

Table 7.1: Diabets Diary Input Restrictions

Input Type	Restriction	Description
Blood Glucose	4-8 times per day [18], or up to 10 times[5]	May wary depending on if the user uses any medication or any personal sircumstances, might be necessary to check more often if the user is ill or feeling other than normal. Generally the user should control before each meal and snack, before bed, and sometimes during night.

[5]According to my co-supervisor, Eirik Årsand

Physical Activity	0-4 times a day.	Doesn't necessary mean four workout sessions a day. This could be anything from small walks to workout sessions.
Insulin Input	2-4 times a day[6]	Insulin is generally taken 15-30 before a meal, depending on brand of Insulin.
Food	3-6 times a day	Breakfast, lunch, dinner, evening meals and possible snacks.
Total	9-24 inputs a day	Ideally the game should be played to input values for each time the user has a new registration.

In Table 7.1 the recommended amount of each input type is presented, and to avoid misuse of the game where children might input several fake registrations to cheat for progression, there has to be set both a daily limit but also a timed limit based on the recommended amount. F.ex. the user should not be able to register all inputs of the day at the same time, but should instead be built around a timed limitation where new registrations cannot be registered directly after the previous one. By restricting the inputs the user is forced to open the game several times through the day to register all the inputs and achieve progress.

7.6 Testing

As mentioned there was little time for significant testing during development. For comparison, [69] had a 1-year thesis within serious games and managed to come in contact with only one child with diabetes and within the age-range for the project. That process took months as it had to go through the

[6] American Family Physician: http://www.aafp.org/afp/1999/0801/p649.html

patient care ombudsman[7] or REK[8].

However, should the project be continued after the period of this thesis, it would require testing by children to ensure good quality and understandable approach to the self-management aspect:

Testing will include children playing with the game and giving feedback of, among other, the **self-management part** where they have to register their input. Based on the feedback the self-management would be tailored to be simple and understandable for the children, and at the same time try to add some fun aspects of registering inputs.

Another part is to gain feedback regarding the tree as the **"virtual pet"** of the game, if a realistic tree is too boring and if it should be built more up as a fun fantasy tree with appealing graphics, animation and fun elements like f.ex. a tree with a face that could talk, animals building houses in the tree, growing in a strange way unlike a realistic tree.

Figure out which types of **minigames** that should be available for **Multiplayer** purposes, if there were any special types of games and which interests children at the specified age-range has.

For **research** purpose it would be interesting to see how an early approach to self-management improves their control of the disease at a later perspective.

7.7 Future Work

A lot of work remains before the game could be publish-ready. This includes:

- Generate educational diabetes information which is presented through the leaves.
- Implement fun, non-diabetes, elements.
- In-game currency and achievements, which will motivate to keep playing and maintaining the feeling of progress.
- Multiplayer functionality, a way of connecting to friends and other in the same situation.

[7] Pasientombudet
[8] Regional Committees for Medical and Health Research Ethics

- Animals representing minigames for multiplayer purposes, but also for single player purposes. Small games to educate about diabetes, but also for fun activities with connections.
- Display friendly connections as trees in the background, gain the illusion of creating a forest eco-system from the trees and animals.
- Improving the graphics and animation.
- Integrating technology to simplify diabetes registration.
- Read information from the Diabetes Diary, currently only writes input to it. This way the tree can represent the current state of the blood glucose values, and display feedback if it is good or bad.
- Add smarter restrictions for registering input. To avoid misuse and cheating for progress.
- Significant testing, and including diabetic children to make child-friendly and understandable.

Chapter 8

Testing and Experimentation

8.1 Usability Testing

Testing of the current implementation of the game was conducted on two classmates which has great knowledge of both software development, and that has spent a great amount of hours with games in general, where they played with the game and diary registrations while I explained the purposes and the concept behind. The main focus is to create a more child-friendly self-management application to encourage younger persons to learn to monitor their disease, and disguising the self-management part into a game which is based on the diabetic registrations.

Their first reaction was the "main" buttons which was placed vertically along the left side of the screen, and they felt it was a little unusual and would have preferred them horizontally at the bottom of the screen. The way the buttons were placed now, they felt like they had to tilt the screen to use them, and the overall place they took made the screen somewhat messy. See Figure 8.1 for an example.

