

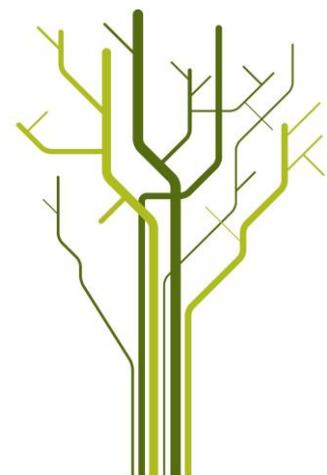
## A mobile phone-based serious game for children with Type 1 diabetes



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INF-3997 Master's Thesis in Telemedicine and e-Health

June 2013





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**Master's Thesis in  
Telemedicine and e-Health**

**A MOBILE PHONE-BASED SERIOUS GAME FOR CHILDREN  
WITH TYPE 1 DIABETES**

**Alexandra Makhlysheva**

**June 2013**

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# Dedication

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**TO MY BELOVED  
PARENTS**



## Preface

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Diabetes is a global burden. Unlike type 2 diabetes, type 1 diabetes cannot be predicted and cured. It starts in young age when children are not prepared for the changes diabetes brings to their lives: blood glucose monitoring, calculation of insulin doses and insulin injecting, and even restrictions in food and physical activity. Inappropriate blood glucose control may lead to various short-term and long-term complications.

Thereby, the thesis project was started with the questions: “How can we help these children? How can we teach them diabetes-related basics to make them more prepared for future life and avoid complications, but make it in a form that is understandable and attractive for children?”

By the moment I started the project, the Tromsø Telemedicine Laboratory (TTL) with the Norwegian Center for Integrated Care and Telemedicine (NST), a branch of the University Hospital of North Norway (UNN), had already implemented the Few Touch Application. It is a mobile-based self-help platform for people with type 1 and type 2 diabetes able to collect blood glucose measurements values automatically transferred to the mobile phone, which helps users control his/ her blood glucose levels, food habits, physical activity, and gives some practical advice. This allowed using person’s real data in the application to address the current project purposes.

People of all ages like playing games. Hereby, a game was chosen as a target form of an educational tool. My game is called DiaSpill. This means “Spillet til barn med diabetes om diabetes” (“The game for children with diabetes about diabetes”). The application is a smartphone-based serious game for 8-12-years-old children with type 1 diabetes. This age group was chosen since pre-teenagers are ready for self-management skills development to make it as habits in the future; meanwhile, they do not need too much parents’ help in diabetes management, but also do not have puberty hormonal changes, and youthful maximalism and desire for overall independency.

Several methods were applied to perform the research. The review of relevant literature, meetings with children of the target age group, doctors, and experts in diabetes were used for the requirements gathering on the design and implementation stages of the project. In regard to the requirements and suggestions for improvements, firstly a paper prototype and then Android-based versions of the application were implemented with a help of the Unity 3D game engine and C# programming language. Knowledge about diabetes along with the user’s real data were seamlessly embedded into the game for a user-dependent gameplay and a multi-level rewards system.

On the final stage of the project, the testing procedure was performed. The test consisted of three parts: a questionnaire for children with type 1 diabetes about their game experience and diabetes-related knowledge and a questionnaire for their parents about children’s diabetes self-management as a preface to testing, testing itself, and an interview of children for getting the feedback after testing. To analyze the test results, a qualitative method was applied. Too short testing period could not properly demonstrate key motivational and educational features of the application. However, the game test demonstrated positive results. Many game features and elements were noticed as remarkable: for example, a choice of a character in the beginning of the game, an interesting backstory, used colors and sounds. Moreover, real-life bonuses and an ability of user’s data to influence the gameplay caused the player’s great excitement. Herewith, the user’s control over a game character’s blood glucose level was quite poor which could be affected by the novelty of the game story; probably, it corresponded to the user’s self-management skills level. The concerned parameters could be different after a longer testing period or several game-playing attempts. For the next version, numerous levels with improved

game content, an ability to share the game achievements and a gradually growing difficulty level which requires a cohesive team-play were suggested by the tester to be implemented. In general, the user considered the game attractive, moderately difficult, and “cool and fun” to play.

I appreciate the financial support from The Norwegian State Educational Loan Fund which made my studying in the University of Tromsø possible. Also, I would like to thank the University for the software purchased for the project and my travel expense support for the 6th International Conference on Advanced Technologies & Treatments for Diabetes in Paris.

I would like to thank my supervisor, Professor Gunnar Hartvigsen and my co-supervisor, PostDoc Eirik Årsand for their advices, feedback and guidelines. This project would never have been done without their expertise and support. I appreciate the time allocated for advising me in their busy schedules.

Special thanks are to an endocrinologist Arild Leknessund and a nurse Astrid Figenschou from the Children’s Department of the University Hospital of North Norway, for their expertise and practical information about diabetes management, and a help in the recruitment process. Without their support, the project would never have been a success.

Of course, a great thank is to children and their parents who were willing to participate in the design and testing stages of the project. Without them, the research would be incomplete.

Also, I would like to thank all employees of the Norwegian Center for Integrated Care and Telemedicine (NST) for a very nice and friendly work environment. In particular, I thank the DiabetesTeam’s skilled developers for their expertise and a provided device for testing the application. In addition, I thank Torje Henriksen, a system developer from the NST, for his support and advices while the game implementation and his help in my progressing in Norwegian.

Finally, I would like to thank my family and my boyfriend for their moral support and constant believing in me.

Tromsø, the 12<sup>th</sup> of June 2013

Alexandra Makhlysheva

# Abstract

---

## **Purpose**

The purpose of this research was to develop a mobile phone-based educational game for children with type 1 diabetes. The game was expected to provide basic diabetes-related knowledge and help children improve their self-management skills.

## **Motivation**

Diabetes as one of the most common non-communicable diseases worldwide is rapidly increasing in children and adolescents in many countries. Often, it is difficult for young children to understand the changes type 1 diabetes brings to their lives. We wanted to help these children: give them knowledge they need for proper self-management of the disease which, in turn, can help them avoid short-term and long-term disease complications in future. In addition, we aimed to make it unobtrusively, and simultaneously ubiquitously.

## **Methods**

DiaSpill, a mobile phone-based game was developed to address the mentioned above problems. The application was implemented on the Android platform with a help of the Unity 3D game engine on C# programming language. In game design, requirements and suggestions for the project gathered via reviews of the relevant literature, meetings with children of the target age group, doctors, and experts in diabetes were considered. On the final stage of the research, the testing procedure was conducted. It consisted of a questionnaire for children with type 1 diabetes about their game experience and diabetes-related knowledge and a questionnaire for their parents about children's diabetes self-management before the test, testing itself, and an interview of children for getting the feedback after testing. To analyze the test results, a qualitative method was applied.

## **Results**

Despite too short testing period unable to properly demonstrate most features of the application, the game was recognized as attractive and moderately difficult with remarkable characters' choice, backstory, colors and sounds, real-life bonuses, and the most impressive feature of user's data influence on the gameplay: a game character, enemies and the rewards. Herewith, the user showed poor control over a game character's blood glucose level which could be affected by the novelty of the game story, or probably, this might correspond to the user's self-management skills level. Both options can be improved while the next game-playing attempts.

## **Conclusion**

Diabetes-related knowledge was seamlessly embedded into the gameplay. In addition, the user's real blood glucose measurements data and other user's parameters such as age and height were used for a user-dependent gameplay and a multi-level rewards system and made a user even more motivated in game results. Real-life bonuses suggested in the game showed a potential to be highly demanded in future. Numerous levels with a gradually growing difficulty and improved game content with abilities of team-play and sharing with others the player's game achievements are suggested to be adopted in future versions of the application.



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# Chapter 1

## Introduction

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### 1.1 Background and Motivation

Diabetes is one of the most common non-communicable diseases worldwide. 366 million people had diabetes in 2011; by 2030 this can rise to 552 million<sup>1</sup>. Such health organizations as the World Health Organization, the World Diabetes Foundation and the International Diabetes Federation consider prevalence of diabetes has reached epidemic proportions<sup>1,2</sup> (World Health Organization). Diabetes complications can include heart disease and stroke, high blood pressure, retinopathy and blindness, kidney disease, neuropathy, and others<sup>3</sup>. Moreover, in 2007, diabetes contributed to total of 231,404 deaths (comprising diabetes as the underlying cause and as a contributing factor) in the USA<sup>4</sup>. According to the World Health Statistics report by the World Health Organization in 2008, diabetes was on the 12<sup>th</sup> rank among the leading causes to death in 2004 and is predicted to be on the 7<sup>th</sup> rank in 2030 (World Health Organization, 2008).

In type 1 diabetes, the pancreas does not produce enough insulin, or stops produce it at all. Insulin is a hormone needed to convert sugar, starches and other food into glucose which then moves from the blood stream into the body cells, where it is used for energy needed for daily life. In the case of type 1 diabetes, the lack of insulin leads to inability of the blood glucose to enter the body cells, causing higher blood sugar levels. Unlike type 2 diabetes, it is impossible to prevent type 1 diabetes. Moreover, it is not clarified what particularly leads to it.

Diabetes is rapidly increasing in children and adolescents in many countries. Approximately 0.26% of all people under 20 years old have diabetes which corresponds to approximately one case of diabetes in every 400 children and adolescents in the USA<sup>4</sup>. The International Diabetes Federation reports about 490.000 children under 15 years old suffering from type 1 diabetes worldwide<sup>5</sup>. The incidence in type 1 diabetes has been increased both in countries having high and low prevalence, but, however, there is some association between the risk increase and gross national product estimates<sup>6</sup>. As a small part of the total burden of diabetes in the world population (with only 5-15% of people with diabetes having this form of the disease<sup>7</sup>), type 1 diabetes is a prevalent form of the disease in younger people of most developed countries<sup>6</sup>. Each year, more than 13.000 young people are diagnosed with type 1 diabetes<sup>8</sup>.

Polonsky (Polonsky, 2006) compared lives of children with diabetes and their families with “a tough, demanding and frustrating job from which there are no vacations”. In Russian, we have also a very good comparison: “Diabetes is not a disease but a lifestyle”. It expresses the very essence of lives of patients with diabetes. Herewith, the aim of this project and many other projects for this audience group is becoming really clear. Though, we are not able to change the

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<sup>1</sup> International Diabetes Federation. IDF Diabetes Atlas. The Global Burden <http://www.idf.org/diabetesatlas/5e/the-global-burden> [Accessed 12.06.2013]

<sup>2</sup> World Diabetes Foundation. Map of the WDF projects <http://www.worlddiabetesfoundation.org/projects/search> [Accessed 12.06.2013]

<sup>3</sup> International Diabetes Federation. Diabetes Atlas. Diabetic Complications <http://da3.diabetesatlas.org/index711b.html> [Accessed 12.06.2013]

<sup>4</sup> American Diabetes Association. National Diabetes Fact Sheet. Diabetes Statistics <http://www.diabetes.org/diabetes-basics/diabetes-statistics/> [Accessed 12.06.2013]

<sup>5</sup> International Diabetes Federation. Facts and Statistics <http://www.idf.org/lifeforachild/facts> [Accessed 12.06.2013]

<sup>6</sup> International Diabetes Federation. Diabetes Atlas. Diabetes in the Young <http://da3.diabetesatlas.org/index1599.html> [Accessed 12.06.2013]

<sup>7</sup> Diabetes.co.uk. Diabetes Types <http://www.diabetes.co.uk/diabetes-types.html> [Accessed 12.06.2013]

<sup>8</sup> Centers for disease control and prevention. Diabetes Public Health Resource. Children and Diabetes <http://www.cdc.gov/diabetes/projects/cda2.htm> [Accessed 12.06.2013]

fact that people have diabetes and we are not able, unfortunately, to cure it, but we can help them deal with it and live normal lives.

Sometimes, it is difficult for young children to understand the changes that type 1 diabetes brings to their lives, such as glucose monitoring, insulin injections, and food restrictions. They feel themselves different from other coevals and friends. Moreover, when puberty comes, adolescents seek autonomy and independency, especially in diabetes management (Diabetes Forecast, 2003). Teens with type 1 diabetes experience not only typical social and emotional struggles associated with growing-up, but they also face widely fluctuating hormonal changes that affect their diabetes management. Mostly it is concerned with Growth Hormone that stimulates the growth of bones and muscle mass during puberty, but also acts as an anti-insulin agent<sup>9</sup>. Herewith, in short term poor-controlled diabetes can lead to such complications as aggressive/violent behavior, confusion, discomfort, anxiety and coma, in extreme cases (Boyle and Zrebiec, 2007), while as long-term complications, the patient can get blindness, kidney disease, neuropathies, amputations and elevated risk of heart attack and stroke (Cryer et al., 2003).

And, it is obvious that parents are concerned and heavily involved in their children's diabetes management (Bosma et al., 1996), (Hanna, 2003). Younger children get all the support and disease treatment management from their parents, and many studies show relationship between parental involvement and better adherence to treatment (Anderson et al., 1997), (Gowers et al., 1995), (Lerman, 2005), (Polonsky, 2006). However, excessive control of older adolescents with type 1 diabetes can retard their self-management skills development (Anderson and Coyne, 1991), (Seiffge-Krenke, 1998). Meanwhile, children of pre-teenage ages (8-12 years old) are ready for self-management skills development, including adherence to blood glucose monitoring, diet and physical activity, to have it as a habit in their further life. This age group was defined as a target group for the project.

Bandura (Bandura, 2004) argued that people, and especially children, learn many behaviors by observing others. Games are the most attractive form of education. Many researchers affirm that serious videogames can increase children's physical activity (Baranowski et al., 1998), (Baranowski et al., 2010), (Baranowski et al., 2011), (Fujiki et al., 2008), (Scheider et al., 2012), (Errickson et al., 2012), improve nutrition habits (Baranowski et al., 2010), (Baranowski et al., 2011), (Scheider et al., 2012), (Frederico, 2012), develop self-management skills (DeShazo et al., 2010), (Brown et al., 1997), (Brown, 1998), (Kahol, 2011), and even improve children's adherence to treatment regimens (Kato, 2012), (Kato et al., 2008), (Mulvaney et al., 2012), (Kumar, 2004). Therefore, video games are extensively used for children's educational and self-management skills purposes (Lewis, 1999), (Lewis, 2007), (Kharrazi and Faiola, 2010), (Capruciu, 2012).

The industry of serious games is rapidly growing. In 2007, a profit from serious games in the world was US\$1.5 billion (Derryberry, 2007). In 2010, according to IDATE's report<sup>10</sup>, the estimated serious game industry's revenue amounted to 1.5 billion EUR, which is going to grow by 47% per year from 2010 to 2015, when the serious games will become a 10 billion Euro market. Being in use in many fields (such as military, educators, government agencies, corporations, hospitals, non-profit organizations, religious groups, and activist groups (Friedman

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<sup>9</sup> JDRF. Improving Lives Curing Type 1 Diabetes

[http://type1diabetes.about.com/gi/o.htm?zi=1/XJ&zTi=1&sdn=type1diabetes&cdn=health&tm=836&f=00&su=p1026.33.342.ip &tt=2&bt=0&bts=0&zu=http%3A//www.jdrf.org/index.cfm%3Fpage\\_id%3D103523](http://type1diabetes.about.com/gi/o.htm?zi=1/XJ&zTi=1&sdn=type1diabetes&cdn=health&tm=836&f=00&su=p1026.33.342.ip &tt=2&bt=0&bts=0&zu=http%3A//www.jdrf.org/index.cfm%3Fpage_id%3D103523) [Accessed 12.06.2013]

<sup>10</sup> Serious Games Market. IDATE: Serious Games - A 10 Billion Euro Market In 2015 (7 July 2010)

<http://seriousgamesmarket.blogspot.no/2010/08/idade-serious-games-10-billion-euro.html>  
[http://www.idate.org/en/News/Serious-Games\\_643.html](http://www.idate.org/en/News/Serious-Games_643.html) [Accessed 12.06.2013]

and Wyatt, 2005)), most of serious games promote positive effects of their implementations on the organizations' learning needs (Derryberry, 2007).

Mobile phones market is also on the increase. Nowadays, there are approximately 4.0 billion mobile phones all over the world<sup>11</sup>, and this number is expected to continue extensively growing in the nearest future. Mobile devices offer a unique opportunity for personalized interaction, and for interaction with the user anytime (just-in-time) and anywhere (in the right place).

Studies show that in the US, there are about 75% of adolescents who own a mobile phone and 46% play games on their phones (Lenhart et al., 2010). In Norway, most youngsters have a mobile phone (Wolf et al., 2004). Adolescents tend to have the latest high-tech mobile phones, a.k.a. smartphones, which are built on mobile platforms and allow amount of entertainment and multimedia applications to be installed.

Nowadays, mobile-gaming market is booming. Its revenue was US\$12.3 billion in 2012, and it is expected to increase to US\$15.2 billion by 2015<sup>12</sup>. Games are the most popular application category on mobile devices<sup>13</sup>. In 2010, 64 million people played mobile games at least monthly, a number that will rise to 94.9 million by 2014<sup>14</sup>.

Use of mobile phones in health applications can help in health education of the patients and improve patients' quality of life, and even health outcomes, while a game is the most attractive form of involving people into taking care of their health. Therefore, a mobile phone-based serious game can address, in particular, the problems of children with type 1 diabetes, give them knowledge about the condition in an understandable and interesting form, and prepare them for adult life.

## 1.2 Scope and Research Problem

We started this project to address the mentioned above problems and challenges in everyday lives of children with type 1 diabetes.

The project is aimed to develop a mobile phone-based educational game for children with this disease. The game is expected to provide basic diabetes-related knowledge and help children improve their self-management skills.

The main research problem of the project is:

*“How can a mobile phone-based game, able to help children with type 1 diabetes in improvement of self-management skills, be designed?”*

Further, the main problem is divided into sub-problems to clearly the boundaries and the scope of the thesis.

Thus, here we can identify two sub-problems which deal with a design of the application, and its educational component.

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<sup>11</sup> Famvin News. Planet has more mobile phones than toothbrushes! <http://famvin.org/en/2012/07/29/planet-has-more-mobile-phones-than-toothbrushes/> [Accessed 12.06.2013]

<sup>12</sup> YAHOO! Finance. Mobile Gaming Market Surges in 2012 as Traditional Gaming Continues to Decline <http://finance.yahoo.com/news/mobile-gaming-market-surges-2012-132000563.html> [Accessed 12.06.2013]

<sup>13</sup> EConsultancy. The rise of the billion dollar mobile gaming market: infographic <http://econsultancy.com/no/blog/9638-the-rise-of-the-billion-dollar-mobile-gaming-market-infographic> [Accessed 12.06.2013]

<sup>14</sup> eMarketer.com. Mobile Gaming Market Tops \$800 Million in 2010 <http://www.emarketer.com/Article/Mobile-Gaming-Market-Tops-800-Million-2010/1007874> [Accessed 12.06.2013]

## **A. Design of the application**

The issue of how an application should be appropriately designed to meet children's needs and expectations to be played with enthusiasm is very important. Therefore, the first question can be articulated as follows.

*Question 1: What makes an application attractive for children?*

This is concerned not only with some tips on game design, but also should include psychological features of this age group. Therefore, both findings of existing studies of serious games and conclusions of psychological behavioral theories are required.

As any other tools (both for adults and for children), the game should not cause any difficulties in its use. Otherwise, the application is doomed to failure. In this regard, the next problem arises:

*Question 2: How to create an application easy to master by children?*

Here we also should consider ages of the game target audience.

The next integral part of the application developed within the project is:

## **B. Educational component of the application**

Obviously, this issue is very important since it focuses on raising the users' awareness and knowledge about diabetes and assistance in children's self-management skills improvement. Herewith, there are two main questions here.

*Question 3: What can help children in improvement of their diabetes-related self-management skills?*

*Question 4: How to embed knowledge about diabetes and the elements able to help children in improvement of diabetes-related self-management skills into the application?*

However, since the application target audience is children with type 1 diabetes, they have particular data about their disease flow from the everyday diabetes management. This can be potentially used in the game. Therefore, the next arisen question can be formulated as follows.

*Question 5: How can the user's real data be applied into the gameplay?*

### **1.3 Summary of Goals**

The goals of the thesis, based on the sub-problems discussed earlier in the Chapter, can be summarized as follows.

- A. The thesis should investigate what game features are the most valuable to be presented in a game for children.
- B. The thesis should investigate the psychological background for game design.
- C. The thesis should show the procedure of designing and implementing an attractive and easy-to-play game for 8-12-years-old children.
- D. This thesis should show how the user's real data can be used in the gameplay.
- E. The thesis should demonstrate a game that provides knowledge about diabetes and helps improve diabetes-related self-management skills for children with type 1 diabetes.

In addition, the project should consider the future prospects of research in the field. Therefore, one more goal of the project is:

- F. The thesis should ultimately end up with reusable results that the future projects can be based on.

#### **1.4 Assumptions and Limitations**

The project focuses on helping quite a limited target group: children of 8-12 years old with type 1 diabetes. In general, worldwide, there are only 5-15% of people with diabetes who have this form of the disease. Herewith, this age group was chosen since pre-teenage children are ready enough for self-management skills development, including adherence to blood glucose monitoring, diet and physical activity, to make all this as a habit in their further life. Moreover, this helped to exclude complications on the implementation and testing stages of the project.

In Tromsø County, according to the data from the Children's Department at the University Hospital of North Norway (UNN), there are only 18 children in a suitable age group and with this form of the disease. This a priori meant a limited number of testers to participate in the application testing on the final stage of the project. Moreover, the recruitment process was conducted by the UNN: parents of the potential users of the implemented game were notified via invitation letters sent by the UNN medical personnel. Hereby, the project author was not able to influence the testers' recruitment not to breach the patients' confidentiality. This gave us only one tester willing to test the game.

The strictest limitation of the project was the time allotted for the research. This caused a very short application testing period which, in combination with a limited number of testers, was not able to give the results which could be considered as undisputed and objective.

Among the assumptions for the project before it has been started, we can name following ones:

- All application data is stored in the internal memory of the user's mobile phone and is not transferred to any external storage.
- In regard to the protection of the user's personal information, we assume that is only the user (the owner of the mobile phone where the application is installed) who has an access to the user's mobile phone and, therefore, authentication is not required. Especially, it concerns children as the target audience of the project.
- In addition, the user's mobile phone platform is Android, and the Few Touch Application, a self-help tool for people with diabetes, is installed on the same mobile phone.

#### **1.5 Methods**

The work presented in this thesis was conducted in the following order:

- Review of serious games and self-management tools for children
- Developing a paper prototype and preliminary scenario
- Developing Android-based versions of the application
- Meetings with a focus group of children regardless type 1 diabetes with demonstrating the prototype
  - Meetings with an endocrinologist and a nurse from the University hospital of North Norway (Children's Department) with demonstrating the prototype versions for gathering the requirements and suggestions for further improvements of the game
  - Meetings with experts in diabetes on the International Conference on Advanced Technologies & Treatments for Diabetes
  - Questionnaire for parents of children with type 1 diabetes about children's diabetes self-management, and Questionnaire for children with type 1 diabetes about their game experience and knowledge about diabetes

- Meetings with children with type 1 diabetes and their parents for testing and evaluating the game
- Interviews of children with type 1 diabetes for getting the feedback after testing
- Analysis of test results

First of all, to figure out the state-of-the-art in the field and understand the future prospects, academic literature about serious games and self-management tools developed specifically for children was systematically reviewed. Moreover, the literature helped to identify the significant game features which further were applied on the application design stage.

An engineering approach suggested by Denning and colleagues (Denning et al., 1989) was used to construct application prototypes being able to solve the identified problems.

In the beginning of the implementation stage of the project, a paper prototype with main functionalities of a future application was developed and discussed with colleagues. Further, the first Android-based version of the application was implemented.

After some improvements in design, the next version of the prototype was demonstrated to children of the target age group. They could express their wishes about the application to make it more enjoyable and attractive to use.

Discussions with experts in diabetes also helped to improve the game prototype.

Meetings with an endocrinologist and a nurse from the Children's Department of the UNN were held for getting feedback about the developed prototypes for gathering the requirements and suggestions for further improvements of the game. Doctors provided the ideas to be implemented which could make the game appropriately used by children with diabetes.

When the doctors were satisfied with the game version, the testing stage of the project started. The testing procedure consisted of three parts. The first one included the questionnaires for children with type 1 diabetes and their parents. The questionnaire for parents was concerned children's diabetes-related self-management, while the questionnaire for children was mostly about their previous game experience and basic knowledge about diabetes. Further, the game rules, features and functionalities were explained to a child and he/ she was left for testing. After, we discussed the user's feedback and the overall impression about the game.

Lastly, the test results were summarized and analyzed.

## **1.6 Significance and Contribution**

The main contribution of the project is the first attempt to develop a mobile phone-based game for children with type 1 diabetes in Norway. The features identified from the state-of-the-art in the field and behavioral theories, requirements and improvements suggestions from the end-users, doctors, and experts in diabetes were considered on the game design stage. The real data about user's blood glucose measurements and user's progress in blood glucose monitoring in real life were seamlessly embedded into the application as a part of its educational component aimed to teach children understand the disease better and improve self-management skills. Herewith, knowledge were introduced in the attractive and interesting form for children, a game. Despite too short testing period unable to properly demonstrate most features of the application, the game was recognized as attractive and moderately difficult with remarkable characters' choice, backstory, colors and sounds, real-life bonuses, and the most impressive feature of user's data influence on the gameplay: a game character, enemies and the rewards. Thereby, the research results can become a basis for other research in the field of Games for Health.

## **1.7 Organization**

The rest of the thesis is organized into the following chapters:

## Chapter 2. Theoretical Framework

This part gives an overview about diabetes, its prevalence and costs, and disease management. Moreover, games in general and serious games in particular are discussed. In addition, the field's state-of-the-art with identified significant game features is provided in the Chapter.

## Chapter 3. Materials and Methods

This chapter describes the research methods used in this project on the development, implementation and the results evaluation stages of the project.

## Chapter 4. Requirements and Specification

The chapter describes the project specification and its functional and non-functional requirements with their sources.

## Chapter 5. Design

The design process of the project with various improvements from one version of the application to another one is shown in this chapter. Also, the chapter describes the game content structure.

## Chapter 6. Implementation

This chapter presents the process of application development and tools used for this. Moreover, the application structure is explained with different code examples and the most significant gameplay features are described.

## Chapter 7. Test and Results

This chapter shows the conducted testing procedure. Also, the obtained test results from questionnaires for children with type 1 diabetes and their parents, game log files, and an interview after testing are described.

## Chapter 8. Discussion

In this chapter, test results are analyzed, interpreted, and discussed. Moreover, other issues that should be discussed are also presented. In addition, the identified points for improvements are described in the chapter.

## Chapter 9. Conclusion and Future Work

Conclusion remarks for this research and suggestions for potential future work are discussed in this chapter.



## Chapter 2

### Theoretical Framework

#### 2.1 Basic knowledge

##### 2.1.1 What is Diabetes?

Diabetes mellitus, or simply, diabetes, is a group of diseases characterized by high blood glucose levels that result from defects in the body's ability to produce and/ or use insulin<sup>15,16</sup>. Insulin is a hormone produced by the pancreas. It allows glucose absorbed from food to enter the body cells where it should be converted into energy which muscles and tissues need to work. Insulin is also important in keeping blood glucose levels within the acceptable limits<sup>9</sup>. As a result, glucose in the blood of people with diabetes stays circulating and leads to hyperglycemia which can cause serious damages in the body systems; especially it concerns the nerves and blood vessels. For more details see Figure 1.

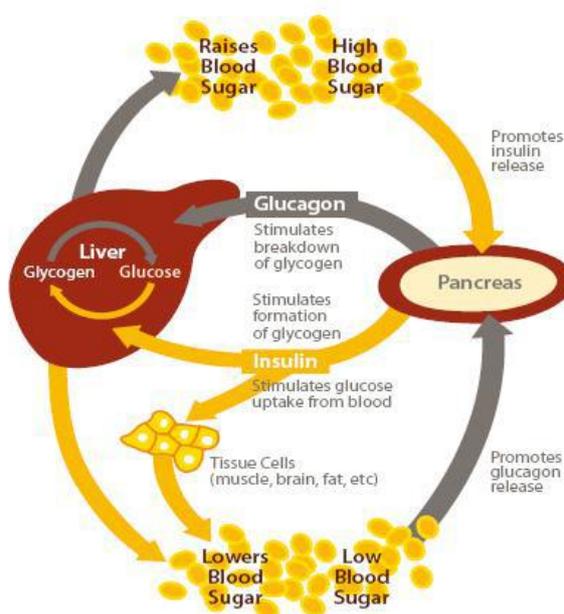


Figure 1. Insulin production and action. Source<sup>9</sup>

##### 2.1.2 Symptoms of Diabetes

The warning signs of diabetes are quite specific, and different people can experience different symptoms. Moreover, sometimes these signs can be not so obvious. But there are commonly experienced symptoms. High blood glucose causes polydipsia (when patients feel thirsty and have to drink a lot of water). This leads to polyuria as they need to urinate more frequently. In its turn, it causes polyphagia (patients feel hunger) since the glucose is discharged through urine from their body. Moreover, patients can lose their weight, feel tired faster, lose interest and concentration, experience vomiting, stomach pain and a tingling sensation or numbness in their hands or feet, have blurred vision, frequently get infections, and have slow-healing wounds<sup>9,16,17,18</sup>.

<sup>15</sup> International Diabetes Federation. IDF Diabetes Atlas, Fifth Edition (2011). What is Diabetes?

<http://www.idf.org/diabetesatlas/5e/what-is-diabetes> [Accessed 12.06.2013]

<sup>16</sup> International Diabetes Federation. Diabetes Atlas. What is Diabetes? <http://da3.diabetesatlas.org/index15e4.html> [Accessed 12.06.2013]

<sup>17</sup> International Diabetes Federation. Diabetes Atlas. Type 1 Diabetes <http://da3.diabetesatlas.org/index367b.html> [Accessed 12.06.2013]

### 2.1.3 Types of Diabetes

There are three main types of diabetes, marked as type 1 diabetes (T1DM), type 2 diabetes (T2DM), and gestational diabetes (GDM).

#### Type 1 Diabetes Mellitus

Type 1 diabetes is also called insulin-dependent diabetes mellitus (IDDM), or juvenile diabetes as it is usually diagnosed in children and young adults. It is not fully clarified why this condition occurs. Only 5-15% of people with diabetes have this form of the disease<sup>19</sup>. In the case of IDDM, body's immune system, which should fight harmful bacteria or viruses, destroys the insulin-producing cells in the pancreas (see Figure 2). Therefore, there is little or no insulin left. And sugar (in a form of glucose) accumulates in the blood stream, but does not go to the cells to give muscles and tissues needed energy<sup>9,17,20</sup>. Therefore, people with diabetes with IDDM inject insulin to control their blood glucose levels; without an access to insulin, they will die. But combining daily insulin therapy, blood glucose monitoring, a healthy diet, and regular physical exercise, these people can live normal, healthy lives.

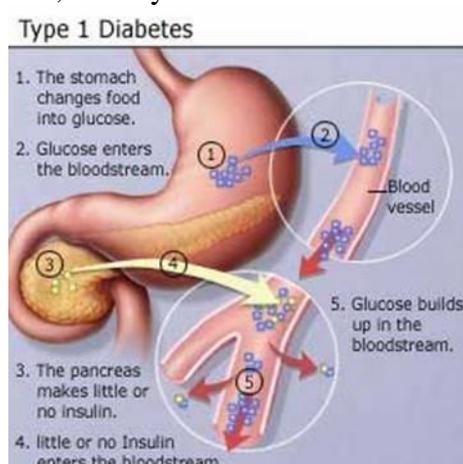


Figure 2. Type 1 diabetes. Source<sup>18</sup>

#### Type 2 Diabetes Mellitus

Type 2 diabetes is also called non-insulin dependent diabetes (NIDDM), or adult diabetes. It amounts about 90% of all diabetes' cases<sup>15,19</sup>. In the case of NIDDM, either pancreas produces not enough insulin or the body is not able to recognize the insulin and use it properly<sup>15</sup>. It refers to insulin resistance. When there is not enough insulin or the insulin is not used as it should be, glucose is not able to get into the body cells and then accumulates in the blood stream<sup>21</sup> (Figure 3). Actually, any person can get type 2 diabetes, but in the risk group people with obesity or overweight, women with gestational diabetes during their pregnancy, people with cases of type 2 diabetes in their family and people with metabolic syndrome which is a cluster of problems, such as increased blood pressure, high blood sugar levels, excess body fat around the waist or abnormal cholesterol levels, that occur simultaneously<sup>22,23</sup>. Also older people can be

<sup>18</sup> Rightdiagnosis.com. Symptoms of Type 1 Diabetes <http://www.rightdiagnosis.com/d/diab1/symptoms.htm> [Accessed 12.06.2013]

<sup>19</sup> Diabetes.co.uk. Diabetes Types <http://www.diabetes.co.uk/diabetes-types.html> [Accessed 12.06.2013]

<sup>20</sup> Taseerdiabetes.com. *Type 1 Diabetes* <http://www.taseerlabs.com/Diabetes/type1diabetes.html> [Accessed 12.06.2013]

<sup>21</sup> Medicinenet.com. Diabetes: Type 2 Diabetes <http://www.medicinenet.com/script/main/art.asp?articlekey=42940> [Accessed 12.06.2013]

<sup>22</sup> Mayo Clinic. Metabolic Syndrome <http://www.mayoclinic.com/health/metabolic%20syndrome/DS00522> [Accessed 12.06.2013]

included into the risk group as their bodies are less tolerant to sugars. While symptoms of type 1 diabetes appear usually sudden and dramatic, type 2 diabetes is quite hard to detect as its symptoms can often be mild or even absent<sup>24</sup>.

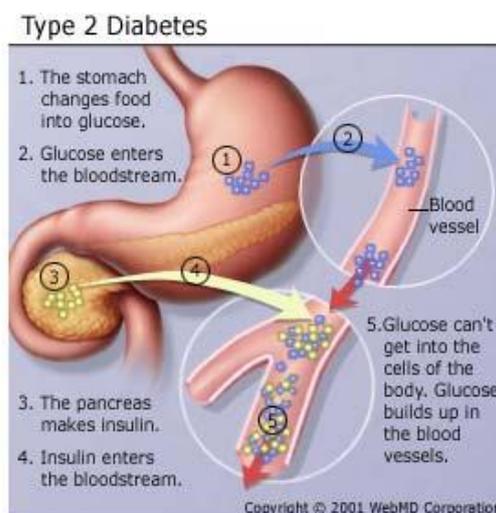


Figure 3. Type 2 diabetes. Source<sup>21</sup>

### Gestational Diabetes Mellitus

Gestational diabetes is a form of diabetes associated with high blood glucose levels during pregnancy which arises because of the body's inability to make and use enough insulin needed for pregnancy<sup>15</sup>. It occurs in 4% pregnancies worldwide<sup>16</sup>. It can be developed around the 24th week of pregnancy<sup>25</sup>. Therefore, the risk to the baby is lower comparing to babies with mothers with type 1 or type 2 diabetes before pregnancy. But anyway, women with GDM have to control their blood glucose levels to avoid developing diabetes in the baby. Usually, it can be done with a healthy diet. But sometimes insulin or oral medication can be used. In most cases, the disease disappears after pregnancy. But there is a risk of developing type 2 diabetes in these women and their children later in their lives. Around 50% of women with gestational diabetes during their pregnancy were diagnosed with type 2 diabetes within 5-10 years after delivery<sup>26</sup>.

### Other types of diabetes

Other specific types of diabetes also exist. Among them, there are genetic defects in  $\beta$ -cell function, genetic defects in insulin action, diseases of the exocrine pancreas, endocrinopathy, diabetes induced by drugs or chemicals, infections, unusual forms of immune-mediated diabetes, and other genetic syndromes, sometimes combined with diabetes<sup>27</sup>.

#### 2.1.4 Complications of Diabetes

Type 1 and type 2 diabetes are chronic diseases which need to be managed carefully. Poor monitoring and control can lead to short-term and long-term complications in various organs and tissues. One of the most serious complications, which cause 50% or more of all

<sup>23</sup> International Diabetes Federation. Diabetes Atlas. Type 2 Diabetes <http://da3.diabetesatlas.org/index755a.html> [Accessed 12.06.2013]

<sup>24</sup> Rightdiagnosis.com. Symptoms of Type 2 Diabetes <http://www.rightdiagnosis.com/d/diab2/symptoms.htm> [Accessed 12.06.2013]

<sup>25</sup> American Diabetes Association <http://www.diabetes.org> [Accessed 12.06.2013]

<sup>26</sup> Rightdiagnosis.com. Statistics about Gestational diabetes <http://www.rightdiagnosis.com/g/gestdiab/stats.htm> [Accessed 12.06.2013]

<sup>27</sup> Medicine Encyclopedia. Diabetes. Other Specific Types Of Diabetes <http://medicine.jrank.org/pages/2131/Diabetes-Other-Specific-Types-Diabetes.html> [Accessed 12.06.2013]

diabetes fatalities, is cardiovascular disease. It affects the heart and blood vessels and can lead to coronary heart disease and stroke. Also diabetic complications include kidney disease (nephropathy) which can cause total kidney failure, and then dialysis or kidney transplant are required. Herewith, diabetes is one of the leading causes of chronic kidney disease<sup>28,29</sup>. Nerve disease (neuropathy) leads to ulceration, problems with digestion and urination, impotence, and many other functions. But the extremities are the most commonly affected, in particular, the feet with possible pain, tingling, and loss of feeling which subsequently can lead to amputation of the toes, feet and lower limbs. One more complication, eye disease (retinopathy) is caused by persistently high levels of blood glucose, high blood pressure and high cholesterol, and can result to permanent vision loss. Moreover, there is an increased risk of obesity and abnormal glucose metabolism during childhood and adult life of the offspring in the case of mother's gestational diabetes<sup>7,15,16</sup>. As you can see, possible complications consider almost all systems in a diabetic patient's organism (see Figure 4).

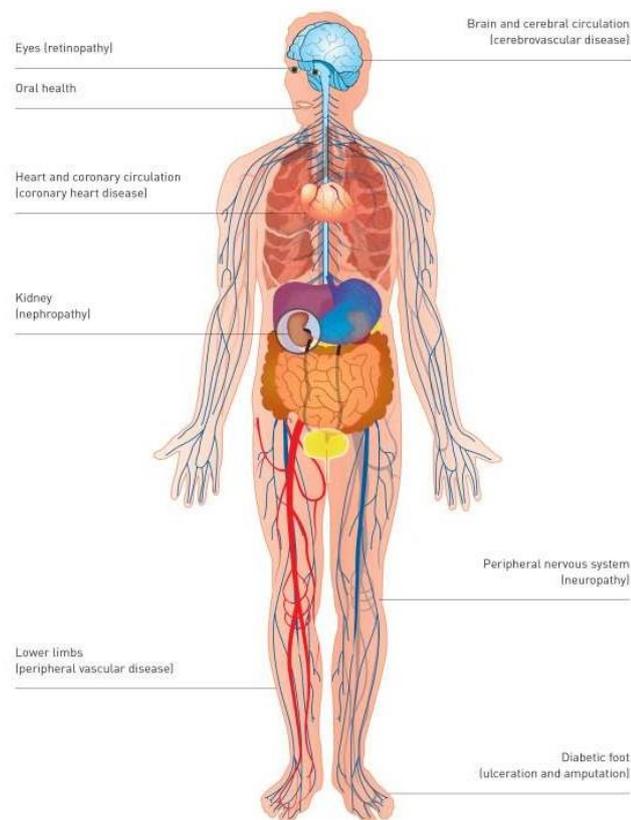


Figure 4. The major diabetes complications. Source<sup>15</sup>

### 2.1.5 Management of Diabetes

Unfortunately, it is not possible to cure diabetes. But, with a help of appropriate medication, good quality of medical care and having a physically active and healthy lifestyle, people with diabetes can reduce the risk of complications development. To keep the blood sugar

<sup>28</sup> Centers for disease control and prevention. National Chronic Kidney Disease Fact Sheet (2010) <http://www.cdc.gov/diabetes/pubs/factsheets/kidney.htm> [Accessed 12.06.2013]

<sup>29</sup> Davita.com. Diabetes Is the Leading Cause of Chronic Kidney Disease <http://www.davita.com/kidney-disease/overview/assessing-your-risk/diabetes-is-the-leading-cause-of-chronic-kidney-disease/e/4786> [Accessed 12.06.2013]

levels within normal limits for diabetics, it is recommended to have minimum 30 minutes of moderate physical activity every day and healthy food intake without high sugar and fat foods<sup>27</sup>.

This is a diabetes food pyramid on Figure 5. It shows proportions of food components for diet for people with diabetes.



Figure 5. The diabetes food pyramid. Source<sup>30</sup>

### **Starches<sup>30</sup>**

Starches include bread, grains, cereal, pasta, and also starchy vegetables (such as corn and potatoes). They provide carbohydrate, vitamins, minerals, and fiber. It is better to buy whole grain breads and cereals because they have more vitamins, minerals, and fiber. Also, it is healthier to eat less fried and high-fat and more low-fat or even fat-free starches.

### **Vegetables<sup>30</sup>**

Vegetables provide vitamins, minerals, and fiber; simultaneously they are low in carbohydrate. It is better to eat raw and cooked or steamed vegetables with little or no fat, sauces, or dressings. It is healthy to sprinkle food with herbs and spices and use canola oil, olive oil, or soft margarines instead of fat from meat or butter.

### **Fruit<sup>30</sup>**

Fruits are rich in carbohydrate, vitamins, minerals, and fiber. The same as with vegetables, it is healthy to eat raw or cooked, or dried fruits. People with diabetes should fruit more often than fruit juice, because whole fruit is more filling and rich in fiber.

### **Milk<sup>30</sup>**

Milk contains carbohydrate, protein, calcium, vitamins, and minerals. As in the case with starches, fat-free or low-fat dairy products are preferred. For example, it is better to substitute sour cream with low-fat plain yogurt, and so forth.

### **Meat and meat substitutes<sup>30</sup>**

In this group, meat, poultry, eggs, fish, cheese, and tofu are included. They provide protein, vitamins, and minerals. People with diabetes should eat small amounts of food in this group each day. But it should be either steamed or cooked in microwave oven, but not fried as then it contains high carbohydrate. Extra fat should be trimmed off, or if it is chicken or turkey, the skin should be removed. And to add more flavor, vinegars, lemon juice, soy sauce, salsa, ketchup, barbecue sauce, herbs, and spices are preferred.

<sup>30</sup> National Diabetes Information Clearinghouse. U.S. Department of Health and Human Services [http://diabetes.niddk.nih.gov/dm/pubs/eating\\_ez/#eat](http://diabetes.niddk.nih.gov/dm/pubs/eating_ez/#eat) [Accessed 12.06.2013]

## **Fat and sweet food<sup>30</sup>**

People with diabetes should limit the amount of fats and sweets they eat, because fats have a lot of calories, and sweets can be high in carbohydrate and fat. Moreover, they can contain saturated fats, trans fats, and cholesterol. It is better to drink diet soda or sugar-free hot cocoa mix, and eat fat-free ice cream or frozen yogurt.

## **Carbohydrate**

Carbohydrate in food increase blood glucose levels. Balance of the carbohydrate in food, along with physical activity and taken medicine or insulin, help to control blood glucose and avoid diabetes complications. Therefore, it is very important to keep blood glucose levels in the target range which requires meal planning. It can be done by several techniques.

The first technique is a plate method<sup>31</sup>. It deals with eating more non-starchy vegetables and smaller portions of anything else. The second possibility is glycemic index method<sup>31</sup>. Glycemic index (GI)<sup>32</sup> is a measure of how quickly blood glucose levels raise after eating a particular food comparing to pure glucose which GI is equal to 100. Using this technique, a person should consider the food with low glycemic index which is less than or equal to 55 according to special charts available, for example, in the Internet.

The third method is carbohydrate counting<sup>31</sup>: making notes of how many grams of carbohydrate a person eats and setting a maximum amount of carbohydrate to eat. Special tables of carbohydrate at a meal are composed<sup>33,34</sup>. It is better to start at 45-60 grams of carbohydrate per meal, with a total of 135 to 180 grams of carbohydrates daily<sup>35</sup>, and then personally figure out the proper carbohydrate amount to be able to vary food and the corresponding portion size in the future.

In addition to all the factors mentioned above, to prevent some diabetic complications, avoiding tobacco can help<sup>36</sup>. Meanwhile, regular foot and eye checks, monitoring blood pressure and blood glucose, and assessing risks for cardiovascular and kidney disease can help in early detection or even prevention of complications<sup>35</sup>.

### **2.1.6 Prevalence and Costs of Type 1 Diabetes**

Type 1 diabetes is one of the most common diseases among children worldwide. The number of children with type 1 diabetes increases rapidly every year. For a total number of 0-14-years-olds children, 1.9 billion, there are about 490 000 children with type 1 diabetes<sup>37</sup>. Hereby, 78 000 children worldwide are newly-diagnosed every year<sup>37</sup>.

Incidence of a disease is the number of newly-diagnosed cases during a specific time period. Despite rather large differences between trends in many countries, the incidence of type 1 diabetes in the world is increased on average by 3% every year<sup>37</sup>. For more details, see Figure 6.