Another issue they felt was the lack of "fun" elements in the game, but when explaining the Animals and their role, and how they unlocked mini-games which the user could play both alone and with friends, they agreed that it was an interesting solution.

One had issues with comprehending how the tree and leaves would represent education or information regarding diabetes in a good way, and how the

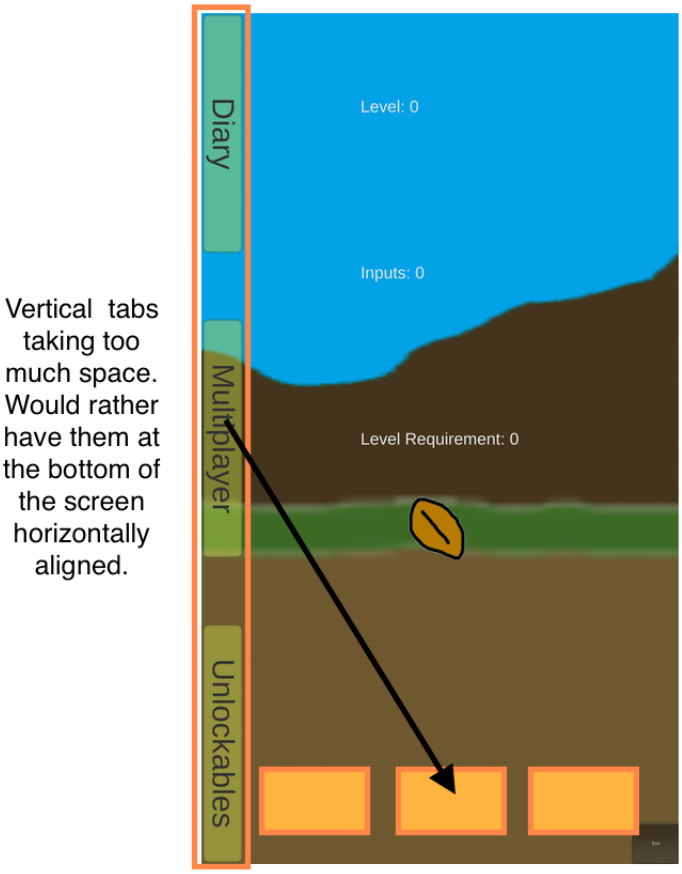


Figure 8.1: Usability test feedback. Testers preferring having the buttons horizontally at the bottom instead of at the side.

growth reward and leaves would motivate the users to continuous use. The importance of having a reward system which motivates the user to want to come back and seek further progress for more rewards is a huge part of games, and in this game perhaps missing a reward system like coins or something which could be spent on either something which increases the fun, e.g. unlock a new game, or to achieve progress, e.g. buying a nutrition extraction which increases the growth rate of the tree, much like the randomly generated fruits.

For the graphic, even though the current version of the game is far from publish ready, they ment I could look at which cartoons or games was popular at the time, and perhaps tailor the game for both girl and boy, since they might

watch different types of cartoons, e.g. frozen[1] for girls and ninja turtles[2] for boys.

Other than the above, they agreed to that Diabetes Diary could be difficult for younger persons to understand and use properly, and that the approach to make it more child friendly through disguising it as a game was a good solution and attempt to make them aware of self-management applications.

8.2 Experimentation

At the current stage of implementation there is not much to measurements to experiment on. There is no network communication, no requests to the web and no traffic out- and inputs. The only communication is through an android intent sent from the game to the Diabetes Diary application, which is explained further down. Other than the intent, the game is basically some graphic with a Graphical User Interface (GUI) that the user can interact with to see changes of graphics and adding a leaf. Since the frequency of submitting a diary input is based on a non-repeatable task done by the child, there is no need to experiment on how the game would handle f.ex. a million submits a second. More about the experimentation follows.

Experimentation of We.Tree is done through the profiler in Unity, and the results can be seen in Figure 8.2. However, the profiling is done of the simulation of the game that is run in the Unity editor and not of the game on an actual device. Since the game communicates with another application, the Diabetes diary, on the same device I wanted to see the profiling results of that communication, but the communication is not available through simulating the game in the editor and is therefore not shown in the profiler.