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<sup>31</sup> American Diabetes Association. Food & Fitness. Planning for Carbs <http://www.diabetes.org/food-and-fitness/food/planning-meals/carb-counting/planning-for-carbs.html> [Accessed 12.06.2013]

<sup>32</sup> Mendosa.com. Revised International Table of Glycemic Index (GI) and Glycemic Load (GL) Values – 2008 <http://www.mendosa.com/gilists> [Accessed 12.06.2013]

<sup>33</sup> E-tools Age web site based on the U.S. Department of Agriculture database for standard reference SR22. Low Carbs List [http://www.etoosage.com/chart/Low\\_Carb\\_Foods\\_List.asp?Cate=0&NutriCate=205&NutriAmount=9&pageNo=1](http://www.etoosage.com/chart/Low_Carb_Foods_List.asp?Cate=0&NutriCate=205&NutriAmount=9&pageNo=1) [Accessed 12.06.2013]

<sup>34</sup> Food items table (Norway) <http://matvaretabellen.no> [Accessed 12.06.2013]

<sup>35</sup> American Diabetes Association. Food & Fitness. Carbohydrate Counting <http://www.diabetes.org/food-and-fitness/food/planning-meals/carb-counting/?loc=ff-diabetesmealplans> [Accessed 12.06.2013]

<sup>36</sup> Kidshealth.org. Long-term complications of diabetes [http://kidshealth.org/teen/diabetes\\_center/basics/complications.html](http://kidshealth.org/teen/diabetes_center/basics/complications.html) [Accessed 12.06.2013]

<sup>37</sup> IDF Diabetes Atlas. Fifth Edition. Diabetes in the Young <http://www.idf.org/diabetesatlas/5e/diabetes-in-the-young> [Accessed 12.06.2013]

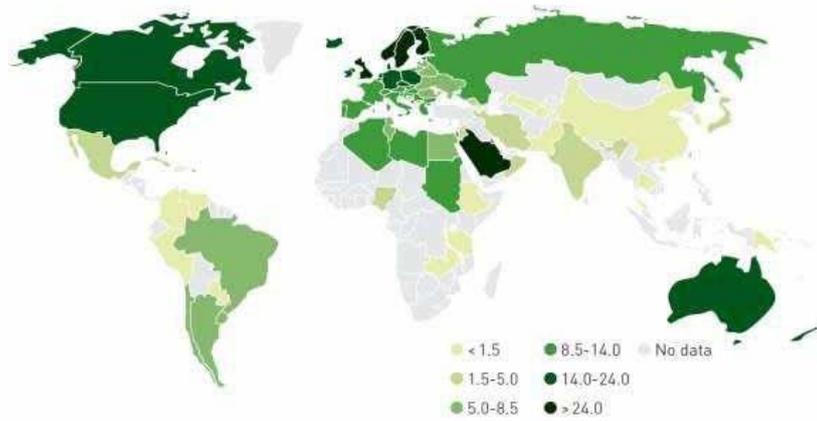


Figure 6. Incidence of type 1 diabetes among children (0-14 years) per 100 000 per year (2011).  
Source<sup>37</sup>

According to this Figure, Scandinavian countries (Norway, Sweden, Finland and Denmark) and Saudi Arabia have the highest incidence of type 1 diabetes in the world. The incidence is also high in Australia, Great Britain, Canada, and the USA. The lowest incidence is in China, Venezuela, Peru, Pakistan and some other countries. The reasons for such big differences are unclear.

In Norway, 32 children are newly-diagnosed with diabetes per 100 000 every year (Barnediabetesregisteret (Norge), 2010). According to statistics from the national Children's Diabetes Registry<sup>38</sup> (Oslo Universitetssykehus, 2011), there was increase in prevalence to about 200 new cases per year during 1973-1982, during 1989-1998 the diabetes incidence was relatively stable, and in 2000-2010, we can observe increasing numbers in the age group 0-18 years (see Figure 7). In 2010, 325 new cases of diabetes among children (0-18 years old) were registered<sup>38</sup> (Oslo Universitetssykehus, 2011). Herewith, there were more boys than girls (56% and 44%, respectively)<sup>38</sup>, who were diagnosed with type 1 diabetes (in 323 cases out of 325) while, in most countries, numbers of boys and girls with type 1 diabetes are approximately the same. Moreover, 301 children with type 1 diabetes were under 15 years old<sup>38</sup> (Oslo Universitetssykehus, 2011) (see Figure 8).

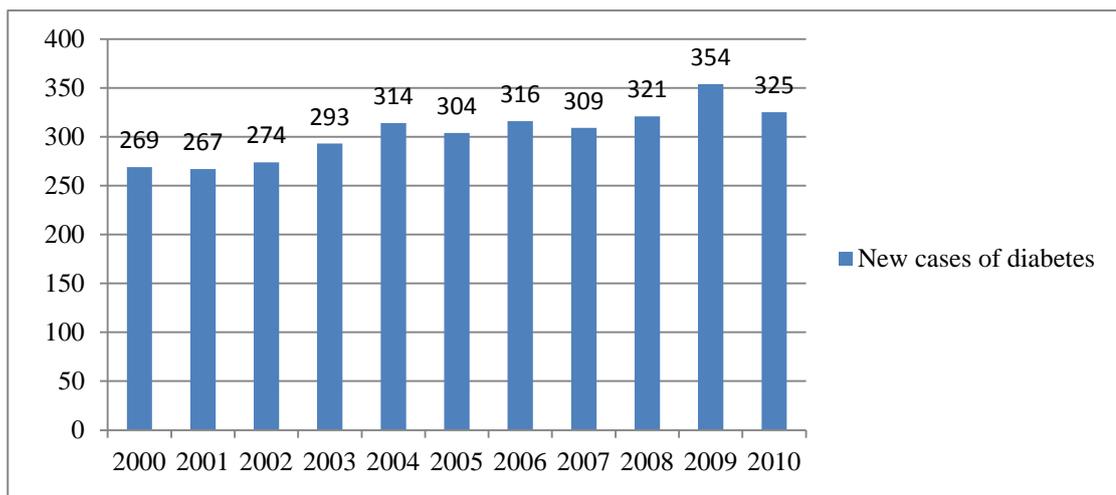


Figure 7. Newly-diagnosed children (0-18 years) with diabetes in Norway in 2000-2010.  
Source<sup>38</sup>

<sup>38</sup> Folkehelseinstituttet. Diabetes - faktaark med helsestatistikk  
[http://www.fhi.no/eway/default.aspx?pid=233&trg=MainLeft\\_6039&MainArea\\_5661=6039:0:15,4577:1:0:0:::0:0&MainLeft\\_6039=6041:70814:15,4577:1:6043:1:::0:0](http://www.fhi.no/eway/default.aspx?pid=233&trg=MainLeft_6039&MainArea_5661=6039:0:15,4577:1:0:0:::0:0&MainLeft_6039=6041:70814:15,4577:1:6043:1:::0:0) [Accessed 12.06.2013]

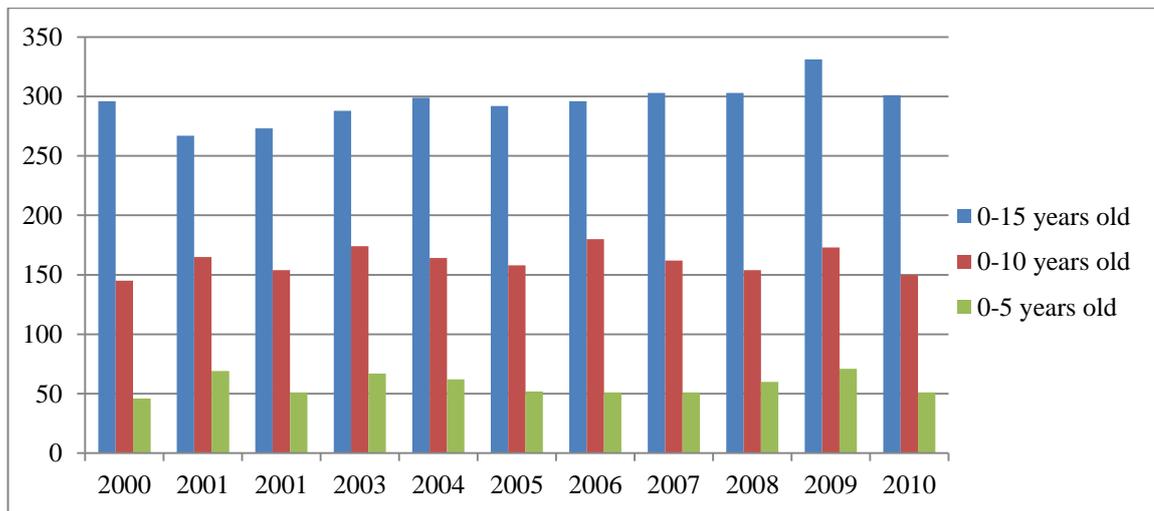


Figure 8. Newly-diagnosed children with type 1 diabetes divided in age groups. Source (Oslo Universitetssykehus, 2011)

As it was mentioned above, the total number of children under 15 years old is approximately 490 000. Prevalence of a disease is the total number of cases of a disease in a given population at a specific time. The worldwide statistics for type 1 diabetes in children is presented on Figure 9.

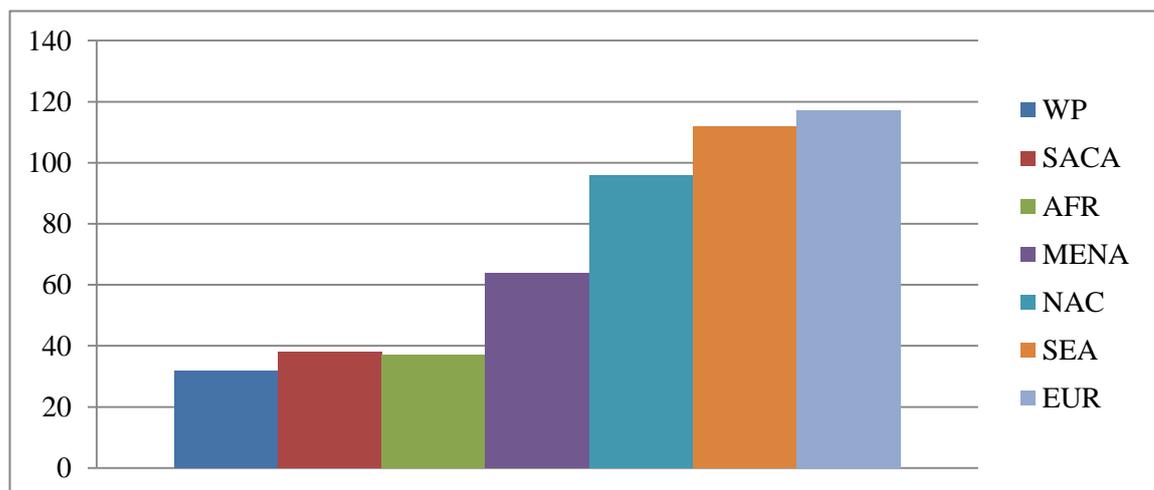


Figure 9. Prevalence of type 1 diabetes among children (0-14 years) in 2011, where WP = Western Pacific, SACA = South and Central America, AFR = Africa, MENA = Middle East and North Africa, NAC = North America and the Caribbean, SEA = South-East Asia, EUR = Europe. Source<sup>37</sup>

Figure 9 shows us the regions with the highest number of cases of diagnosed type 1 diabetes among children. They are Europe and South-East Asia. North America and the Caribbean are on the third rank. About 60% of the total number of children under 15 years old with type 1 diabetes live in these three regions. The lowest prevalence is in the Western Pacific region, South and Central Africa, and Africa as a whole. The results are similar to the incidence numbers while we should understand the absence of registered data about diabetes in some regions, for example, in Africa.

To find confirmed financial costs for type 1 diabetes is quite difficult because it is usually considered to calculate costs both for type 1 and type 2 diabetes. But type 1 diabetes requires insulin therapy during the whole life, and endocrinologist's, physician's and dietitian's consultations to manage the disease.

Tao and colleagues (Tao et al., 2010) studied diabetes costs in the US. They estimated type 1 diabetes medical costs as \$14.4 billion per year. Tao talked about \$422.9 billion costs for type 1 diabetes treatment which could be avoided in the case of the disease elimination by the therapeutic intervention. In 2007, costs per each T1D patient in the United States were \$14 856, according to Dall and colleagues (Dall et al., 2010).

In Australia, type 1 diabetes costs totaled US\$170 billion in 2011 which could double to \$340 billion in the nearest future<sup>39</sup>.

For Norway, diabetes costs (T1DM and T2DM in 2005) were estimated by Solli and colleagues (Solli et al., 2010). The total costs composed of €293 million. This implies direct and indirect costs. Direct costs included €95 million for medicines (€35.1 million for insulin and analogues), €48 million for disability pensions, €40 million for medical equipment expenditure, and €21 million for hospital stays. As indirect costs, such as sick leave due to diabetes, disability pensions, and basic and supplemental benefits related to diabetes amounted to €70.1 million.

Therefore, we can conclude diabetes is a considerable burden for the whole world.

## 2.2 Psychological Framework

One special thing about children with diabetes is that they are rather young to understand what is happening with them and to be aware of the seriousness of the disease and the importance of its treatment by means of following some rules and restrictions which concern diabetes maintaining. It is hard for them to understand that only systematical adherence to the treatment can allow them enjoy a normal life and avoid complications in the future (Boyle and Zrebiec, 2007), (Cryer et al., 2003), (Lerman, 2005), (Polonsky, 2006). Another issue here is that parents of children with diabetes, of course, worry about them and do not want their children to stay alone (Bosma et al., 1996), (Hanna, 2003), (Anderson et al., 1997), but for children, especially in adolescent ages when they want to be more independent from their parents and not to differ from their friends and coevals, this parental solicitude can seem too intrusive and over-protective (Anderson and Coyne, 1991), (Diabetes Forecast, 2003). Sometimes, this may lead to misunderstandings in a family (Laursen et al., 1998), (Carlson et al., 1994) which can become a psychological burden for the diabetic child (Diabetes Forecast, 2003), (Sessa and Steinberg, 1991), and therefore, can inhibit the adherence to the treatment (Hanna and Guthrie, 2000), (Amiel et al., 1986).

Approximately 30-50% of children and adolescents with type 1 diabetes are non-adherent (Kovacs et al., 1992). In Weissberg's and his colleagues' study (Weissberg-Benchell et al., 1995), such results were published: while not following the prescribed diet was one of the most common mismanagement behaviors, 29% of youngsters with IDDM missed blood tests, 29% made up blood test results to give lower numbers (because adolescents felt that family members and healthcare workers wanted them to produce good results), and 25% missed insulin shots. Poor-controlled condition may intermediately lead to incorrect clinical decisions such as, for example, incorrectly prescribed insulin doses. Adherence to medical regimens can be improved by psychological interventions (Lehmkuhl et al., 2010). In turn, it impacts better blood glucose levels control and overall health condition with a reduced risk of complications; and consequently, this improves self-awareness and social well-being of the individual.

According to Hochbaum (Hochbaum et al., 1992) and Jackson (Jackson, 1997), behavior change theory is indispensable if we want to effectively help people modify their lifestyles which include blood glucose monitoring, diet and activity behaviors. It is significant to apply behavioral theories while developing a cohesive and comprehensive behavior change intervention since they provide information on why people behave the way they do and how we

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<sup>39</sup> Medicalnewstoday.com. Type 1 Diabetes Treatment Cost Could Rise Considerably  
<http://www.medicalnewstoday.com/articles/236323.php> [Accessed 12.06.2013]

can influence on this behavior to change it. There are four theories usually applying in this case. They are social cognitive theory (Bandura, 2004), self-determination theory (Ryan and Deci, 2000) (Deci and Ryan, 2000), elaboration likelihood model (Petty and Cacioppo, 1986), and behavioral inoculation theory (McGuire, 1961). As a rule, all these behavioral theories are used together to cover most aspects of behavior changing while separately the theories are range-limited.

### **2.2.1 Social Cognitive Theory**

Social cognitive theory was created by Bandura in 1986 (Bandura, 2004). It is mostly used as a theoretical framework for obesity prevention interventions (as examples see (Baranowski, 2010), (Thompson et al., 2007a) and (Thompson et al., 2007b)). The theory asserts the joint use of behavior-specific knowledge (for example, health practices and risks), self-efficacy (which is a personal confidence in an ability for performing the behavior), self-regulatory skills (such as goal setting, goal monitoring, and problem solving), and the environmental facilitators to be able to promote behavior changing (Bandura, 2004) (Thompson et al., 2007a) (Thompson et al., 2010) (Baranowski et al., 2011).

Behavior-specific knowledge is knowledge required to properly perform the specified behavior (Thompson et al., 2010). For example, in the case of diabetes, it can concern with an ability to measure the blood glucose, interpret the results, and take appropriate actions; or it can deal with an ability to select the right healthy food. Behavior-specific knowledge is necessary for successful behavior changing interventions, herewith, knowledge per se may not lead to behavior changes (Thompson et al., 2007a).

Self-efficacy is a person's level of confidence in an ability to properly carry out a task or behavior (Thompson et al., 2007a) (Thompson et al., 2010). Affecting task selection, stamina while facing the obstacles and efforts made to reach the aim, self-efficacy has an indirect impact on behavior (Bandura, 2004). Social modeling, such as an experience of personal success or an observation of others while mastering the challenges and obtaining feedback afterwards, encourages the behavior changes (Bandura, 2004) (Thompson et al., 2007b). The first named above type of social modeling has the biggest effect on self-efficacy, whereas the second one is a typical method of learning a new behavior (Thompson et al., 2007a) (Thompson et al., 2010).

Self-regulatory skills, such as goal setting, goal monitoring and problem solving, are also effective for perceived behavior changes control and self-management improvement (Thompson et al., 2007a) (Thompson et al., 2010). An elementary particle of goal setting, the main component of self-regulation, is a goal. Goals state behavioral intention, provide the directions or standards for behavior changing efforts. Herewith, specific, short-term and corresponding to the efforts goals are more likely to be reached (Schunk, 2001). Goal intentions (the goal itself) and implementation intentions (plans or methods and their evaluation for the goal attainment) are two tightly coupled phases of goal setting (Thompson et al., 2007a). To automate behavior and, thereby, increase the goal attainment likelihood, environmental cues (external instructions), which require a goal-directed response, are most suitable (Bargh et al., 2001). Goal monitoring (goal review, in other sources (Thompson et al., 2007a)) allows monitoring and regulating the goal progress toward the desired goal and, thereby, promotes behavior changes (Thompson et al., 2007a) (Thompson et al., 2010). If a person faces actual or perceived barriers (for example, environmental barriers to healthy diet and physical activity (Thompson et al., 2007a)) which interfere to his/ her goal attainment, problem-solving skills can help by finding the effective (sometimes non-standard) solutions to overcome them (Thompson et al., 2010).

Therefore, providing behavior-specific knowledge, promoting self-efficacy, supporting such self-regulatory skills as goal setting, goal monitoring, and problem solving, and ensuring the corresponding environment, it is possible to develop an effective behavior change intervention.

### **2.2.2 Self-Determination Theory**

According to self-determination theory (Ryan and Deci, 2000), motivation is used to perform a behavior. There are two types of motivation: intrinsic and extrinsic. While extrinsically motivated behaviors are motivated by some source outside, such as rewards or punishments, intrinsically motivated behaviors are instead self-motivated and self-determined. Intrinsically motivated behaviors are performed by intrinsic regulation for personal interest, enjoyment, and internal satisfaction (Ryan and Deci, 2000). Extrinsically motivated behaviors can be distinguished depending on the degree of personal involvement into the behavior motivation and regulation: from completely externally regulated, which are motivated by compliance, and external rewards and punishments, to behaviors with integrated regulation, which are close to internally motivated, but performed for the achievement of separate results and goals rather than for an individual's enjoyment or satisfaction (Ryan and Deci, 2000). Intrinsic motivation, in spite of being not goal-directed, is more successful in behavior changing interventions maintenance (Baranowski et al., 2011).

According to authors of SDT, when an individual has a personal experience for competence (which combines personal skills and abilities for performing the behavior properly), autonomy (which is a feeling of full control over performing the behavior or a feeling of having the choice while performing the behavior), and relatedness (which is an importance of the behavior and its results for an individual), intrinsic motivated behaviors and, the closest to them, behaviors with integrated extrinsic motivation are most likely to perform (Ryan and Deci, 2000) (Thompson et al., 2007a). Herewith, strong competence, autonomy and relatedness are characteristics of intrinsically motivated behavior, and weak parameters of the same characteristics are typical for completely externally motivated behavior (Thompson et al., 2007a). Moreover, positive feedback can enhance internal motivation, providing satisfaction of the need for competence, whereas negative feedback (for example, threats or deadlines) can cause the relocation of an internal motivation of the behavior to external and, therefore, destroy internal motivation (Deci and Ryan, 2000).

Therefore, performing behavior changing interventions, we should provide high levels of competence with positive feedback, choices for a feeling of personal autonomy, and a possibility to correlate results with personally important goals.

### **2.2.3 Elaboration Likelihood Model**

Elaboration likelihood model was developed by Petty and Cacioppo in the early 1980s and has been used as a framework in health behavior message design projects (for example, (Thompson et al., 2007a)). The theory explains how persuasive messages build attitudes. An individual elaborate persuasive messages either by via the central, highly cognizant, route or via the peripheral route (Petty and Cacioppo, 1986). The first route requires long pondering and deliberation of the message. In the second one, external (environmental) characteristics of the message (for example, it can intuitively seem to be attractive or reliable due to the author's name or the source name) are enough for the individual's attitude formation. For more details, see Figure 10. High-elaborated (via the central route) attitudes are stronger than those that are low elaborated via the peripheral route (Petty and Cacioppo, 1986). Attitudes produced under high elaboration are time-stable and are less exposed to changes by counterarguments or to full destruction, whereas the peripheral-route attitudes are inclined to cause a attitude's change in a short term (Petty and Cacioppo, 1986). Moreover, the theory claims that the more attention is paid to the message building the attitude, the higher the likelihood of central route processing (Baranowski et al., 2011).

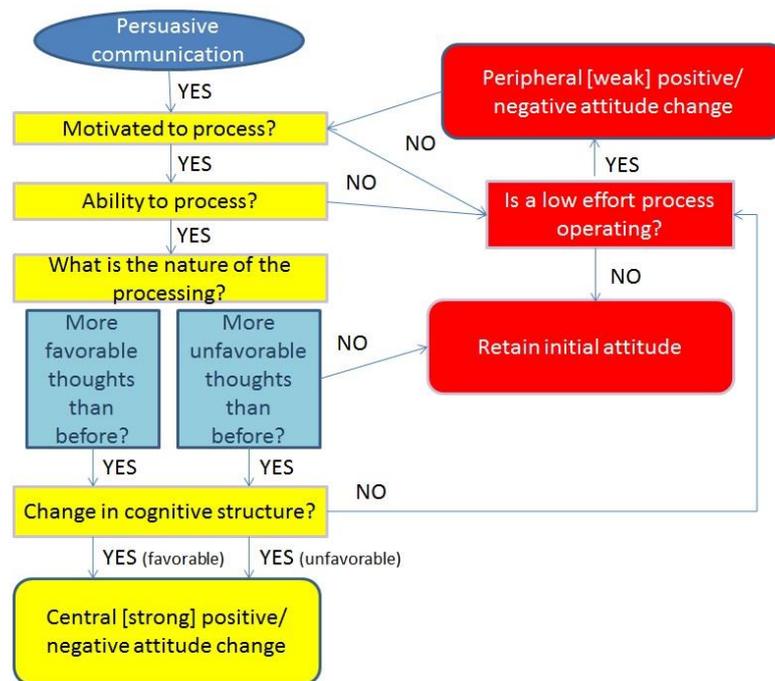


Figure 10. Central (in yellow) and peripheral (in red) routes to persuasion. Source (Petty, 2003)

According to elaboration likelihood model, the intensity of attention and efforts for processing the message following the central route of high elaboration is determined by two factors: ability (an individual's comprehension and concentration on the message without distractions) and motivation (a personal relevance (involvement) to the message topic and responsibility) (Thompson et al., 2007a) (Petty and Cacioppo, 1986). Such components as prior knowledge, comprehension, non-distraction influence the ability of processing and working on a message, while a personal relevance to the message (in contrast to generic messages processing) forms a desire to act on the message and, therefore, motivates the person (Thompson et al., 2007a). This means that to build the strong attitudes about behaviors, persuasive messages should correspond to the personal comprehension and relevance. To enhance personal relevance while behavior changing, tailoring can be rather effective (Thompson et al., 2007a).