An attempt of getting experimentation results on the communication was done by connecting the device to the computer via USB cable and looking in the Android Debug Bridge (ADB) logcat[3] to see if it gave any relevant measurements, which it did not. When looking for an answer regarding the overhead of sending an Android Intent[4] it is said that Android's Intent-based Inter-Process Communication (IPC) is a simple to use and Low-Overhead

[1] `https://en.wikipedia.org/wiki/Frozen_(2013_film)`

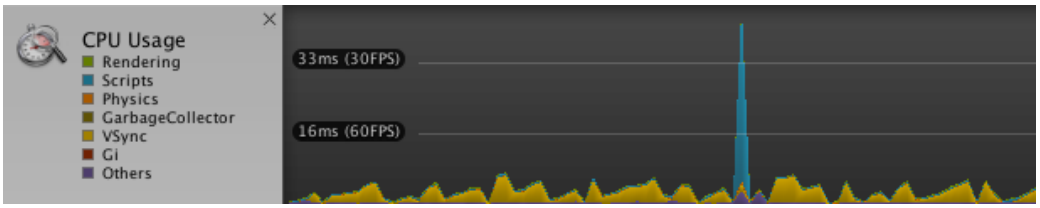
[2] `https://en.wikipedia.org/wiki/Teenage_Mutant_Ninja_Turtles`

[3] Android logging system mechanism for collecting and viewing system debug output

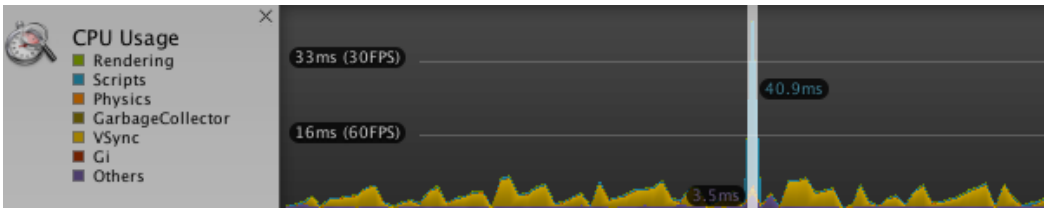
[4] The package of information sent from the game application to the Diabetes Diary application

IPC [4].

In Figure 8.2 you see the Central Processing Unit (CPU) Usage of 3-4 diary submission and eventually the blue spike when the tree levels up. The general usage, and when submitting diary inputs, is according to the figure at around 3.5ms - 5ms[5] and way above 60fps[6], while when the tree levels the CPU it uses 40.9ms up from 3.5ms. The leveling of the tree includes changing of image, setting new ranges for variables and so on, but nothing significant is affected by this increase.



(a) The blue spike shows the increase of overhead when the tree is leveling up.



(b) The blue spike uses 40.9ms, compared to 3.5ms in the general run.

Figure 8.2: CPU Usage during simulation of the game

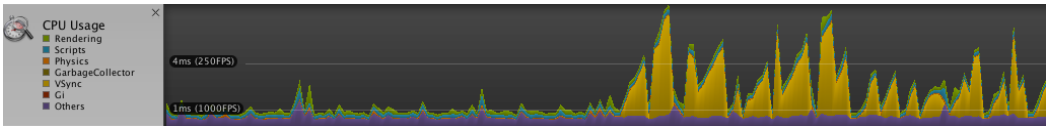


Figure 8.3: VSync OFF to the left vs. VSync ON to the right

Figure 8.3 shows the difference between VSync[7] OFF in the left half vs. VSync ON in the right. In Figure 8.2 the yellow spikes is the same as the yellow spikes in Figure 8.3, to put the differences in another perspective.

VSync, or Vertical Synchronization, is a graphic card method to synchronize its actions with the monitor. With VSync on, the graphic card cannot send

[5]Milliseconds
[6]Frames Per Second
[7]Vertical Synchronization

out a new frame until the monitor says that it is ready to repaint the screen [47]. With VSync off, the graphic card and monitor may become out of synch as the graphic card may generate more fps than what the monitor can handle, and the user may therefor experience “Tearing”.

Tearing is a concept which affects the graphic in the game, and can be seen in Figure 8.4 where the frames of the urinals are out of sync, causing them to appear as torn, or slightly displaced to the side.

Figure 8.4: Tearing, Source: [47]

So in this case I can turn off VSync and ease the CPU usage as seen in Figure 8.3 since tearing is mostly a problem which may occur in games with a lot of movement or camera rotation, which is not the case for this game. I could also let VSync be on, since in this case the FPS will consistently be above the refresh rate of the monitor, or screen, and therefore not result in a drop of FPS. Had the game been more complex and including much more elements and CPU intensive operations I could skip the VSync.

Chapter 9

Discussion

9.1 Result and Related Solutions

The current stage of implementation is a very early prototype of how an eventual product would be. There are much future work left to do before this will be able to satisfy the full purpose of this research. However, the self-management functionality of this game is, even at this stage, really promising. When more motivational and encouraging gameplay is added it could possibly have great effect on self-management awareness among children.

Making the self-management part as the main progression method of the game may be risky because of the unusual approach and because it reflects the users values. If children find this difficult to use they may quickly lose interest as they struggle to learn how to use it, and it is therefore important to make this approach as child-friendly as possible and add some fun into registering inputs from the game. Another thing is to make sure the game motivates enough through rewards and gameplay so the user keep using the game as a way of registering inputs, no matter how hard or easy they find the self-management part.

From the results of the related work research we could see that there was not an enormous amount of smartphone based serious games regarding diabetes and self-management. The amount of pure self-management approaches was a lot bigger, but few of these appealed to children and even less offered a gamified approach that motivate to increased use.

Another discovery made from the research is that much of the current literature presents solutions based on bigger devices, like tablets and web solutions. The same came clear during the Games for Health conference presentations, where most of these systems were depending on sensors or cameras which set limitations for portability and the platform of choice. Web solutions requiring registrations and log in adds another obstacle for children, as it most likely would require assistance from their parents or grown-ups, but also makes it tougher and less appealing to open and use since it takes several steps to enter the page and use it. Through this project the game is based for handheld smartphones basically for the purpose of making it easy to use the game at any given time and place. This way the game is also registered through the device which is downloaded on, which keeps registrations and accounts simple. It might be questionable how many of the youngest within the current target age-range (8-13) that is in possession of a relatively new smartphone. The game does not require the newest of the new smartphones, but at one point the game will not be usable because of outdated hardware or model.

Smartphone is a fitting device for this type of serious game since it requires several uses during the day when the user has to register their input. Larger devices like tablet and computers limits the use to both location and time of the day since it is not as portable, and often there is several users on the same tablet.

None of the published serious games reviewed in this thesis includes any significant multiplayer functionality or socializing aspects. Being able to socialize with friends and other in the same situation might motivate and help the user get through difficult times, and also making friends understand the diabetic situation to gain clarity. This aspect was greatly focused on during planning and development, and figuring out how to be able to include friends and connections into the game. The resulting solution from this project presents a single player game, with features that is used to have fun and include friends and connections in the process. Together they face the diabetes and motivate each other to keep going.

9.2 Graphics

9.2.1 Current graphics

Graphics is an important part of the overall game experience, but in this project there were no artists involved and I have no artistic skills, which made it hard to get great and tailored graphics for this project. During the development of this project I got to a point where I needed graphics to continue, and at that point I used the Unity Asset Store[1] and similar graphic resource distributers[2] was checked for free graphics which could be used for the project. No graphic which fitted my needs were found during this process, which both costed me time looking for, but also since I then had to create my own dummy-graphics to have something presentable.

The graphics is far off how it would look as a finished product. Currently it does not appeal to children at all, which is required as the end-result is meant for children and therefore has to present graphics for the given age-range.

Few things could have been done differently through the graphic process, but initially the project were supposed to include a graphic artist which had experience from Plus Point, that took a 10 study point "special curriculum" at the art/artist department at University of Tromsø (UiT) to gain credits for assisting. This did not succeed however.

9.2.2 Appealing graphics for children

I mentioned earlier the possibility of making the tree in a more childish manner. Currently the tree is a realistic tree which grows and gains leaves and roots, but how appealing this may be for children is uncertain. Perhaps they would better prefer a fantasy tree approach, where the tree is represented in a more imaginary way to make it more fun.

This could be a topic for a future testing of the game, which type they prefer the most.

[1] https://www.assetstore.unity3d.com

[2] http://www.pixelprospector.com, portal for game development resources, like graphics, and contains a big list of sites which has user-created graphics or other resources.