## 2.2.4 Behavioral Inoculation Theory

According to behavioral inoculation theory (McGuire, 1961), it turns out that personal initially strong truisms, being overprotected, are quite vulnerable under strong counterarguments. An "inoculation" or a mental preparation of the person to the possible temptations (counterarguments) strengthens personal persuasion and beliefs. An individual is then able to resist these temptations when they occur. Such an "inoculation" can be implemented by, first of all, identifying and presenting the potential threat to the proper behavior (which challenges a person to change behavior (Baranowski et al., 2011)), and then offering counterarguments to this threat which conform the benefit of the behavior chosen before (McGuire, 1961). Thereby, we provide a forced exposure to person's truisms in a weakened form offering relevant knowledge and resources which stimulates performing the correct behavior and resisting the temptations. Moreover, to enhance intrinsic motivation of the behavior, we can provide tailored motivational messages (Baranowski et al., 2011).

Therefore, we can present temptations against adherence to treatment regimens (considering non-adherence to blood glucose monitoring, insulin injections, healthy diet and physical activity) to children, and then refuse these protections by strong arguments supported by approved knowledge and resources. This will enhance children's attitude to the proper behavior and make them better prepared to resist such temptations when they face them in a real life.

### **2.2.5 Conclusion**

Mediating variables are factors accounting for differences. By behavior-changing interventions, we can influence directly on mediating variables. They, in turn, influence behavior, and changes in behavior lead to health outcomes (Baranowski et al., 1998). Social cognitive and self-determination theories provide such key mediating variables to focus in a serious game promoting self-management as knowledge (both self-regulatory and behavior-specific), skills, self-efficacy, and motivation (Bandura, 2004), (Ryan and Deci, 2000), (Deci and Ryan, 2000), (Baranowski et al., 1998).

According to self-determination theory, motivation is influenced by competence (ability to perform a behavior), autonomy (presence of a choice and ability to control the behavior), and relatedness (accordance of behavior to personal ideals) which are mentioned above (Ryan and Deci, 2000). Hereby, competence is influenced by repetition and positive feedback. Also, intrinsic motivation is more effective for behavior formation (Ryan and Deci, 2000).

Via central, high-elaborated route, a strong positive attitude to the behavior can be formed in the case of strong motivation which can be enhanced by personal relevance to the topic (Petty and Cacioppo, 1986). Therefore, we should support desirable behavior by relevant educational information.

Additionally, providing a challenge which can make a person change behavior and then offering counterarguments to it which conform the benefit of the behavior chosen before strengthens the confidence in the correct behavior (McGuire, 1961). This can be reached by counterarguments in a weakened form.

## **2.3 Serious Games**

### **2.3.1 Basic Knowledge about Games**

Looking backward, we can find out that people play games during the whole mankind life from ancient times. French sociologist Caillois, in his book "*Les jeux et les homes*" (Caillois, 2001), defined a game as an activity that must be "*fun, separate, uncertain, non-productive, governed by rules, and fictitious*".

The spread use of technology, however, has pushed the experience of playing games to another level. Thereby, video games have emerged, leading to an industry of billions of dollars. A video game can be defined as "any game played on a digital device such as arcades, PCs, game consoles, or handheld units" (Baranowski et al., 2008).

Nowadays, video games are a huge industry. In support of this, take a look at global retail sales of some video games on various platforms in 2012 which are presented on Figure 11.

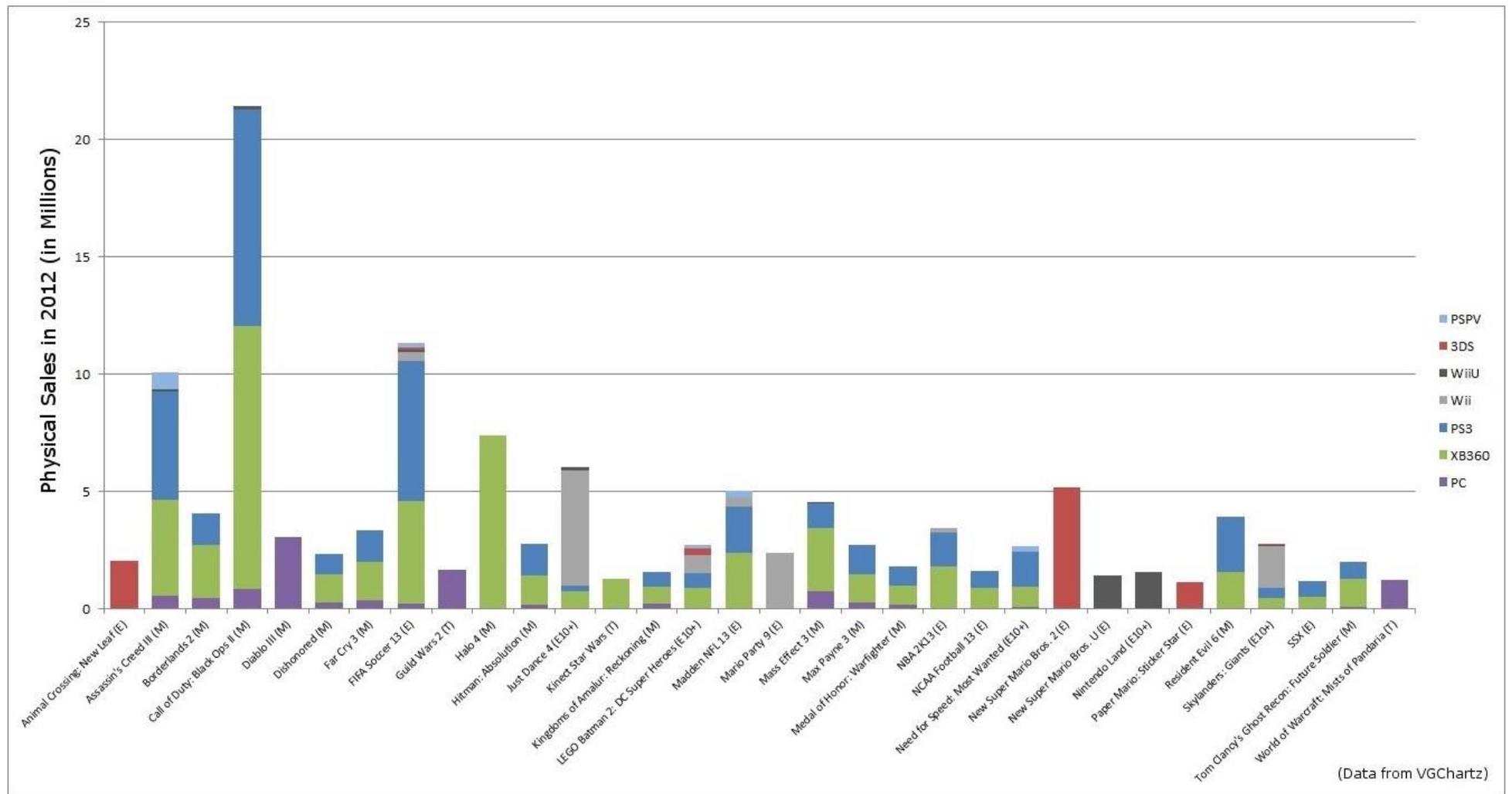


Figure 11. Global retail sales of some video games on various platforms in 2012. Source<sup>40</sup>

<sup>40</sup> Reddit.com <http://www.reddit.com/user/NcikVGG/submitted/> [Accessed 12.06.2013]

13). There are many genres of video games. A specter of game types and platforms the games are built on are really broad (see Figure 12 and Figure 13).

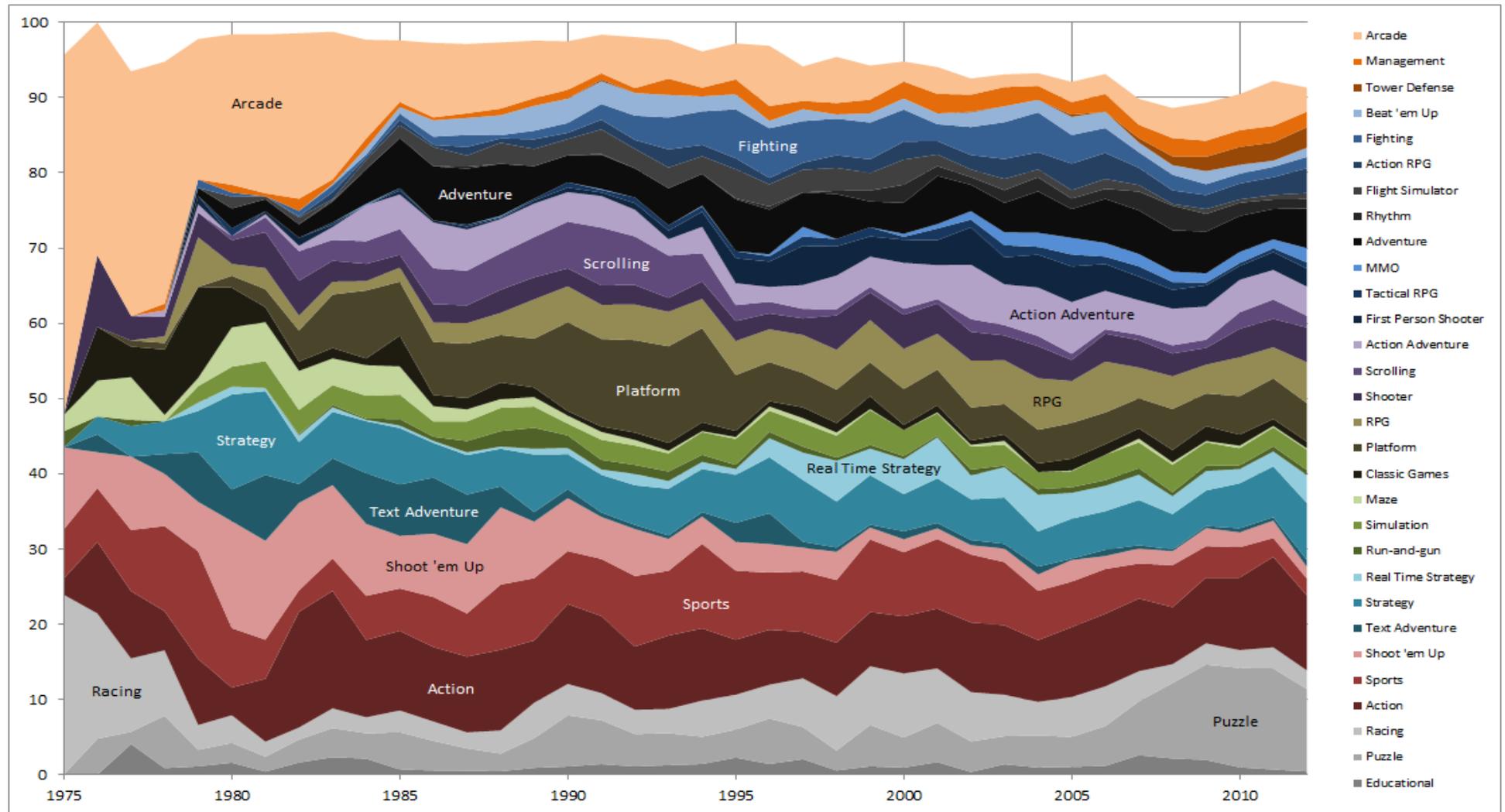


Figure 12. Genres of video games. Source<sup>40</sup>

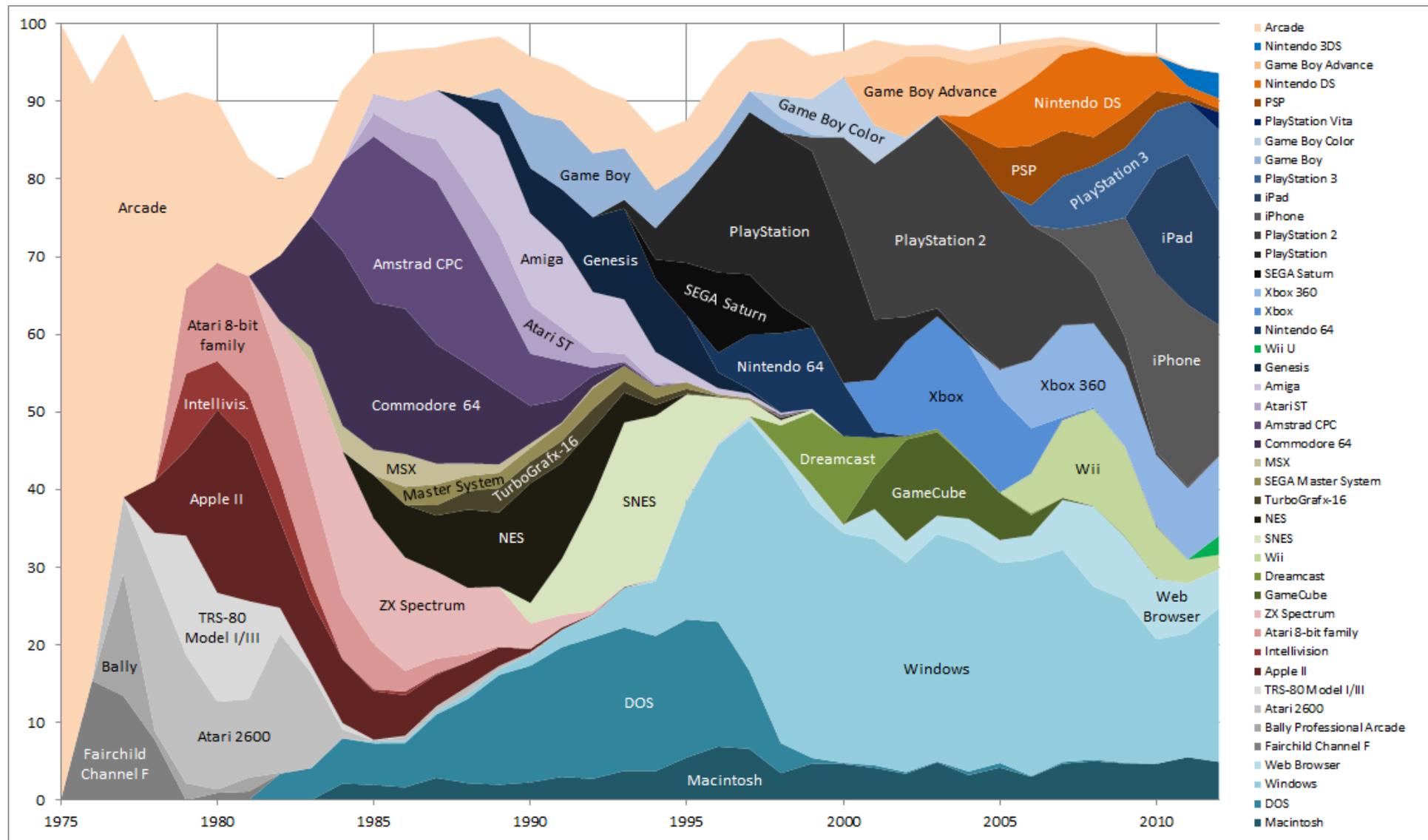


Figure 13. Video games platforms. Source<sup>40</sup>

The analysis of content and ratings of teen-rated (with “T” on the game box) video games was done by Haninger and Thompson (Haninger and Thompson, 2004). The “T” rating games are determined as suitable for children aged 13 years or older by the Entertainment Software Rating Board (USA) which reviews the games submitted by the game manufacturers to determine the age-based rating and content descriptors. The study showed that out of 396 T-rated video games 98% involved intensive violence, 90% (69%) rewarded or required the player to injure (to kill) characters, 42% / 27% / 15% depicted blood / sexual themes / substances, 27% contained profanity, and 1% of games involved gambling. Mention of this research here was supposed to get better understanding of the difference between “video games” and “serious games” which, first of all, have the educational goal and cannot have the content described above, especially when it comes to children.

According to Roberts and so-researchers who studied links between 8-18 years-old youngsters and media in their lives (Roberts et al., 2005), 86% of children and teenagers have a computer, 83% - a video game console, 55% - a handheld video game player, 39% - a cell phone, and 12% - a laptop computer. All these devices can be used to play video games. Results of another survey with 12-17 years-old adolescents (Lenhart et al., 2008) show that 99% of boys and 94% of girls of this age play video games. Thereby, video games are potentially convenient (being applicable for both genders) and available (since video game devices are almost ubiquitous) means for self-management skills development.

Serious games are computer- and videogames of any genre which are used for persuasion or educational issues (Derryberry, 2007). At the first sight, it seems to be similar to educational games. But the target audience often is not just primary or secondary school pupils who we would like to learn something from the school program. The title “serious games” stresses that these games are designed to attain serious outcomes, such as behavior change. According to Ben Sawyer (Sawyer, 2004), a serious game is “any meaningful use of computerized game/game industry resources whose chief mission is not entertainment”. But then it is even more interesting that many serious games are considered as a kind of *edutainment*: such *serious* games are supposed to be *fun*.

Nowadays, serious games is a huge industry earned about US\$1.5 billion in the global market in 2007 (Derryberry, 2007). Serious games are in use in military, corporate, education, and health care organizations responding with positive feedback (Derryberry, 2007), (Zhang and Liu, 2012), (Kunkler, 2006), (Dai et al., 1997). They are so popular because of availability and ubiquity of devices, easy-to-use interfaces, attractive highly motivational graphics and sounds, and an ability of self-paced, entertaining learning through role playing and simulation.

Mobile devices are widely used due to their availability anytime and anywhere. Hereby, mobile phones market is rapidly growing (see Figure 14 and Figure 15): nowadays, there are more than 4.0 billion mobile phones all over the world<sup>11</sup>, and this number is expected to extensively rise in the future.

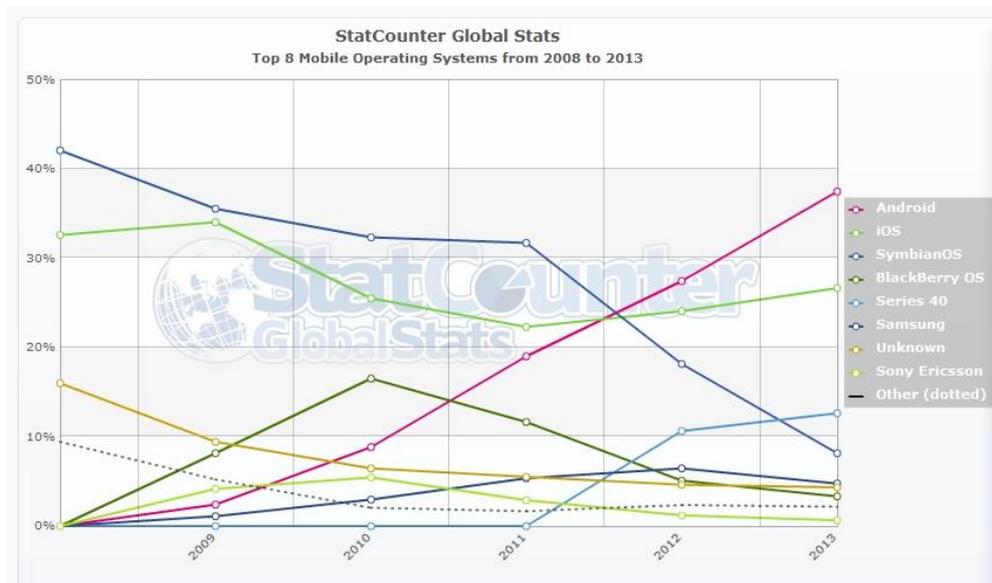


Figure 14. Top 8 Mobile Operating Systems from 2008 to 2013 (line form). Source<sup>41</sup>

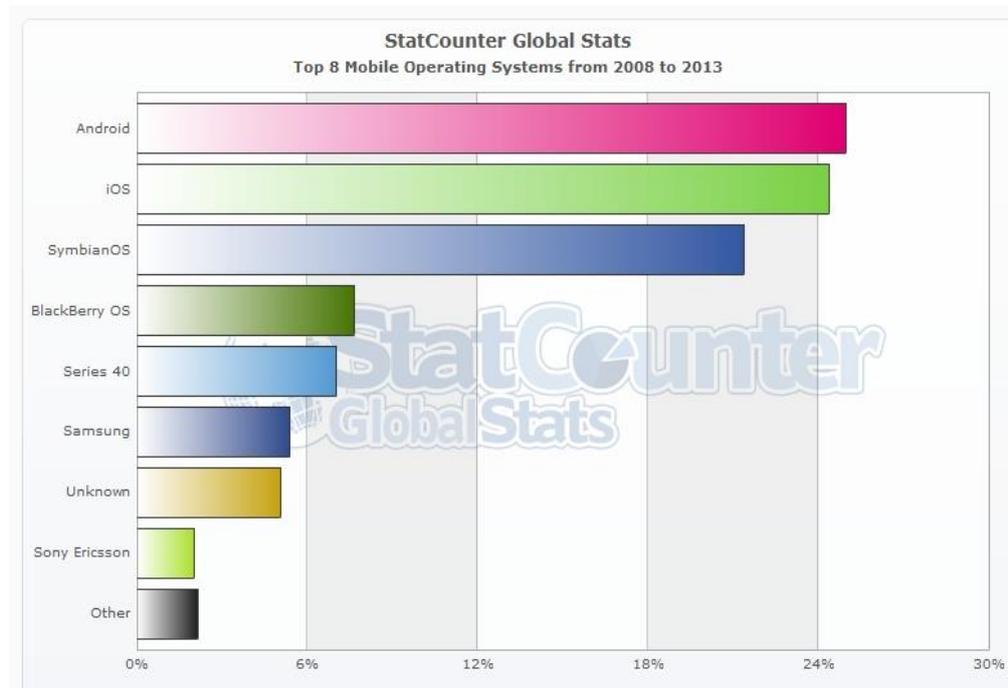


Figure 15. Top 8 Mobile Operating Systems from 2008 to 2013 (bar form). Source<sup>42</sup>

Moreover, mobile-gaming market is booming nowadays. Its revenue was US\$12.3 billion in 2012, and it is expected to increase to US\$15.2 billion by 2015<sup>43</sup>. In 2010, 64 million people played mobile games at least monthly, a number that will rise to 94.9 million by 2014<sup>44</sup>. Mobile games are the most popular application category on mobile devices (see Figure 16 and Figure 17).

<sup>41</sup> StatCounter Global Stats. Top 8 Mobile Operating Systems from 2008 to 2013 (line form) [http://gs.statcounter.com/#mobile\\_os-ww-yearly-2008-2013](http://gs.statcounter.com/#mobile_os-ww-yearly-2008-2013) [Accessed 12.06.2013]

<sup>42</sup> StatCounter Global Stats. Top 8 Mobile Operating Systems from 2008 to 2013 (bar form) [http://gs.statcounter.com/#mobile\\_os-ww-yearly-2008-2013-bar](http://gs.statcounter.com/#mobile_os-ww-yearly-2008-2013-bar) [Accessed 12.06.2013]

<sup>43</sup> YAHOO! Finance. Mobile Gaming Market Surges in 2012 as Traditional Gaming Continues to Decline <http://finance.yahoo.com/news/mobile-gaming-market-surges-2012-132000563.html> [Accessed 12.06.2013]

<sup>44</sup> eMarketer.com. Mobile Gaming Market Tops \$800 Million in 2010 <http://www.emarketer.com/Article/Mobile-Gaming-Market-Tops-800-Million-2010/1007874> [Accessed 12.06.2013]



Figure 16. Mobile applications in use daily. Source<sup>13</sup>

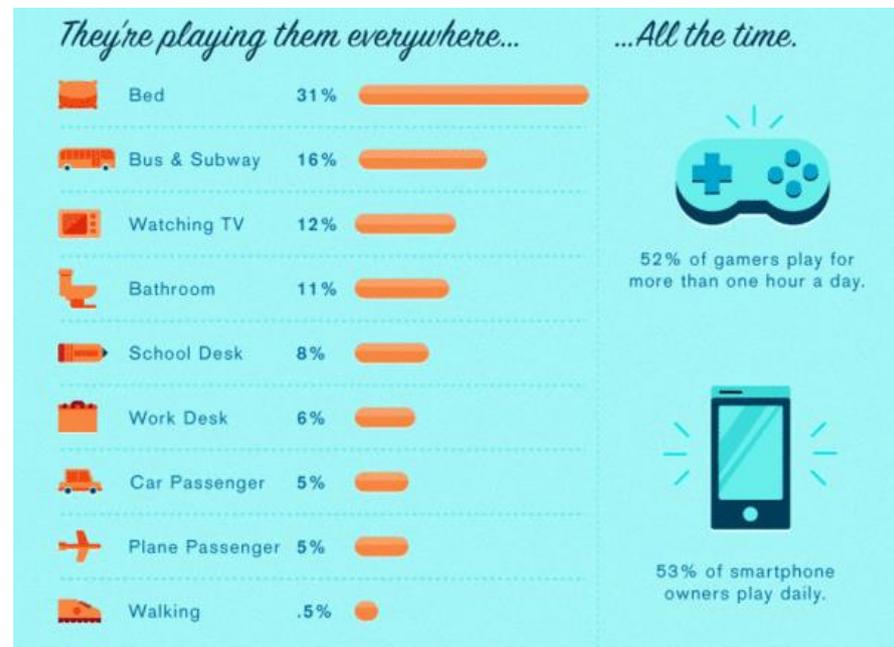


Figure 17. Percentage of time spent for playing games. Source<sup>13</sup>

### 2.3.2 Effectiveness of Serious Games

Bandura (Bandura, 2004) argued that people, especially children, learn many behaviors by observing others. It supports our choice of game as an educational tool.

Despite of big differences in understanding and cognition levels between children and adults (Swift, 2009), there are some general guiding principles while developing a game environment for efficient learning.

According to the principles adapted from (Beale, 2011), we should teach a user such skills that are actually needed: skills which are required as a precondition or a basis for more advanced skills. Additionally, we should provide maximum motivation for participation and learning which is achieved by:

- providing a choice;
- immediate auditory and visual feedback for
  - correct actions – positive feedback, rewards;
  - incorrect actions – immediate correction of errors;
- extrinsic rewards;
- minimizing of errors by:
  - gradually growing difficulty of tasks which includes ensuring that basic skills are mastered while starting with higher level skills;
  - focus user's attention to important features;
  - providing self-paced learning;
  - minimal loading of user's working memory;
  - repeated instructions for activities.

These principles completely are consistent with psychological behavior theories mentioned above. Moreover, conclusions from analyzed literature in the state-of-the-art (reviewed further in the Chapter) correspond to them and to the key game elements adapted from Derryberry's paper (Derryberry, 2007).

Additionally, it should be noticed that player's emotions during a game are also very important as they directly influence on the actions made by a player in the gameplay. According to Frijda (Frijda, 1986), there are five phases of emotions which lead to a certain action as a result. These phases are:

- appraisal (a person recognizes the event which causes the emotion),
- context evaluation (a person plans what to do with this event),
- action readiness (a person is willing to act),
- action tendency (a person's tendency to communicate with environment),
- and physiological change (a person expresses the emotion and acts).

Jarvinen (Jarvinen, 2008) found similar phases in the gameplay, where a player first recognizes a significant element or event in the game, then he/she decides to act on it in a certain way, and finally, a player makes a concrete action. Moreover, Stevens and his colleagues (Stevens et al., 2008) found out psychological interconnections in the chain "in-game - in-room - in-world". This means that behavior in the game, behavior in the current environment while playing the game and behavior in everyday life of children playing videogames have strong linkage.

According to the Lewis' literature review (Lewis, 1999) (where approximately 76% of reviewed research-based reports, which are related to use of computer technology in education of patients suffering from chronic diseases, showed a significant effect in clinical outcomes), computer-based education is quite effective for patients' knowledge transfer and skills development. Conclusions about better health outcomes are also made by Benjamin (Benjamin, 2002) during the research concerning constant patients' education and self-monitoring of blood glucose.

Baranowski and colleagues (Baranowski et al., 2011) consider that through serious videogames designed for behavior-change procedures other than for simply enjoyment, children can improve their knowledge, skills, and the overall learning experience.

According to Thompson and colleagues (Thompson et al., 2010), serious video games are potentially effective for promoting diabetic adolescents' self-management skills. Being easy to use, fun, able to provide useful educational material regarding diabetes, and with intuitive, user-friendly interfaces, these games keep the balance between entertainment as a core and educating, training and health care informing, and provide players an ability to discover and learn skills through exploration and experimentation (Thompson et al., 2010). Moreover, they promote high

level of interactivity and active learning, which are not captured in traditional teaching-and-learning environments (Bassilious et al., 2012).

Therefore, if we can provide such a learning environment which satisfies all the principles and has all key elements mentioned above, there is a high likelihood that a behavior will be intrinsically motivated which, in turn, leads to the enhanced likelihood of a behavior to be long-term maintained (Thompson et al., 2010).

### 2.3.3 Diabetes-Related Serious Games

There are many diabetes related serious videogames. After analysis, we suppose they can be structured as follows (see Figure 18), regarding to diabetes cornerstones they are aimed to.

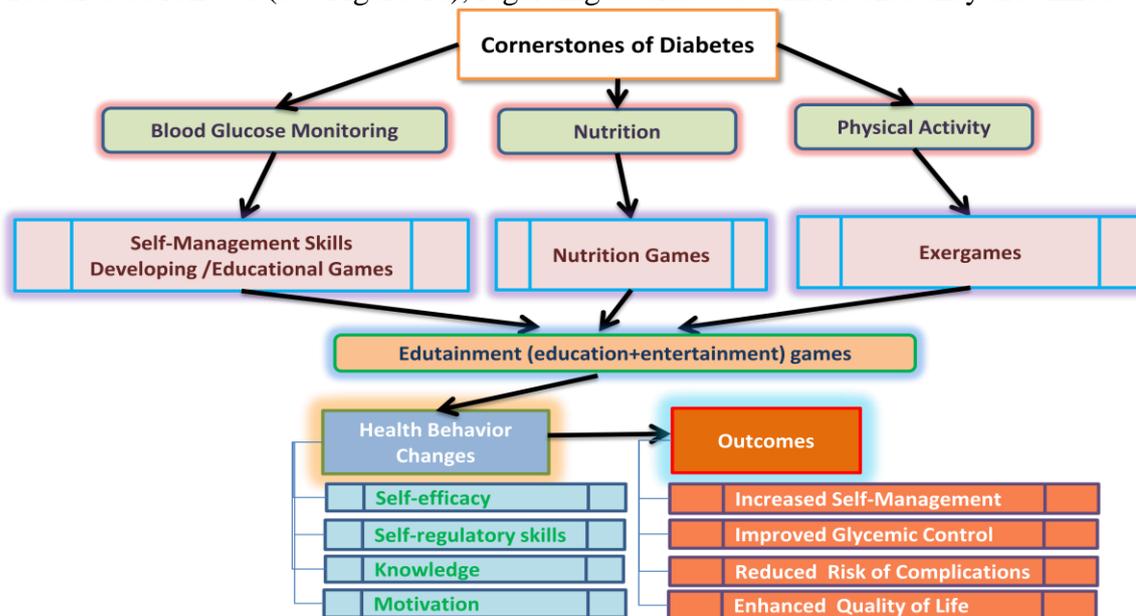


Figure 18. Connections between diabetes cornerstones, serious videogames and their goals

Serious games are reviewed further in the State-of-the-art part of this Chapter. Here, we offer some scenarios of diabetes-related games.

*Packy & Marlon*<sup>45</sup> is one of the most popular games in literature reviews by researchers. Here, a player should monitor characters' blood glucose level (elephants) and avoid enemies (rats) which can harm a player if touched. He/ she can balance the BG by injecting insulin, and collecting different food items.

*Ketones Attack*<sup>46</sup> is a top-down shooter. A player shoots all sugar cubes on the screen using an "insulin gun". To charge the gun, a player should pick up insulin randomly appearing on screen. A player loses if too many enemies hit him/ her.

*The Diabetic Dog Game*<sup>47</sup> is a game where a player should take care of a dog with diabetes. To do this, a player should walk-out the dog, inject insulin (both alternatives decrease the dog's blood glucose level), or feed it (which increases the dog's BG level). A player loses if he/ she is not able to take proper care of the dog.

*Diabetes Dash*<sup>48</sup> is a first-person game where a player should balance a blood glucose level by moving left and right to collect the correct amount of food and insulin. To be able to

<sup>45</sup> Packy & Marlon game description <http://www.comm.ucsb.edu/faculty/lieberman/> [Accessed 12.06.2013]

<sup>46</sup> Ketones Attack game web site <http://www.jdrft1.org.uk/games/attack.html> [Accessed 12.06.2013]

<sup>47</sup> The Diabetic Dog Game web site <http://www.nobelprize.org/educational/medicine/insulin/game/insulin.html> [Accessed 12.06.2013]

<sup>48</sup> Diabetes Dash game web site <http://www.jdrft1.org.uk/games/dash.html> [Accessed 12.06.2013]

“eat” a lot of food without effects on the blood glucose level, an insulin shot should be collected first.

These games can be viewed as educational/ self-management skills-developing games. And we can observe some similarities in their storylines.

## **2.4 State-of-the-Art\***

This part shows a review of academic literature about behavior changing, motivating, educating videogames and self-management tools developed for children with diabetes.

### **2.4.1 Purpose**

Motivation of the diabetic patient’s adherence to treatment is one of the most challenging tasks of diabetes self-management skills development. Especially when it comes to children and teenagers who are most psychologically sensitive for their peers’ attitude to them and do not want to differ from others. Therefore, they are most likely not to adhere to medical regimens which make restrictions in their life, such as measuring blood sugar, taking insulin injections or following a special diet. Now it is time of an active use of videogames in health for development of self-management skills and enhancing chronic patients’ self-efficacy. Literature describing motivating, education-targeted videogames for behavior changes and self-management skills development, in addition, self-management tools developed specifically for children with diabetes were investigated to be considered as state-of-the-art for the thesis topic.

### **2.4.2 Data Sources and Search Criteria**

Electronic databases of PubMed (National Library of Medicine and National Institute of Health), ACM (Association for computer machinery) digital library, IEEE (Institute of Electrical and Electronics Engineers) Xplore, Google Scholar, Google Books, Google, SAGE journals database, the GamesForHealth journal and Journal of Diabetes Science and Technology were searched for relevant literatures. Moreover, a search in the database on the web-page of the Health Games Research program (University of California, Santa Barbara) was used for examples of games for children with diabetes which probably were not observed in publications.

Searches were conducted in August-September 2012.

Several exclusion criteria were applied. They were a) papers in other languages than English; b) papers without an available full text; and c) papers focusing exclusively on improving the diabetes care abilities of the parents of children with diabetes. Review papers were accepted in the literature search. The relevance of each publication was examined by reading the abstract and the whole text if needed.

### **2.4.3 Search Methods**

As it was mentioned above, literature search was performed in August-September 2012. For searching the relevant literature, multiple combinations of keywords were used. First of all, we were interested in games (video games/ serious games) for children (or adolescents) with diabetes which educate or motivate self-management skills development and/ or adherence. After the primary search, the duplicate literature was eliminated from the result. The total number of papers fitting the criteria is 149. In Table 1, there are the results of primary search (“Found”), and the articles identified after the first round of selection (“Hits”).

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\* This state-of-the-art has been accepted for a poster presentation in The 6<sup>th</sup> International Conference on Advanced Technologies & Treatments for Diabetes (27.02.2013-02.03.2013, Paris, France) (see Appendix 5).

Table 1. The results of data extraction

Source	Keywords	Found	Hits
Google Scholar	mobile + games + type + 1 + diabetes + adolescents + self-management + adherence	299	0
	mobile + games + type + 1 + diabetes + adolescents + self-management + adherence + motivation	219	0
	mobile + social + games + type + 1 + diabetes + adolescents + self-management + adherence + motivation	155	0
	mobile + social + games + type + 1 + diabetes + mellitus + adolescents + self-management + adherence + motivation	64	0
	mobile + social + games + type + 1 + diabetes + mellitus + education + adolescents + self-management + adherence + motivation	63	0
	mobile + social + games + type + 1 + diabetes + mellitus + education + children + adolescents + self-management + adherence + motivation	57	0
	mobile + social + games + type + 1 + diabetes + mellitus + education + children + adolescents + self-management + self-care + adherence + motivation	37	14
PubMed	(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management	309	1
	(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management) AND videogame	2	2
	(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management) AND video game	14	4
	(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management) AND game	16	2
	(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management) AND game) AND motivation	12	0
	(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management) AND video game) AND motivation	10	0
	(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management) AND video game) AND mobile	6	0
(((diabetes) AND type 1 diabetes mellitus) AND adolescents) AND adherence) AND self-care) AND self-management) AND videogame) AND mobile	0	0	
IEEE	video + games + children + diabetes + adherence	9	3
	video + games + children + diabetes + motivation + social + adolescents + self-management + adherence	4	0
	video + games + children + diabetes + motivation + social + adolescents + self-management + adherence + education	4	1
	videogames + children + diabetes + mobile + adolescents	22	3
Google books	mobile + social + games + type + 1 + diabetes + mellitus + education + children + adolescents + self-management + self-care + adherence + motivation	6	0
	mobile + social + games + type + 1 + diabetes + mellitus + education + adolescents + self-management + adherence + motivation	7	4
	serious + games + diabetes + adolescents + self-management	8	8
Google	mobile + games + type + 1 + diabetes + adolescents + self-management + adherence	248000	0

	mobile + games + type + 1 + diabetes + adolescents + self-management + adherence + motivation	167000	0
	mobile + social + games + type + 1 + diabetes + adolescents + self-management + adherence + motivation	3750	0
	mobile + social + games + type + 1 + diabetes + mellitus + adolescents + self-management + adherence + motivation	1900	0
	mobile + social + games + type + 1 + diabetes + mellitus + education + adolescents + self-management + adherence + motivation	2040	0
	mobile + social + games + type + 1 + diabetes + mellitus + education + children + adolescents + self-management + adherence + motivation	12000	0
	mobile + social + games + type + 1 + diabetes + mellitus + education + children + adolescents + self-management + self-care + adherence + motivation	11000	48
Journal of Diabetes Science and technology	self-management	13	5
	game	14	5
	education	7	0
	self-management + game + education	0	0
	self-management + game	2	0
	serious + game	4	0
	/category "Clinical Applications"/	25	2
	/category "Diabetes Computing & Internet Watch"/	4	2
	/category "Diabetes Information Technology"/	7	2
SAGE journals	/category "Perspectives of Diabetes Information"/	10	3
	videogame AND children AND diabetes AND self-management	5	2
	videogame AND children AND diabetes AND self-management	3	0
	game AND children AND diabetes AND self-management	144	1
Games for Health Journal	game AND children AND diabetes AND adherence	204	5
	/free access/ + /diabetes, games features as a topic/	61	16
ACM	video + game + diabetes + children + adolescents	32	8
	video + game + diabetes + children + adherence	12	0
	video + game + diabetes + children + education	73	8
	video + game + diabetes + children + education	12	0
<i>Total</i>		447645	149

#### 2.4.4 Findings

149 papers were found in the sources mentioned above. After removal of duplicates, 127 works left. 119 articles had an available full text. After meeting exclusion criteria and based on titles and abstracts, 66 papers were selected as relevant to the thesis topic. Among not included papers were those studying traditional forms of children's education in diabetes or patient-healthcare professional communication, or with adult target population, or applications which were neither serious games, nor specifically developed for children. Finally, these articles were divided into two groups: (1) papers studying clinical effects and health outcomes of serious games and (2) papers identifying success criteria for serious games which mean the gameplay features that might interest the player and motivate one to continue playing the game. Thereby, 25 studies hit the first group, and 41 articles were placed into the second group. Moreover, following data were extracted from the finally selected papers: 1) target disease (since interesting features can be found in other nearby areas), 2) type of the game in dependence of the main

purpose it was developed for (see Figure 18 for the defined types of serious games), 3) target population, 4) a platform the game was developed for, 5) target population, and 6) the findings for the study or significant features of the game, depending on the group which the paper was defined in. Obviously, the most important parameter was the last one, the studies' findings since they identified the game features and criteria which should be considered in game development.

The detailed results are presented in Table "Detailed list of reviewed relevant literature" in Appendix 1.

### 2.4.5 Discussion

The second group of research which consisted of the papers identifying success criteria for serious games was properly investigated. All the relevant literature and some Internet resources (such as GamesForHealth, Google, Google Play, and iTunesStore) were searched for serious games for chronic diseases (including diabetes, asthma, cancer, and HIV) and obesity. On the mentioned web pages, a systematic search for keywords "children" and "diabetes" was performed. The results are composed in Table "Videogames for chronic diseases mentioned in relevant literature and elsewhere" in Appendix 2.

The most attention was paid for the platforms and the age groups these games were developed for. Moreover, the reviewed games were divided into three groups in accordance to Figure 18:

	Diet/ Nutrition Games
	Physical Activity/ Exergames
	Self-Management Skills Developing/ Educational Games

Results of the quantitative analysis of the Table with all the reviewed video games for chronic diseases in Appendix 2 are presented below.

Number of games (totally)	Number of games (without duplicates)	Diabetes-related games	Games for mobile platforms	Games for Web	Games for PC	Games for game consoles
164	89	65	28	26	20	12

Out of 65 games concerned the diabetes cornerstones, we found:

Nutrition games	Exergames	Educational games
24 (37%)	13 (20%)	28 (43%)

Analyzing the Table in Appendix 2, we found out 89 videogames (without duplicates) mentioned in the relevant literature and on web pages of the Health Games Research program, iTunesStore, and Google Play (formerly, GoogleMarket). According to this Table, reviewed serious games were approximately equally mobile phone-based (31%, 28 out of 89) and web-based (29%, 26 out of 89). About 22% of videogames (20 out of 89) were from the PC platform market; 13% of games (12 out of 89) were developed for game consoles, such as Nintendo, Xbox Kinect and others. Considering mobile platforms, 47% (13 out of 28) applications were built for iOS (iPhone, iPod Touch, iPad), and 14% were developed for Android OS (4 out of 28). For the rest mobile games and tools (39%, 11 out of 28), platforms were not specified; it is supposed to include Symbian OS, Sony Ericsson, Samsung, and some other mobile operating systems (according to Figure 14). Hereby, we can state a lack of games specifically developed Windows Mobile platforms (since it had not been mentioned at all) and for Android operating system.

Out of the total number of games, 65 games are connected with diabetes cornerstones, such as healthy nutrition, physical activity and blood glucose monitoring. Rests of the games either were developed for other chronic diseases than diabetes (for example, asthma, cancer, HIV), or a target disease or a target group were not specified, but, herewith, they were considered serious videogames in the reviewed literature. The biggest part of the diabetes related games (43%, 28 out of 65) were focused on education of patients and their self-management skills development. Approximately 37% of performed games were connected with healthy diet (24 out of 65) while exergames took the fifth part of the diabetic games (20%, 13 out of 65) and were mostly developed for specific game consoles and mobile platforms. It should be mentioned that none of the games (except exergames for game consoles) directly used user's data for one's motivation.

In addition, after analysis of the Tables in Appendix 1 and Appendix 2, such significant gameplay features were found: (1) a player learns some skill (skill development) by playing a character empathetically related to the player and improves the skill by learning the subtleties of the game and further planning of strategy (goal setting, goal review); (2) a player gets rewards; some virtual trophies for the player's achievements, and new game content were used (referred to feedback and extrinsic motivation); (3) a player faces challenges; either he/ she can compete with other players or surpass one's own score or record, or resist time constraints or gradually increasing difficulty of levels, or locked context (seen as intrinsic rewards being a part of self-regulatory behavior); (4) games had attractive design including graphics, sounds, animations. The features (2)-(4) could make the game immersive and motivate players to continue playing, while the game stays educational owing to (1). Almost all the authors affirm games for health should be enjoyable and fun while being educational, and, thereby, staying so-called "edutainment" tools. Considering serious games for children, we could add that an easy game access and understandable gameplay, novelty of game scenario, an ability of team play, and an attractive colorful, "cartoons"-style design could become additional attractions.

Moreover, according to reviewed literature, many researchers used psychological theoretical frameworks for the game design, applying *social cognitive theory* (Baranowski et al., 2008), (Lu et al., 2012), (Baranowski et al., 2010), (Boren et al., 2006), (Chen et al., 2011), (Thompson et al., 2010), *self-determination theory* (Baranowski et al., 2008), (Baranowski et al., 2010), (Lu et al., 2012), (Boren et al., 2006), (Chen et al., 2011), (Thompson et al., 2010), *behavior inoculation theory* (Baranowski et al., 2008), (Baranowski et al., 2010), (Fuchslocher et al., 2010), (Thompson et al., 2010), *elaboration likelihood model* (Baranowski et al., 2008), (Baranowski et al., 2010), (Thompson et al., 2010), *health belief model* (Arteaga et al., 2010), (Kharrazi and Faiola, 2010), (Kharrazi et al., 2009), *planned behavioral model* (Arteaga et al., 2010), (Kharrazi et al., 2009), *mediating/moderating variable model* (Baranowski et al., 2011).