9.3 Usability Testing

As mentioned, the amount of children with T1DM in Troms county was around 18 persons in 2013 [69], and todays number is unlikely much higher. As mentioned in 7.6, the author of [69] had a 1-year thesis and managed to get in contact with one child with diabetes through UNN after several months. In comparison I had close slightly less than two months in general for the whole implementation process. Due to the small amount of potential testers within the desired age-range with T1DM, and a long bureaucratic process to get in touch with them through UNN, the testing has been performed on classmates with great knowledge of game development, but also with several years of experience with gaming.

I mentioned the importance of including stakeholders and users early in the development process to ensure good quality of the end-result, but in this case the time restrictions and long process and restrictions when dealing with hospital patients made it impossible to continuously include users. Another option was to use non-diabetic children as testers to gain some feedback of the game, but in my opinion that was not a good solution. Firstly the children must have been made aware of how children with T1DM has to act through the day, which could be a lot of tough information to fully understand, but also a difficult situation to place themselves into when testing the game since the gameplay currently focuses on the diabetes part. Since the development process was quite short and focusing on the core diabetes functionality, and developed by a software engineer with close to none graphical skills, the value of playing the game for the non-diabetic children would be close to none because of the lack of relevant gameplay and bad graphics.

Instead the testing was conducted on classmates with knowledge of gaming and programming to gain feedback of usability and functionality.

9.4 Diabetes Diary misuse

One issue with encouraging to register diabetic values is the possibility of misuse or cheating to achieve progress within the game. F.ex. when a user pricks the finger to read the blood glucose values they consume a test strip, and occasionally has to change the lancet used to prick the finger, which costs money. 10 measurements a day with test strips costs around 20,000 -

30,000 NOK through a whole year[3]. Most of this will probably me covered by insurances and similar, but anyway. It is therefore important both to educate to proper use, and to have restrictions for how often inputs can be registered.

[3]DiabetesForbundet: http://www.diabetes.no/

Chapter 10

Conclusion

Throughout this thesis project I've had a game development-approach at building an early prototype version of a serious game for children with T1DM living in rural areas. The game will educate the users about diabetes and self-management, and by building upon the Diabetes Diary application the game uses diabetic inputs like blood glucose level, carbohydrates, physical activity and insulin units to make progress. By basing the serious game on real-time values from the user, the game presents feedback in a fun and childish way by nurturing and growing this "virtual pet" the user has to take care of. The growth of the virtual pet is a direct result of the children learning how to use an self-management tool to control their lifestyle and reflects their progress of registering input values. The game will also be a socializing tool to connect them with friends and also other children with diabetes, since living in rural areas may include large distances to friends, and specially other in similar diabetic situation.

This serious game targets children with T1DM living in rural areas since they may face additional challenges to maintain optimal blood glucose regulations because of scattered population and less friends, including long distances to the closest doctor or hospital.

During research and development of this project I found that there exists several applications similar to the Diabetes Diary which is used for self-management purposes, but with the same issue as Diabetes Diary. They require significant knowledge of the values submitted and appeals mostly to adults, making it hard for children to use. I found one example of a self-management application which appealed to children, which is mentioned in

Chapter 3, but this was a pure self-management approach and could not be used as a game.

On the other hand I found a few serious games based on the same gameplay as this project, the tamagotchi element and a "virtual" pet. However these games illustrated the virtual pet as the diabetic, and based on their decision regarding food, insulin and activity the pet illustrated the effect of their choice.

I found no serious games or literature regarding a game which combined the self-management and game aspect, and based the gameplay around the real-time diabetic values from the user. Therefore I conclude that the proposed solution from this thesis is of a unique kind, where game and self-management educates and informs the user from the diabetic registrations of real-time diabetic values.

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Appendix A

Readme

The README explains the process of installing the game on an android smart device from the provided .apk file which is delivered together with the thesis, and additional information for how to get the correct functionality. See the next pages.

We.Tree - README

The We.Tree game communicates with the Diabetes Diary (DiabetesDagboka) application, therefor the Diabetes Diary application has to be installed on the same smartphone where the game is to be run.