#### **2.4.6 Conclusion**

We identified lack of diabetes related games built for Android and Windows mobile platforms. Additionally, only exergames use user's data directly for one's motivation. An increased use of psychological theoretical frameworks for game design was noticed. Such significant gameplay features were found: skill learning and its improvement by planning the game strategy, rewards, involvement in competition, attractiveness of game design implying graphics and sounds; all of these features correlate with psychological theories mentioned above. Moreover, an easy game access, immersive, novel and moderately difficult gameplay, and an ability to play in a team are additional attractions for children.

#### **2.5 Summary**

This chapter provides basic knowledge about diabetes, and its management. Additionally, psychological behavioral theories, which should be applied for learning environment

development, are discussed. Further, serious games concept is introduced. Moreover, a certain amount of relevant literature is reviewed in the State-of-the-art part of the Chapter.



## Chapter 3

# Methods and Materials

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### 3.1 Research Paradigm and Tools

In this thesis, the engineering approach is used. This approach with four aspects was described by Denning (Denning et al., 1989) in the task force committee report titled “Computing as a Discipline”. According to it, developers have to state requirements, first; then, state specifications; after that, design and implement the system; and finally, test the system.

The process is iterative; hereby, requirements can be changed or transformed in later phases of implementation.

### 3.2 Materials

To develop the application, several tools were applied. Graphical user interfaces for a paper prototype were constructed with a help of 10screens.com<sup>49</sup> free service. For further implementation of the application prototype for the Android operating system, the following software was installed.

- Java SE Development Kit 7u9<sup>50</sup>, a platform for development and deployment of portable applications<sup>51</sup>;
- Unity3D<sup>52</sup> (version 3.5.5f3), a game engine for apps development with an option to build and run projects on the Android mobile platform (this tool was purchased for the project by the University of Tromsø). In addition, some add-ons were purchased by the author for design issues (such as Parallax<sup>53</sup>, RageSpline<sup>54</sup>, and some others);
- Eclipse for Mobile Developers<sup>55</sup> (version: Juno Service Release 1, build id: 20120920-0800) with installed ADT plugin, Android SDK (software development kit with a debugger, libraries, a handset emulator) (for Android 1.5 (API 3) to Android 4.1.2 (API 16)), and AVD Manager, was used as an IDE (Integrated Development Environment).

A suggested application was developed for the Android mobile platform with Android 4.0 “Ice Cream Sandwich” (API level 14) and .NET 2.0 Subset API compatibility level. For the application testing, Sony Xperia Acro with a 4.3" HD Reality Display touchscreen with a resolution of 1280x720 pixels was used.

For application development for the Android OS, Java is used as a scripting language. In Unity3D, which was chosen as a development environment for the implementation part of the application, C#, JavaScript, and Boo can be used for behavior scripts<sup>56</sup> which are originally are not supported in Android, but can be compiled by Unity3D for this platform.

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<sup>49</sup> 10screens.com. Powerpoint for Prototyping <http://www.10screens.com/> [Accessed 12.06.2013]

<sup>50</sup> Java SE Development Kit download page <http://www.oracle.com/technetwork/java/javase/downloads/index.html> [Accessed 12.06.2013]

<sup>51</sup> Oracle web site. Java SE at a Glance <http://www.oracle.com/technetwork/java/javase/overview/index.html> [Accessed 12.06.2013]

<sup>52</sup> Unity3D web site <http://unity3d.com/> [Accessed 12.06.2013]

<sup>53</sup> Unity3D's Asset Store. Parallax add-on for animation <https://www.assetstore.unity3d.com/#/content/696> [Accessed 12.06.2013]

<sup>54</sup> Unity3D's Asset Store. RageSpline editor extension <https://www.assetstore.unity3d.com/#/content/555> [Accessed 12.06.2013]

<sup>55</sup> Eclipse web site. Eclipse for Mobile Developers <http://eclipse.org/mobile/> [Accessed 12.06.2013]

<sup>56</sup> Unity Manuals. Using scripts <http://docs.unity3d.com/Documentation/Manual/Scripting.html> [Accessed 12.06.2013]

C# was chosen for development of the project despite the author's lack of programming experience in this language but simultaneous presence of experience with other object-oriented languages.

### **3.3 Data Collection and Experiment Methods**

#### **3.3.1 Literature Review**

For gathering the complementary functional and non-functional requirements for the system, review method of relevant literature and psychological theories described in details in the "State-of-the-art" part of Chapter 2 was used. There the main features which would lead to the appropriately implemented game were identified.

The identified significant gameplay features can be summed up as follows.

A player should learn some skill by playing a character he/ she liked; this skill can be further improved by planning the game strategy. Obviously, different rewards which include some virtual trophies for the player's achievements, and available game content should be provided. A game should provide different challenges for a player with resist time constraints or gradually increasing difficulty of levels or locked context. A game should involve a player into competition with him/ herself or with other players. Also, it is very important for an appropriately implemented game that it has attractive design which includes graphics, sounds, and animations. In addition, an easy game access, immersive, novel and moderately difficult gameplay, and an ability to play in a team were recognized as additional attractions for children.

Moreover, after analysis of these features, it turned out that all of them correlate with psychological behavior theories mentioned in Chapter 2.

#### **3.3.2 Meeting with Children**

A meeting with a small group of children of the target age group regardless diabetes took place for discussing children's preferences in gaming, their game playing experience in general and features of the best game they would like to play if they could create a game themselves. Also a preliminary version of the application was demonstrated to see if it could attract the end-users audience and to collect additional requirements and wishes for improvements of the game. The discussion was in Norwegian since the target audience is Norwegian children with diabetes. The meeting was recorded for more convenient further analysis of the discussion. No personal data were used for research. The record was available only for the application's author and was removed after the record processing. Parents were notified about the meeting procedure (see Appendix 3).

All four children were girls; they were classmates. All of them had mobile phones and PCs; three of them had also a Play Station; and one had an iPad. They got their first phones when they were about 8 years old, but then they used it just to make calls. Right now they consider phones as "livs nødvendig" (vital), and spend a lot of time with them. According to them, nowadays, the most popular game (at least in their class and among their friends) is a game for mobile platforms, "QuizBattle", where a user should answer questions from different fields of knowledge. In addition, girls recognized more than a half of popular games posters which were prepared for them. It was noted that more often they play alone, but it would be nice to share their achievements in games with friends in popular social media, such as Instagram, Facebook, and different blogs.

Interviewers mentioned that they play games on mobile phones when they have time; and they would prefer to be able to finish the "mission" fast.

They thought that a game should be "artig og morsomt" (amusing and fun) and moderately difficult, give more freedom and choice, be close to reality to be played a lot. Also

they added that usually they played one or two months as maximum: after that it was becoming to be boring. Games with good graphics and bad sound were named as more preferable than games with bad graphics and good sound, because the sound could be always switched off, especially when it was on mobile phones and in public places. They said they did not like intrusive ads, unpredictable fails, and cruelty in games.

As ideas for a game children would be interested in, they actually described an avatar game where a player should take after a game character that had the same parameters, did the same physical activity, and ate the same.

For the DiaSpill game prototype, potential users suggested to create more levels and more equipment, to simplify the game control, and to make it possible for a user to choose characters and to change something in characters. Girls extremely liked the idea of use the points from the game for some prizes in real life.

After analysis of the discussion, the following conclusions were made: children extensively use mobile phones and are used to play games. Mini games are preferred by them. Also as an advantage, an ability to share the results with friends in social media can be indicated. Gameplay should be attractive, simply understandable, and interesting enough to immerse children, provide choice to a user, and have good graphics; in addition, the closer a game to reality the better.

The discussion plan is attached to Appendix 4.

### **3.3.3 Discussions with Experts in Diabetes**

As extra requirements sources, discussions with experts working with diabetes who were met on the 6<sup>th</sup> International Conference on Advanced Technologies & Treatments for Diabetes in Paris (France) were used. At the end of conversation, experts were asked to fill in the questionnaire about games as an educational tool for people, in particularly, for children with diabetes, and their opinions about the current development stage of the prototype and ideas for improvement.

All respondents considered serious games as a good means for education of people, especially children as such games pay more attention to disease management. Someone thought that age group is not so important when it deals with games, but most experts defined an age group which in their point of view suits better for diabetes-related self-management skills learning and motivated it by the meaning that age influences children's interests, so game complexity, content and design should be changed when children grow up. These distinguished age groups included children of 5-6, 6-12, 8-14 and 8-12 years old. The last age group was the same as for the current project; moreover, it was motivated with the same reasons. Children of this age are pre-teens, they are smart enough to learn self-management skills, but they are not teenagers who want to do whatever they want and do not obey their parents; therefore, educated pre-teens can get these skills as habits for their adult life.

Researchers' ideas about diabetes-related gameplay were as follows: include relations between nutrition and insulin, sports exercises and glucose level, frequency of being monitoring, glucose and insulin control.

As motivational game content, experts named: music, colors, simple, fun and competitive gameplay, rewards, social aspects (such sharing players' achievements in social networks, for example), positive feedback, and making children know how their decisions affect their health.

All the respondents liked presented screenshots of the game prototype, but some wishes about game design (such as to make it more colorful, more 3D-like) were taken into account in further game versions.

Most ideas and motivational game features suggested by experts were considered in the game version available at that time which was recognized as the game development process was moving in the appropriate way.

The questionnaire sample is available in Appendix 6.

### **3.3.4 Meetings with Doctors**

Several meetings with an endocrinologist (Arild Leknessund) and a nurse (Astrid Figenschou) from the University Hospital of North Norway (UNN) were held also for gathering the requirements and ideas to be implemented which could make the game appropriately used by children with diabetes. After each meeting, the application was improved and new features were added. During the last meeting, doctors were satisfied with the game prototype and allowed to test the game by children of the target group. Invitation letters for game testing were written by the project developers and sent by the nurse to parents of 8-12 years-old children with type 1 diabetes.

Among the suggested by doctors improvements were to simplify a presentation of carbohydrate amounts in food items, to make the game more understandable by children via changes in language (for example, “lavt blodsukker” instead of “hypoglykemi” and “høyt blodsukker” instead of “hyperglykemi”), to make the game more realistic (as it is in life: the more mass of food you eat the more insulin units are required to compensate the “damage”), to pay more attention for teaching children to understand interconnections in the chain “carbohydrate amount in food – result blood glucose level – insulin dose to be injected”.

### **3.3.5 Application Testing**

As an experimental method, testing of the application in the target audience took place.

Out of 18 potential users, only one contacted us for meeting and testing. Meetings took place at the Norwegian Centre for Integrated Care and Telemedicine (NST) after school/ work hours and were in Norwegian. Audio recording of the discussion was taken, then listened to only by the project’s developer, and removed after that. No names or other personal data were used.

The testing procedure was as follows. At the beginning the meeting, the main project features were explained. Then parents were asked to fill in a questionnaire about their children’s diabetes-related self-monitoring skills, and afterwards, they had a discussion with one of the researchers from the NST for a subsequent project they would start soon.

Meanwhile, we talked with a child about his game preferences and diabetes self-monitoring in general. Then different gameplay features, game rules, and how to play the game were explained by a researcher. Then the child got a chance to try the system and was left alone for playing the game for approximately 30 minutes.

In author’s opinion, a standard usability testing schema is hard to be applicable in such a new project type in a developing field of serious games. Therefore, after the testing, a questionnaire with some elements of a usability testing schema in combination with verbal questions was applied. Mostly we discussed child’s impression about the game to realize whether it meets children’s requirements and expectations, and whether children can learn something about diabetes and understand the disease better.

Questionnaires and a plan for a meeting are attached to Appendices 8-11B of the project.

## **3.4 Evaluation Methods**

To get feedback on whether the application suits the requirements and needs of the target audience and to collect user’s opinions, wishes and suggestions for improvement, which can be

used for further improvements of the application and in future projects, the game testing took place.

Analysis of the test results regarding answers to an interview which combined a usability-related questionnaire and verbal questions after the prototype testing was done by a qualitative method.

### **3.5 Critique of the Methods Used**

The main remark here, in author's opinion, is that it should be more meetings both in the beginning with potential users for deeper user-oriented implementation of the game prototype and in the end, for the prototype testing.

There are also other remarks. For example, on the first meeting with users for demonstrating the first Android prototype for its further improvements, only girls were presented. Have male meaning about the prototype, their game experience and game preferences is also very important. Moreover, this could lead to bias during the game prototype implementation.

And, as it was said before, since there was only one user who tested the game, the test results should not be considered as objective and convincing. For the same reason, a comparative method which was planned to be used in the case of more testers, as it is a good method to compare between groups (for example, boys and girls), was not applied.

Before we were allowed to test the game prototype, a long process of establishing contact with patients who are children with type 1 diabetes took place. That involved establishing contact with doctors in the hospital, planning and validation of interventions with patients together with the health personnel. Moreover, since we had not been given any contact information about potential users, we could not influence the process of the participants recruiting.

Despite it was said in invitation letters that a meeting might be arranged at any time after school/ work time and a meeting place could be changed, we did not get too many willing testers. As a result, we had three weeks of waiting until we got just one call from a parent of a child with type 1 diabetes.

Possibly, if longer time for recruitment of testers was allowed, more participants we would get and more objective results would be obtained. Also, if we had no strict time limitation, we could test the game during much longer period of time (at least, one-two weeks could be sufficiently enough).

And one more thing, which is concerned with reviews of relevant literature and games, should mentioned here. Since serious games are a growing field, more and more games have been developing. This means that if the review was conducted later, possibly additional game features applicable to the current project could be found.

### **3.6 Summary**

The following methods were used for this project:

- System design (engineering approach)
- Data collection
  - Literature review
  - Meeting with children
  - Discussions with experts and colleagues

- Meeting with doctors
- Experimentation
  - Questionnaires for parents and children
  - Game testing
  - Questionnaire and verbal questions for barn after testing
- Evaluation (qualitative method)

In this chapter, it is described how the project follows an engineering approach. Materials that are used in the project are also introduced. Further, there are an introduction to Android operating system which was selected as a target platform of the project, and an overview of C# programming language that was used for development. Data collection, experimentation and evaluation are also explained in this chapter. In addition, the critique of used methods is given in the end of the Chapter.

## Chapter 4

# Requirements Specification

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In this chapter, we define functional and non-functional requirements for the application. To work with functional requirements systematically, an event list and a UML Use Case diagram were created. Moreover, the Volere Requirements Specification Template (Robertson and Robertson, 2006) was applied for functional requirements specifications.

In addition, certain assumptions for the system in regard to existing components and data availability were made.

- All the data is stored in the internal memory of the user's mobile phone and is not transferred to any external storage.
- Regarding the protection of the user's sensitive information, we assume that is only the user (the owner) who has an access to the user's mobile phone and, therefore, authentication is not required. Moreover, since the target audience is children, this assumption is a fortiori demanded.
- Likewise, the operating system on the user's mobile phone is Android and the Few Touch Application (Årsand et al., 2012) is installed there.

### 4.1 Source of Requirements

Requirements are the mandatory needs for the system. Functional requirements are the fundamental subject matters of the system; they can be measured by concrete means like data values, decision making logic and algorithms (Robertson and Robertson, 2006). Non-functional requirements are the behavioral properties that the system must have, for example, performance, usability and others (Robertson and Robertson, 2006).

The main source of the non-functional requirements was the relevant literature and serious games which were reviewed in the State-of-the-art section of Chapter 2.

Most functional requirements were based on the previous software engineering experience of the author. Moreover, some requirements were based on advice given by colleagues at NST (Norwegian Centre for Integrated Care and Telemedicine) and experts met on the 6th International Conference on Advanced Technologies & Treatments for Diabetes in Paris who work with diabetes, and, in particular, with self-management for children with type 1 diabetes.

Likewise, the experts' suggestions and requirements of an endocrinologist and a nurse from the Children's Department of the University Hospital of North Norway (UNN) were considered. Moreover, some requirements were based on opinions and desires of children of the target audience's age group who are used to play games on PC, mobile phones, and other platforms, and children from the UNN register of children with diabetes. All the children could express what they wanted to have in the application to be more enjoyed and attracted to use it, while doctors provided the ideas to be implemented which could make the game appropriately used by children with diabetes.

### 4.2 Requirements

To figure out all the functional requirements for the project, likewise, the required functions in the application, two scenarios presenting possible problems of children with type 1 diabetes are given.

### 4.2.1 Scenarios

Per is 10 years old. He has type 1 diabetes. Recently during school classes, he began feel anxiety, palpitations, sweating, and sometimes even headaches; also he noticed heightened hunger. Per and his mother went to the doctor. When the doctor measured Per's blood glucose, it was 3.8 mmol/l. Doctor said it was too low. Now Per has to monitor his glucose thoroughly to avoid troubles, as Doctor said. Therefore, Per measures blood glucose before and after meal, even when he is at school. Sometimes his classmates look at him queerly. He hesitates to measure blood glucose and eat only special food for diabetics which his mother gave him for school lunch.

In Per's class, there is one girl who also has type 1 diabetes. Her name is Kari, and she is also 10. Sometimes Per noticed her injecting insulin when there was nobody in the class. When Per and Kari talked last time, she complained about bad sleeping, thirst, and weight loss. She added that her blood glucose was at the 7.5 mmol/l level and called it "hyperglycemia".

From these scenarios, we could conclude that both children need a tool which will help them live a life full of interesting events, give a new exciting topic to be discussed with peers, and, at the same time, teach them self-management skills which will be useful during the whole life. Therefore, children with diabetes need a tool which is

- up-to-date, used by peers, and therefore, able to improve communications with coevals, and
- able to teach them diabetes self-management skills, but not in a form of school lessons.

### 4.2.2 Required Behaviors

To have children motivated to adhere to treatment regimens, with basic self-management skills, such behaviors are required:

- a) Anyway, children should measure their blood glucose to control it;
- b) Children should get information about a lifestyle of patients with diabetes and follow the doctors' prescriptions, and hereby, learn the skills required for good diabetes self-management;
- c) The skill learning process should be interesting and attractive for children to make them really concerned in the progress.

### 4.2.3 Functional Requirements

Based on scenarios above, main features for the application were defined.

A. Provide a tool which promotes basic knowledge about diabetes and helps children to learn basic self-management skills.
---

Since usual educational programs seem boring to children and sometimes hard to understand, and, therefore, are bad-to-remember and bad-to-reproduce, a game was chosen as a mean which combines education and edutainment at the same time.

B. Get an access to the blood glucose measurements database in the Few Touch Application.
---

For children's motivation for monitoring their blood glucose, we can directly use blood glucose measurements data from the Few Touch Application in our application.

## Event Listing and Use Cases

We created an event list (Table 2) to work with functional requirements systematically. It includes all the events in the system and input and output for each event.

Table 2. Event list

#	Event name	Input/Output	Summary
1	Measure blood glucose	<b>In:</b> BG measurements <b>Out:</b> collection of BG data	The user measures his/ her BG. These measurements are stored in the FTA BG database for further use in the game.
2	Enter the application	<b>In:</b> application icon is pushed <b>Out:</b> access to the game content	The user opens the application, and gets the access to the game content.
3	Register in the game	<b>In:</b> user's information <b>Out:</b> access to the game content	If it is the first use of the application, the user fills in some information about him/ herself. Then he/ she gets the access to the game.
4	Play the game	<b>In:</b> pushed the game button <b>Out:</b> provided gameplay	The user pushes the button to play the game and follow the provided gameplay.
5	Get points and rewards	<b>In:</b> played game <b>Out:</b> points and rewards regard the achievements	The user plays the game and afterwards gets points and rewards.
6	Get feedback	<b>In:</b> played game <b>Out:</b> application's gameplay	The user plays the game and gets feedback messages from the system.
7	Get knowledge	<b>In:</b> gameplay and feedback <b>Out:</b> knowledge and skills	The user learns from the game.
8	Exit the application	<b>In:</b> "Exit" button is pushed <b>Out:</b> application is closed	The user pushes "Ut" ("Exit") button and after a while the DiaSpill application is closed.
9	Launch the application	<b>In:</b> saved user's parameters <b>Out:</b> access to game content	The system extracts the user's data from the database and provides the access to the game content for the user.
10	Create a new user's account	<b>In:</b> user's parameters <b>Out:</b> game content	The system loads the game content considering the saved user's parameters. If there are no data in the database about the user, the system redirects the user to the registration page where the required information can be gathered.
11	Access the FTA BG database	<b>In:</b> BG measurements in database <b>Out:</b> further use of BG data by DiaSpill	The system opens the connection to FTA BG database, work with these data, releases the connection.
12	Use the user's BG measurements in the application	<b>In:</b> user's BG measurements <b>Out:</b> gameplay	The system embeds the user's personal BG data into the gameplay.
13	Provide the game	<b>In:</b> saved user's parameters and data about the user's BG measurements <b>Out:</b> appropriate gameplay	The system extracts the user's data from the database and provides the gameplay considering this.
14	Provide the attractive gameplay	<b>In:</b> game features and user's real data <b>Out:</b> user attracted by the game	The system is designed considering the attractive for children features and uses the user's real data about blood glucose level.
15	Provide feedback	<b>In:</b> played game <b>Out:</b> points and rewards, feedback messages	The system reflects the user's game playing.
16	Charge points and rewards	<b>In:</b> played game <b>Out:</b> points and rewards for the user	The system calculates points and awards rewards considering the user's game achievements.

17	Provide knowledge	<b>In:</b> user's playing <b>Out:</b> knowledge via gameplay, questions, feedback messages	The system teaches the user.
18	Switch off the application	<b>In:</b> user's forced exit <b>Out:</b> closed connections, released phone memory	The system closes all the connections if they were opened, close the application with the phone memory release.
19	Save the user's parameters	<b>In:</b> current user's parameters <b>Out:</b> parameters saved into the database	The system saves the user's parameters into the DiaSpill database.

An actor is a role that a user (or another system) plays in a system (Scott, 2004). According to the event list, two actors within the developed application can be identified: the user with Android smartphone with installed the Few Touch Application and the DiaSpill on it (further called User), and the system which is the DiaSpill as a whole system (further called System).

A use case is a sequence of actions performed by an actor within the system boundaries which leads to a certain, measurable result (Scott, 2004). The events in the list above correspond to the use cases within the system.

For the graphical representation of these use cases and connections between them, a UML use case diagram (Figure 19) was created by means of a trial version of the Enterprise Architect v.10.0, SPARX Systems©<sup>57</sup>.

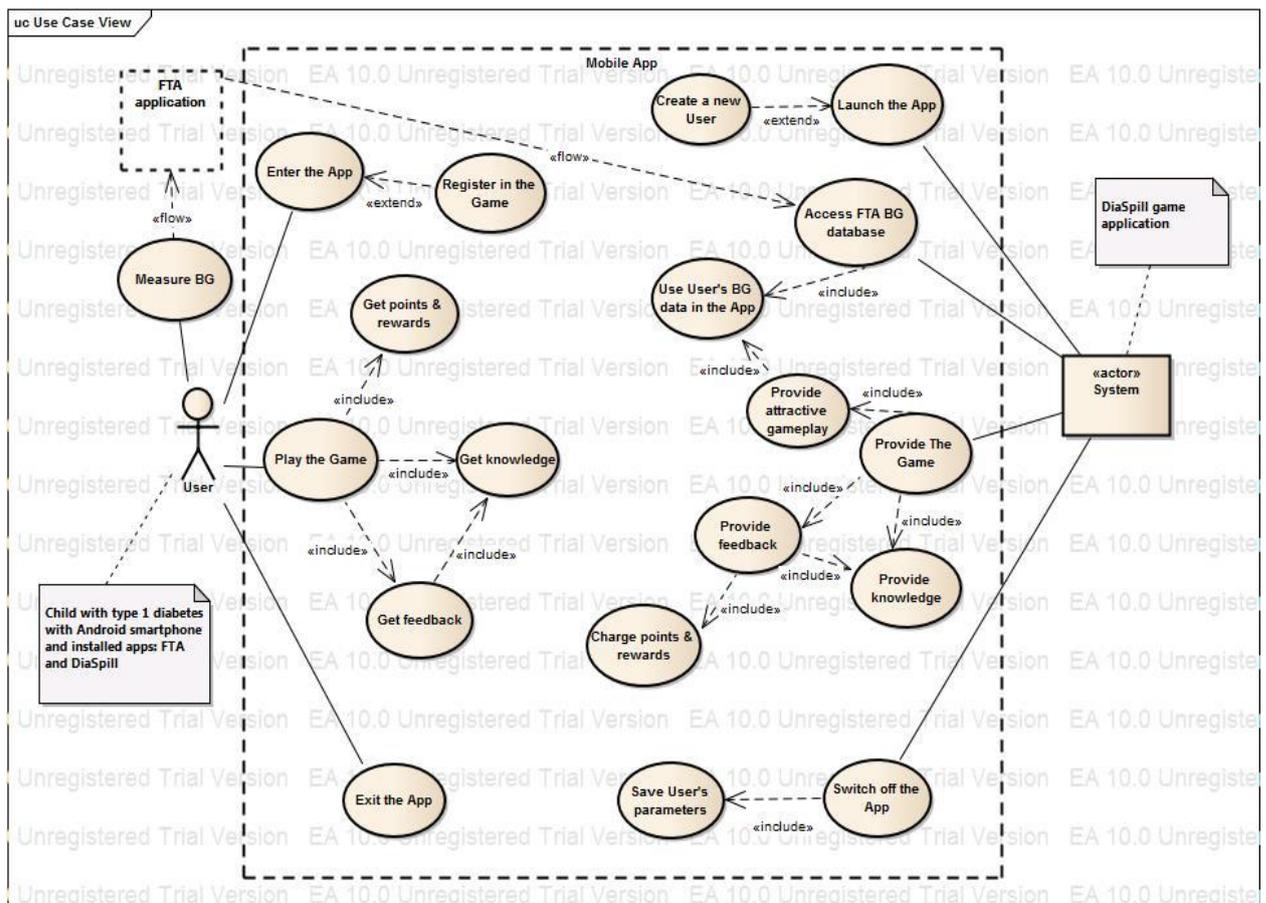


Figure 19. UML Use Case diagram

<sup>57</sup> Enterprise Architect website <http://www.sparxsystems.com/products/ea/trial.html> [Accessed 12.06.2013]

On the use case diagram, some use cases are visualized by “extend” and “include” arrows. While “extend” means special cases of the “main” use case, “included” use cases are implied in the “main” one.

All the use cases are described in details below.

Use case 1: Measure blood glucose level (Actor: User)

*A. Ordinary glucometer*

1. Open the FTA application.
2. Measure blood glucose.
3. Register the BG measurement in the FTA database manually.

*B. In the case of the Bluetooth connected glucometer*

1. Measure blood glucose.
2. The BG measurement is automatically registered in the FTA database.

Use case 2: Enter the application (Actor: User)

1. Click the DiaSpill icon on the mobile desktop.
2. Get an access to the application content.

Use case 3: Register in the game (Actor: User)

If it is the first use of the application,

1. On the registration page, enter registration information.
2. Make other user settings.
3. Click the “OK” button.

Use case 4: Play the game (Actor: User)

1. Click the “Play!” (“Spill!”) button.
2. Follow the game scenario.

Use case 5: Get points and rewards (Actor: User)

1. Regard the game achievements, get rewards and points.
2. Use the points in the game.

Use case 6: Get feedback (Actor: User)

1. Get feedback messages from the game about the game progress.

Use case 7: Get knowledge (Actor: User)

1. Learn from the gameplay.
2. Learn from the game feedback.

Use case 8: Exit the application (Actor: User)

1. Click the “Exit” (“Ut”) button.
2. Exit.

Use case 9: Launch the application (Actor: System)

1. Load user’s data from the application database.
2. If there is no data in the database, redirect to the registration page.
3. Provide an access to gameplay.

Use case 10: Create a new user (Actor: System)

If it is the first time when the application is used after installation,

1. Show the registration page.
2. Save the User's parameters after the registration is finished.

Use case 11: Access the Few Touch Application blood glucose database (Actor: System)

1. Connect to the FTA blood glucose database.
2. Work with the data.
3. Release the connection to FTA blood glucose database.

Use case 12: Use the User's blood glucose date in the application (Actor: System)

1. Get the latest data about the User's BG measurements.
2. Embed it into the gameplay.

Use case 13: Provide the game (Actor: System)

1. Load the game content regard the user's parameters.

Use case 14: Provide an attractive gameplay (Actor: System)

1. Load the gameplay considering the User's BG data.
2. Use the game features found out in the "state-of-the-art" part of the project.

Use case 15: Provide feedback (Actor: System)

1. Show immediate feedback in the game.
2. Provide the follow-up feedback.

Use case 16: Charge points and rewards (Actor: System)

1. Calculate points and rewards regard the User's achievements in the game.

Use case 17: Provide knowledge (Actor: System)

1. Give the basic knowledge to the User via the gameplay.

Use case 18: Switch off the application (Actor: System)

1. Use case 19.
2. Close the application.

Use case 19: Save the User's parameters to the database (Actor: System)

1. Push the accumulated data into the application database.

The use cases for both actors, the User and the System, are interconnected. Therefore, the requirements for some use cases are likely overlapped.

All the functional requirements for the System actor identified in the application were documented in accordance with the Volere© requirements specification template (Robertson and Robertson, 2006) (see Figure 20).

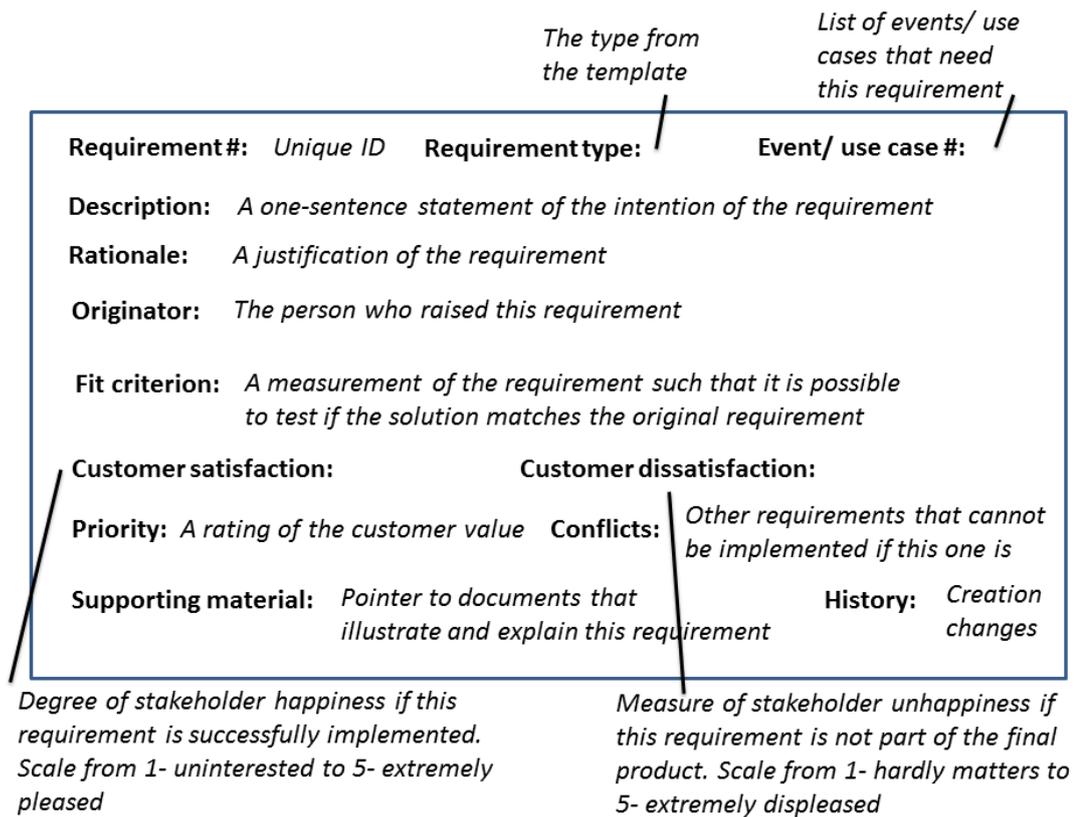


Figure 20. Requirement shell. Source (Robertson and Robertson, 2006)

In Table 3, all functional requirements are described in details.

Table 3. Functional requirements specification

# UC	Use Case	Conn. UC (#)	# Req	Req. Description	Purpose	Source	Fit criteria	User satisfaction	User dissatisfaction	Priority	Depend (# Req)	Conflict (# Req)	Support Mat.	History
9	Launch the application	2	1	The system should be able to launch the application	The user is able to use the application	author	The user has an access to game content	5	5	1				october 2012
10	Create a new user's account	3	2	The system should be able to create a new user's account on start of the game	Provide the game specially for this user	author	The registration page is displayed. The user's registration data is in the database	5	3	2	1			october 2012
11	Access the FTA BG database	1	3	The system should be able to connect the FTA BG database	Interaction with the FTA application. For further usage of the BG data by the DiaSpill	author	The DiaSpill has found the database file and opened it	3	3	3	1			october 2012
			4	The system should be able to work with the data from the FTA BG database without data corruption		author	Integrity of BG data in database	3	3	3	1, 3			october 2012
			5	The system should be able to release the connection with the FTA BG database		author	No connection with the FTA database	3	3	3	1, 3			october 2012
12	Use the user's BG measurements in the application	4	6	The system should be able to use user's blood glucose measurements data in the gameplay	Increased user's motivation	author, experts, colleagues	The system is able to apply algorithms to the BG data	3	3	3	4			december 2012
13	Provide the game	4, 5	7	The system should be able to support at least Norwegian language, but English and Norwegian are desirable	Localization of the application. Children can play the game on their mother tongue.	author, colleagues	Gameplay and other stuff in the game are displayed on chosen language	5	4	1	1, 19			october 2012

			8	The system should be able to extract data from the DiaSpill database	Provide the gameplay based on the saved user's parameters	author	Gameplay is given considering the latest game settings	4	4	2	19			october 2012
			9	The system should be understandable for children	To teach children, the educational material should be simple to understand	reviewed literature	The game content is adapted for children	5	4	1			state-of-the-art	october 2012
14	Provide the attractive gameplay	4, 5, 6	10	The system should provide choice	Children's higher intrinsic motivation	reviewed literature	The user has choice in the gameplay	4	4	2	1		state-of-the-art	october 2012
			11	The system should provide moderately difficult gameplay	For gradual skills development	reviewed literature	Despite the gameplay considers the user's BG data and reflects the user's progress, it is easy to be mastered by children	5	4	1	9		state-of-the-art	october 2012
			12	The system should provide the gradually growing game complexity	Promote user's skills improvement in goal setting and goal review	reviewed literature	The levels difficulty grows from the 1st level to the final one. The further the user is, the more game content is available	5	3	2	9		state-of-the-art	october 2012
			13	The system should provide an empathetically related character and backstory	Children's higher intrinsic motivation	reviewed literature	The choice of character is provided. Interesting backstory	4	4	2			state-of-the-art	october 2012

15	Provide feedback	6	14	The system should provide feedback about the game flow	Inform user about the game flow. Educate users	colleagues experts	Feedback is provided in the form of rewards, points, bearing-up messages	4	4	2	15			december 2012
16	Charge points and rewards	5, 6	15	The system should provide rewards considering user's achievements	Children's higher intrinsic motivation	reviewed literature, experts	Rewards are performed in a form of trophies and unlocked game content	4	5	1			state-of-the-art	october 2012
17	Provide knowledge	7	16	The system should provide basic knowledge about diabetes	Educate users	author	Informative messages about diabetes are contained in the game	5	4	1	14			october 2012
			17	The system should teach a user to understand the interconnections within the chain "carbohydrate in food – blood glucose level – insulin to be injected"	Promote user's skills development	UNN doctors	This chain is seamlessly embedded into the gameplay	4	4	2				februar 2013
18	Switch off the application	8	18	The system should be able to switch off the application.	Close the application	author	Mobile phone memory allocated for the game is released	5	5	1	1, 19			october 2012
19	Save the user's parameters	3, 4, 8	19	The system should be able to store game-related user's parameters in the DiaSpill database.	Provide an appropriate gameplay	author	The user's parameters are stored in the database	5	4	1				october 2012

Hereby, the application has functional requirements as follows.

- The system should be able to launch the application.
- The system should be able to create a new user's account on start of the game.
- The system should be able to connect the FTA BG database.
- The system should be able to work with the data from the FTA BG database without data corruption.
- The system should be able to release the connection with the FTA BG database.
- The system should be able to use user's blood glucose measurements data in the gameplay.
- The system should be able to support at least Norwegian language since the game is for Norwegian children, but two languages (English and Norwegian) are expected.
- The system should be able to store game-related user-sensitive data in the DiaSpill database.
- The system should be able to extract data from the DiaSpill database.
- The system should be understandable for children.
- The system should provide choice (for higher intrinsic motivation).
- The system should provide moderately difficult gameplay considering the data about user's blood glucose measurements and reflecting the user's progress (for gradual skills development).
- The system should provide the gradually growing game complexity to promote the user's strategy planning (to promote user's skills improvement in goal setting and goal review).
- The system should provide feedback about the game flow in the form of rewards, points, bearing-up messages.
- The system should provide rewards (in a form of trophies and unlocked game content) considering user's achievements (that can be seen as intrinsic rewards).
- The system should provide an empathetically related character and backstory (to promote user's intrinsic motivation to play).
- The system should provide basic diabetes-related knowledge.
- The system should teach a user to understand the interconnections within the chain "carbohydrate amount in food – result blood glucose level – insulin dose to be injected".
- The system should be able to switch off the application.

#### **4.2.4 Non-Functional Requirements**

One of the main factors influencing all the non-functional requirements is the target audience. We implement an educationally-entertaining tool for self-management skills development for 8-12 years old children.

##### *Appearance*

Despite the prototype does not have any strict requirements for graphical user interfaces, it should have a user-friendly and attractive for children design which includes graphics, animations, sounds for tasks and rewards.

##### *Usability*

We should develop a positive experienced game in order not to make users experience failure or frustration. Therefore, we should provide some kind of support to solve possible problems during game playing. The game should be self-paced for individual self-management skills development, thus, the gameplay should be intermediately difficult (at all game levels) to

be played independently. Moreover, for durable adoption and gradual progress of skills development, the application should consider the conclusions (in particular, principles for game design and additional attractions for children) from the reviewed literature and the psychological theoretical frameworks described in Chapter 2.

### *Security*

A mobile phone is considered to be private and personal. One of our assumptions states that a smartphone is used only by its owner. This is important because health-related data is personal and, therefore, confidential. But at the same time, an authentication of the user on every game launch can considerably reduce the tool usability, particularly considering the application target audience.

### *Legality*

Legal issues are also quite important. We should not transmit any personal data over non-secure channels without proper authorization. The Few Touch Application is assumed to be installed on the same mobile phone as the DiaSpill application. The FTA makes backup of the app database approximately every ten minutes and stores it in the phone internal storage. The DiaSpill application communicates with the FTA database backup for further use of data about the user's blood glucose measurements. Hereby, the prototype does not need transmitting the user-sensitive data of any form outside the phone.

The application is not expected to be risky or harmful to potential users. However, any experiments may not be done on real patients.

## **4.3 Summary**

This chapter uses the Volere© requirements specification template to describe the functional requirements for the application. Most requirements were obtained from the author's previous software engineering experience. Advice from experts, colleagues, doctors and children of the target age group served also as a source for requirements. Scenarios are presented to explain the main features of the application better.

Measuring blood glucose by children and getting the information about diabetics' lifestyle and following the doctors' prescriptions, and, hereby, learning self-management skills were identified as required behaviors. Based on the required behaviors, a detailed event list and a use case diagram were created. The Chapter concludes with discussion of non-functional requirements, which should be met by the application and the reasons for them.

## Chapter 5

### Design

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This chapter describes a history of the project design process. Here, it is explained how the theoretical background has been applied to the game design. Further, a game scenario and the most important game content parts are discussed in details. Lastly, the chapter describes the project development process. Improvements from the very first paper prototype to the final Android-based version are based on the requirements and suggestions from the meetings with the target audience, doctors, and experts in diabetes.

#### 5.1 Game Title and Logo

The application title can be also considered as a part of the design process. The game was named “DiaSpill” being an acronym for “Spillet til barn med diabetes om diabetes” (“The game for children with diabetes about diabetes”). The title was created by the application author.

An icon (logo) for the game was also created by the project author (Figure 21).



Figure 21. The game icon

It was inspired by the logo of the Few Touch Application (see Figure 22).



Figure 22. The Few Touch Application icon

The blue circle here is the universal symbol for diabetes which is aimed to give diabetes a common identity<sup>58</sup>. Green color expresses blood glucose values within a normal range; red is hypoglycemia (too low blood glucose level), and yellow color represents hyperglycemia, or too high blood glucose values.

Sounds and images used in the application were found in the Internet. Some images were additionally processed with the online photo editor, Pixlr<sup>59</sup>.

#### 5.2 Identified Game Features as a Basis for Application Design

The application design considers the results of the review of relevant literature and games in the “State-of-the-art” part of the thesis, theoretical background (psychological behavioral principles) in Chapter 2, and non-functional requirements identified in Chapter 4.

First of all, if we talk about the game appearance, we should provide a user-friendly and attractive for children design which includes graphics, animations, sounds as feedback for tasks and rewards.

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<sup>58</sup> Diabetes Blue Circle web site <http://www.diabetesbluecircle.org/> [Accessed 12.06.2013]

<sup>59</sup> Pixlr. Photo editing services <http://pixlr.com/editor/> [Accessed 12.06.2013]

Also, as we need to provide a tool which promotes knowledge and helps users to learn certain skills, these requirements should be also considered in a game design. We need to embed an educational content which is accomplished by positive feedback, rewards, choices for user's feeling of personal autonomy, and different challenges with gradually increasing difficulty of levels.

Moreover, the game should have an interesting backstory with a character empathetically related to a player, understandable gameplay, and an immersive scenario, which, in addition, makes a player to be aware of how his/ her decisions affect the subsequent game scenario.

### **5.3 Game Scenario**

In the beginning, a player specifies some information about him/ herself and chooses a character he/ she wants to play in the game. Then, he/ she gets a notification message as a call for help.

The game backstory is as follows. The Evil Cake tribe with its leader, Super Boss, has attacked our planet. They would like to make all people fat. They even have stolen the main character's friends. Therefore, a player's help is required. All people hope a player can help get rid of the Evil Cakes. He/ she has to fight against the tribe to free his/ her friends and the rest of the world.

When a player agrees to help, the game is started.

There are several levels where a character fights against the "enemies". The levels have an increasing difficulty and are distinguished by a number and types of enemies on each level. The game character has type 1 diabetes. The main mission of a player while playing a game is to monitor the character's blood glucose level via the glucometer available on the screen. During the game a player runs, jumps on blocks, throws Coke bottles against enemies, collects insulin pens (as an antidote to high blood glucose level) and orange juice boxes (missiles against Super Boss in the final). On each level, a player resists sweets, cupcakes, French fries, and other invaders which can increase the character's blood glucose level. A player can regulate the character's blood glucose by using insulin pens collected on each level, and healthy food (fruits, vegetables, etc.) and sports equipment bought in the game Shop.

On the final level, a character fights against SuperBoss. Since SuperBoss is very strong and dangerous, to win in the game a player should have a big collection of extra power: orange juice boxes, insulin pens, healthy food, and sports equipment.

### **5.4 Game Content**

In the following sections, details about the various game content features are given.

#### **5.4.1 Game Start**

There are two possible situations for the game start. It depends on whether it is the first use of the game after its installation or not.

1. If it is the first time of the game use, then, first of all, since the game is available in two languages, a choice between English and Norwegian languages is given to a player (Figure 23).

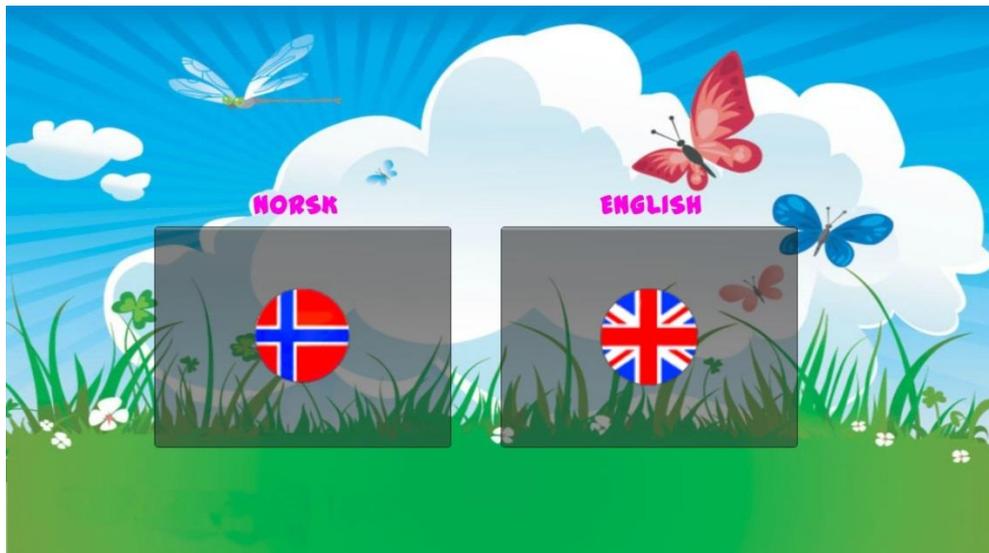


Figure 23. Language choice in the game

Then, a user specifies certain information about him/ her. In particular, user's gender, name, age and height should be written (see Figure 24).