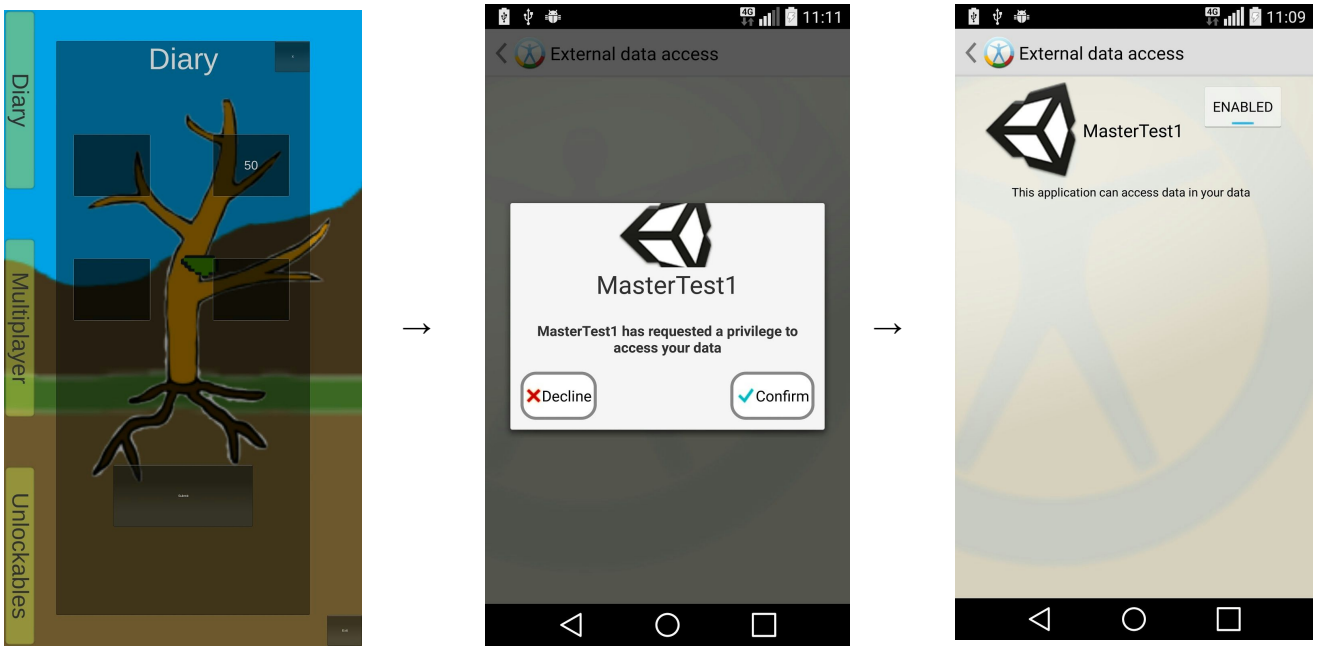
Installing the game from the attached .apk file

The .apk file is basically the install file of the project when it is built into a version that can be run on android devices. To build the .apk file on the smarthphone:

- Connect the android smartphone to the computer through USB
    - Android device has to be in developer-mode and on
- Locate the Android SDK installation on the computer
- Place the .apk within the same folder as the adb
    - (on Mac its within the platform-tools folder)
- in the terminal, run “./adb install [NameOfAPKPacket].apk”
    - This is done on Mac, and replace [NameOfAPKPacket] with the name of the .apk file.

Diabetes Diary Permission for External Data Access

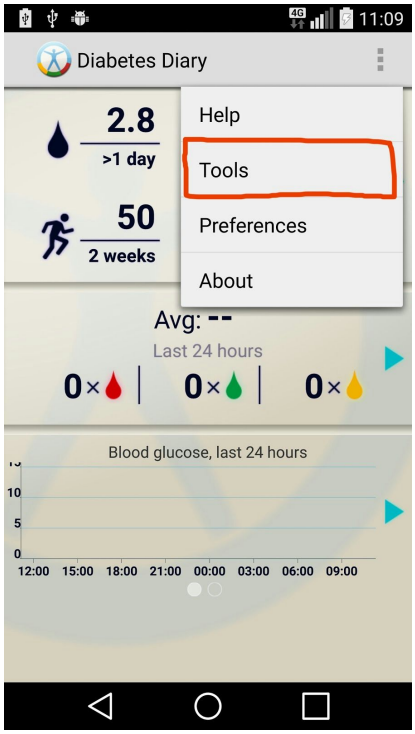
The first the the player attempts to submit a diary input, the diabetes diary will ask for permission of the user to be connected. This has to be accepted to allow the game to pass information to the Diabetes Diary application:



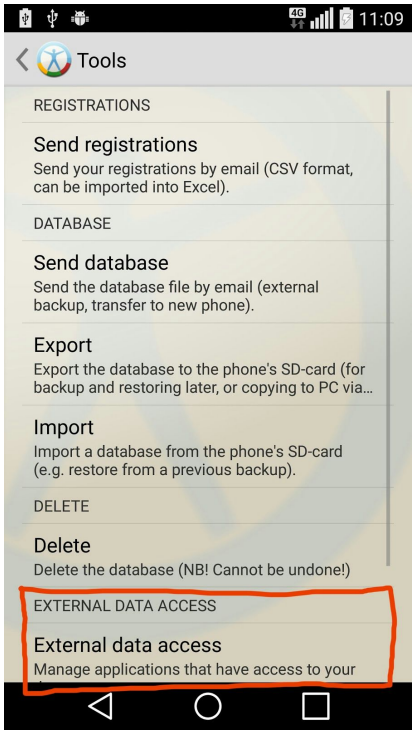
This permission request will only happen on the first submit, unless any of the applications is reinstalled or removed manually from the External data access tab in the diabetes diary.

External Data Access to the Diabetes Diary application

Should there be any need to see which applications that has access to give or receive information to/from the diabetes diary application, this can be done by accessing the tools options -> External data access, you will then get the



→



Appendix B

Sequential Game Structure

The Sequential Game Structure is like a text based playthrough of the game. The document explains all the steps and the expected output from start to end, and differentiates on first time players versus what regulars see.

We.Tree – Sequential Prototype Structure

This structure is a suggested sequence of events for the purpose of making the step-by-step interactions with the game clear, even though the state of the game is not fully implemented.

The main purpose of the creation of this game, is to make the use of the Diabetes Diary (Diabetesdagboka) easier for young individuals. The game should keep the user engaged for a few(2-5) minutes, but at several times during the day.

Challenges

- Making sure the user registers all the diabetes diary relevant inputs throughout the day
- Build in the Diabetes Diary in a understandable way for young individuals
- Identify good rewards / achievments
    - Keep motivating the players with in-game rewards
- Creating asynchronous mini-games for playing against friends

Before Game Sequence

- User starts We.Tree

We.Tree Main game menu

- Main screen – In the background, A fully grown tree with leaves, roots, flowers, weeds, and animals. Possible final result of the gameplay.
    - GameUI – Play Game button
    - Settings, etc.
- Welcome Screen – Same picture/Background as Main
    - Dialog box, welcoming the user
- First time users
        - Presented with a “big” seed in the middle of the screen
    - Click the seed and it will be planted in the ground
    - Introduction to the diabetes diary input tab, and how it makes the tree grow
    - Tutorial example of a Diary Input, could be a real value from the user, or a fake one represented in the game just for an example to the user.
    - During the tutorial stage, the Root should also become visible during tutorial to make connecting with friends clear
    - Finalizing tutorial with pointing out the importance of the diary inputs, and that it will keep growing the tree
- Returning users – Notifications regarding the player’s diary progress

- "Professional" reminders
    - If long time since food, remind the user to eat or register the last meal
    - If long time since blood glucose input, remind the user
    - Ask if the user has been training, feature which knows when the last training occured should be implemented. This to avoid training-preassure.
    - Fetch insulin information from the diary to check the status, possible give advice if values are within ranges which requires actions. Pop-up to mention the importance of insuling for T1DM persons.
- "Encouraging" reminders
    - Training is healthy
    - (Food (with recipe) which is healthy for diabetes
    - Something Motivational Insulin
    - Something Motivational blood glucose

Continuous gameplay

- Open the diary tab and insert "diabetesdagboka" input
    - *Growing the tree*
        - Additional features may take effect
- In-game elements other than Diabetes Diary inputs
    - Weather elements, let the tree gain water from the clouds, but also light from the sun
    - Weeds and other pesky objects stealing nutrition from the tree

Additional growth features

- Leaf spawns
    - For every "Diabetesdagboka" input the user does, a new leaf is added to the tree
- Fruit spawns
    - Fruit spawns are rare versions of a leaf, and provides a boost bonus when clicked on
- Animals
    - Occasionally a new animal may seek refuge at the tree
- Root connections
    - See online features

Online features (idea, not to be implemented)

- Growth of tree increases number of roots
- Roots works as connections to friends
    - The more roots, the more space for friends
    - Click on a root to view options for the given friend
        - View progress
        - "Help" growing tree
        - Invite to asynchronous mini-game