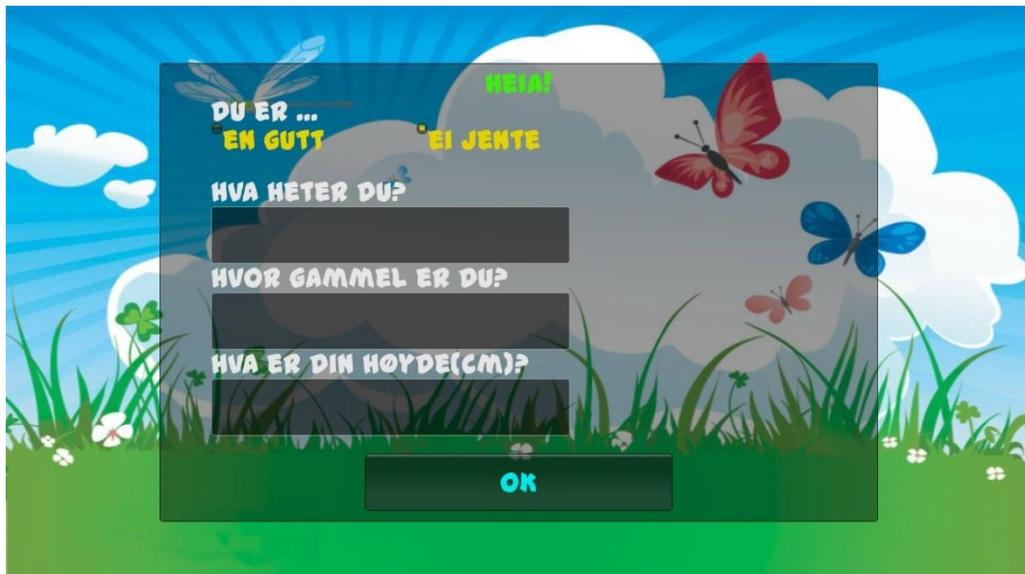


Figure 24. Registration of a new user in the game

Next, we show the story about the planet's invasion by the Evil Cake tribe and the need for a player's help (see Figure 25).



Figure 25. The game backstory

Then, a user can choose a character out of ten alternatives in regard to a specified gender (see Figure 26).

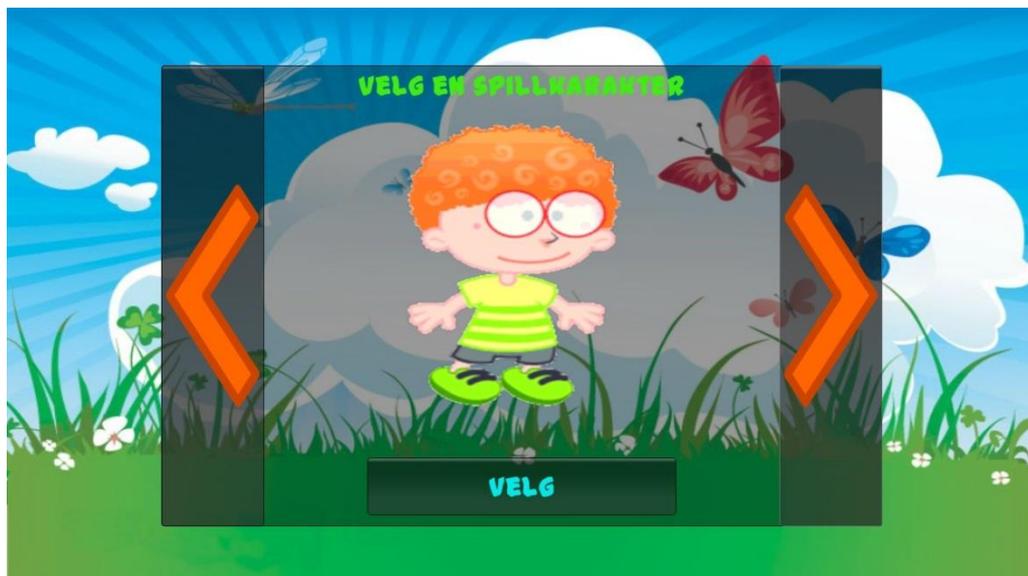


Figure 26. Character choice in the game

Then, the main menu page is available for a player.

2. If a player is registered in the game, then the first page with buttons “Spill!” (“Play!”) and “Ut!” (“Quit!”), greeting words, and a disclaimer on the top of the page is shown to him/ her (see Figure 27). Also, a gameplay language can be changed on this page.



Figure 27. The first page of the game

The disclaimer says: “This game uses the player’s own data from the Few Touch Application to make it as realistic as possible, and to increase training effectiveness. Nevertheless, it is NOT recommended to do the same in the real life as in the game!”.

When the “Spill!” (“Play!”) button has been pressed, the main menu page is available for a user.

#### 5.4.2 Main Menu

When a user is on the main menu page, several alternatives for subsequent actions in the game are available (see Figure 28).



Figure 28. The main menu page of the game

First of all, a user observes the progress scale on the bottom of the page. To get higher percentage here, a player needs to control his/ her blood glucose. This includes a certain number of measurements during a day, an interval between measurements, and measurements regularity. Depending on these parameters, a player gets one, two or three stars for his/ her progress during a day. In addition, he/ she gets different comments about the progress.

After clicking on the button with a question mark, a player can read the game rules (Figure 29) which include tips on how to move a character in the game and how a player can progress and get different points during the game.



Figure 29. The game rules

Also, a user can go to the game Shop (see Figure 30). There is some information about each available item there.

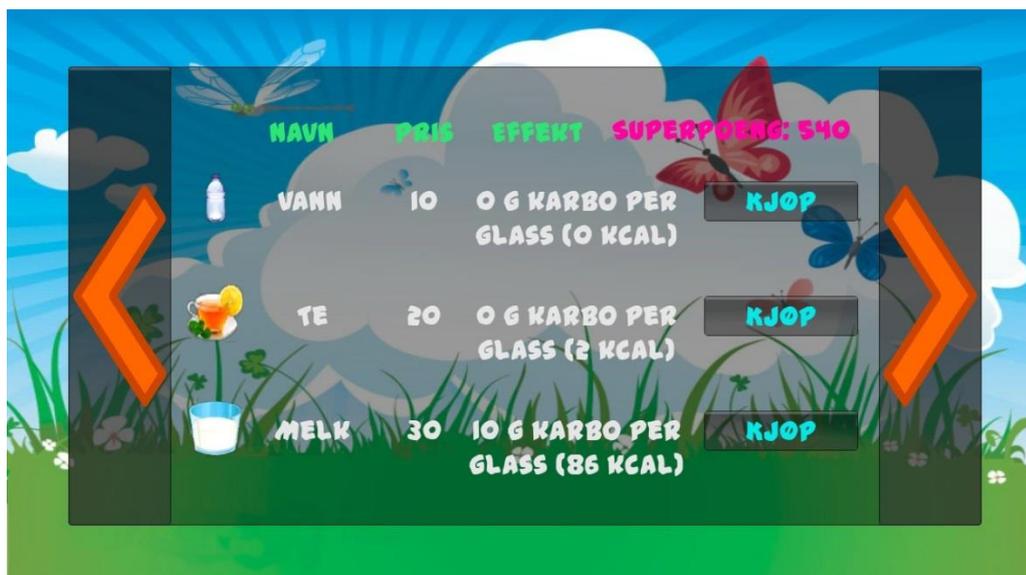


Figure 30. Shop in the game

When a player has bought something, he/ she will find this in his/ her backpack (Figure 31). Any item can be used in the game.

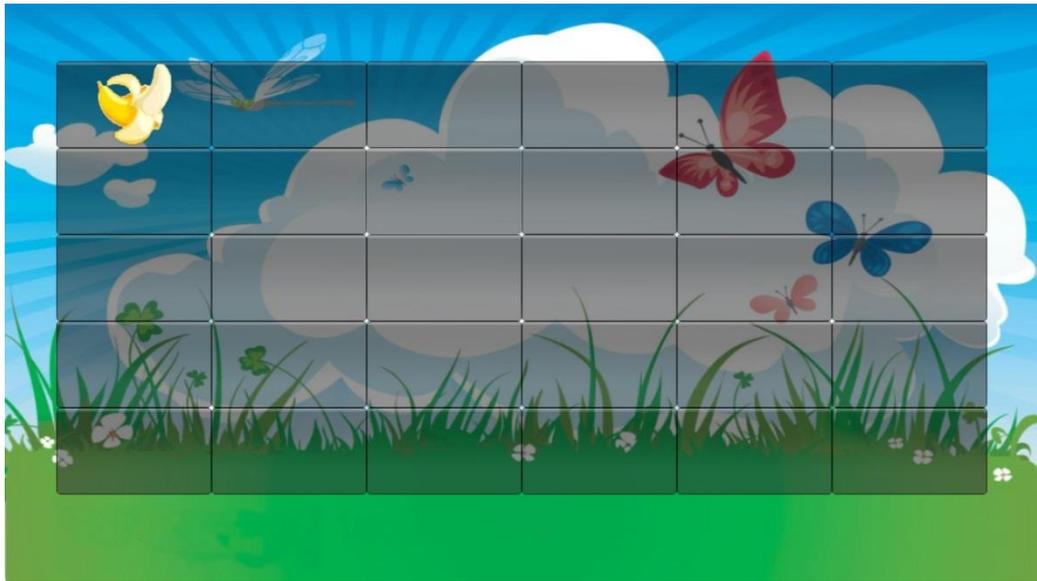


Figure 31. Backpack: bought equipment items

Moreover, a player can take a look at real-life bonuses and get some of them if he/ she has earned enough Goldpoints (Figure 32).



Figure 32. Goldpoints menu

The left top icon is the Levels menu (see Figure 33). Here a player can choose a level to play. Information about last score and record score on each level is also available on this page.

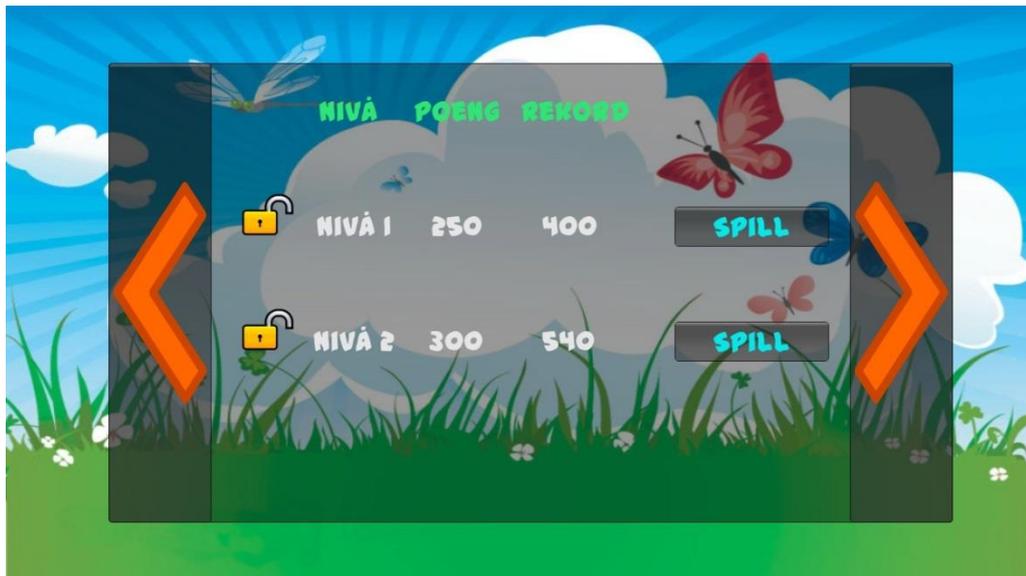


Figure 33. Levels menu

Finally, after completing some level, a user can see the rewards he/ she has been awarded for the game achievements (Figure 34). Rewards (cups and medals) are given for user's achievements on each level and for the whole game.

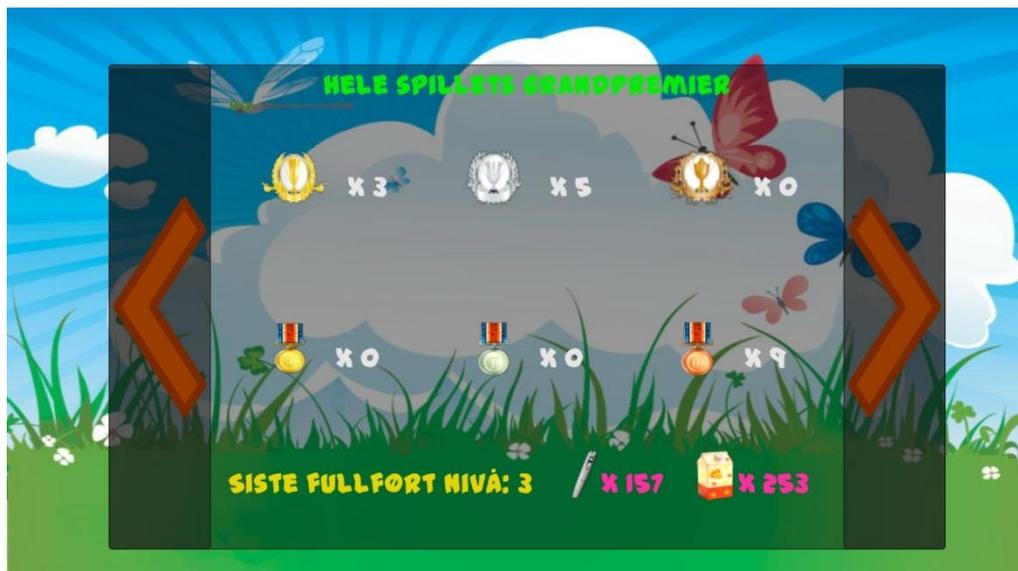


Figure 34. Rewards menu

More details about user's various rewards in the game are given in the "Rewards" section of this Chapter.

### 5.4.3 Levels

There are eight levels in the current version of the game. A player is not able to play the next level before lower levels are not completed.

When it is the first time of the game use, only the first level is available in the Levels menu to be played (Figure 35). After each level is finished, a next level can be played. Otherwise, levels are locked.

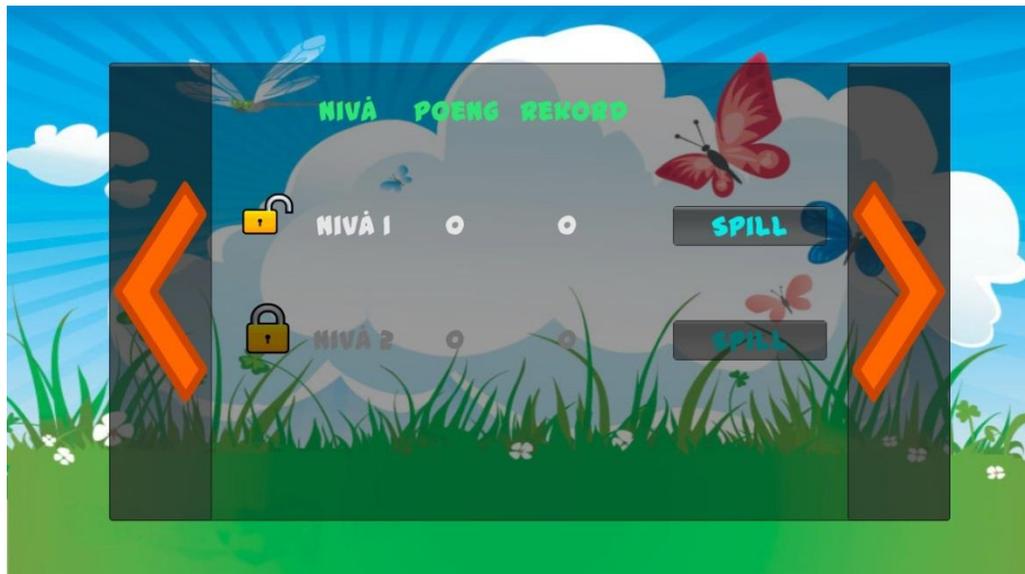


Figure 35. The first level is available after registration

A character has type 1 diabetes. In the beginning of each level, the user's blood glucose level value from the last measurement registered in the database is considered as a character's blood glucose level. If there is a lack of measurements during the current day, a level starts with 5.5 mmol/l blood glucose level.

In the first seven levels, a character fights against various enemies: cupcakes, French fires, lollipops, pizzas and others.

During each level (Figure 36), a character should go to the finish sign, collecting orange juice boxes and insulin pens. But on his/ her way to the finish, there are obstacles: blocks which a character should jump over and enemies which can raise a character's blood glucose level. Thus, he/ she should run, jump, and throw the missiles into the invaders. Every time a character hits enemies, a player gets some points.

On the bottom of the screen, there are icons of available equipment. To use them, a player just clicks on the icon of the item he/ she wants to use.

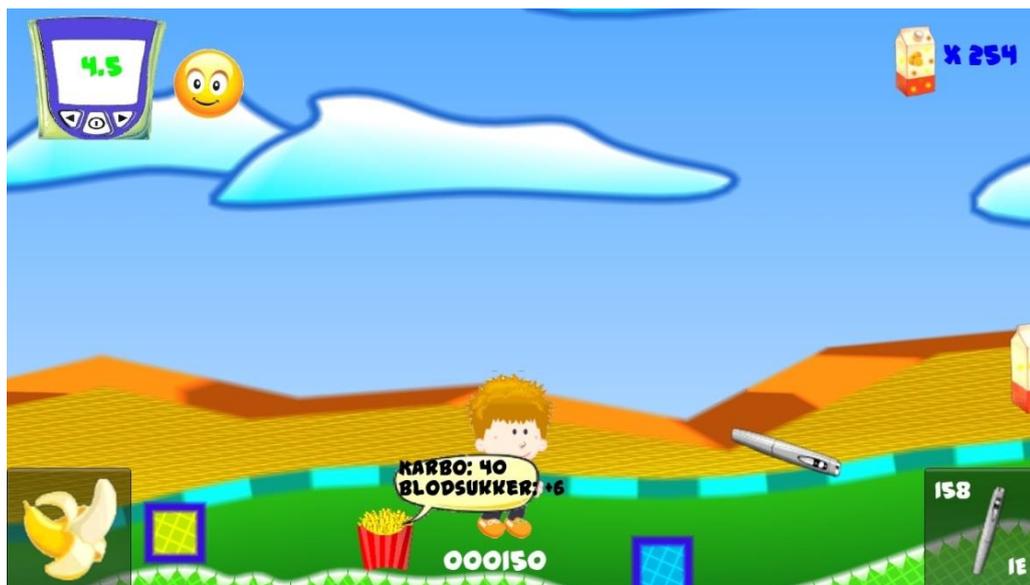


Figure 36. Level gameplay

For healthy and unhealthy food and sports activities in the game, the data amount carbohydrate amounts in food items and burnt calories while different physical activity from

reliable sources<sup>34,60</sup> were used (see Table 4). Being aware of the fact that 1 g of carbohydrate is 4 kcal<sup>61</sup> and using data about calories for each physical activity, we can calculate amounts of carbohydrates which could be expended by these physical activities during a certain period of time. In our case, we used 15 minutes trainings.

Table 4. Carbohydrate content in different food items and sports activities

Item	Carbohydrate per 100 g	Mass (in g)/ duration (in min)	Carbohydrate consumed/ expended	Kcal per portion/ time period
water	0	200	0	0
tea	0	200	0	2
milk	4,7	200	9,4	86
apple	10,6	200	21,2	98
anasanas	10,1	50	5,1	12
banana	18,1	180	32,6	150
paprika	4,7	130	4,7	39
carrot	6,7	150	6,7	44
cabbage	0,9	100	0,9	19
cheese	0	50	0	70
fish (codfish)	0	100	0	82
meat (beef)	9,9	100	9,9	170
skiing	9	15	33,8	135
skating	4	15	15	60
snowboarding	8,3	15	31,1	125
jogging	8	15	30	120
bicycling	6,6	15	24,8	99
ice cream	26,9	80	21,5	163
french fries	39,8	100	39,8	330
candy	78	10	7,8	33
burger	12,6	250	18,9	505
cupcake	43,8	80	35,1	321
pizza	25,6	150	30,7	290
orange juice	9,6	200	19,2	86
hot dog	51,4	150	51,4	459
cake	29,4	200	58,2	626
pop corn	50,7	20	10,1	83

In the case of too high blood glucose level, a character experiences hyperglycemia symptoms: lower character's movement speed, the message about the thirsty character, flashing glucometer, yellow blood glucose level digits on the glucometer, and blinking drinks and insulin pen icons (see Figure 37).

<sup>60</sup> Hudeemvmeste.ru web site. A table of physical activity and calories expenditure (in Russian)

<http://www.hudeemvmeste.ru/aktivnost.htm> [Accessed 12.06.2013]

<sup>61</sup>Prime Fitness Consulting. Calories calculation <http://primefc.ru/categories/dietology/110-pravilnoe-kolichestvo-kalorij-raschet.html> [Accessed 12.06.2013]

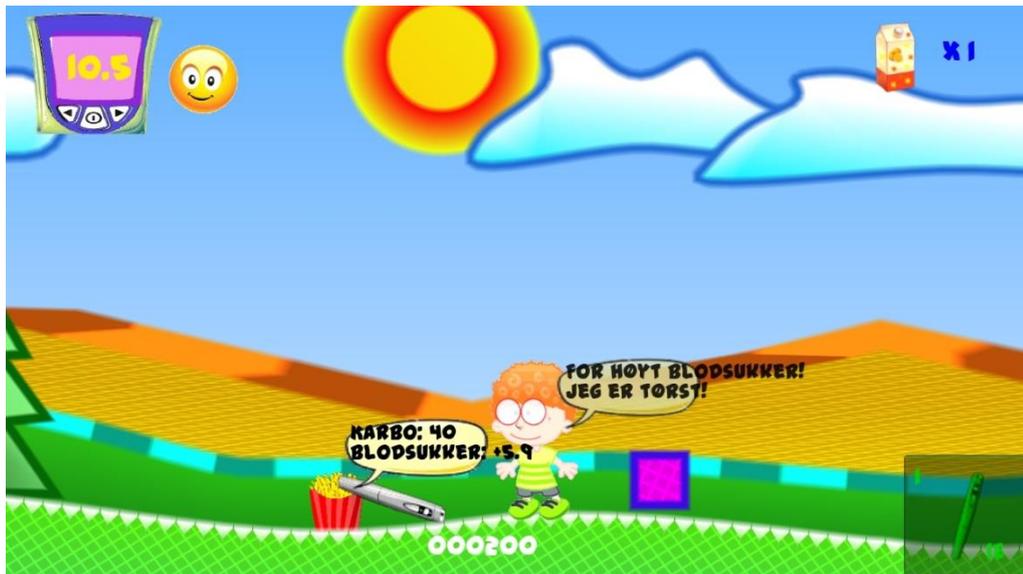


Figure 37. Hyperglycemia symptoms in the game

Or, if the blood glucose level is too low, then a character gets tremor, the message about the hungry character, flashing glucometer, red blood glucose level digits on the glucometer, and blinking healthy food items icons (Figure 38).



Figure 38. Hypoglycemia symptoms in the game (version 7)

Since hypoglycemia is a more severe condition in the real life because of various serious long-term effects, it is penalized stricter than hyperglycemia in the game. In the case when a character has got too often hypoglycemia (5 times) or hyperglycemia (8 times), a player gets a penalty: he/ she is able to play the level previous to the level he/ she has just completed.

After the level is finished, a user gets a question about diabetes to answer (Figure 39).



Figure 39. A diabetes-related question

Then, a window with the level results is shown to a player (Figure 40).



Figure 40. Level results

In regard to the level achievements, which include score and collected orange juice boxes, a player is awarded with a gold/ silver/ bronze cup and a gold/ silver/ bronze medal (Figure 41).

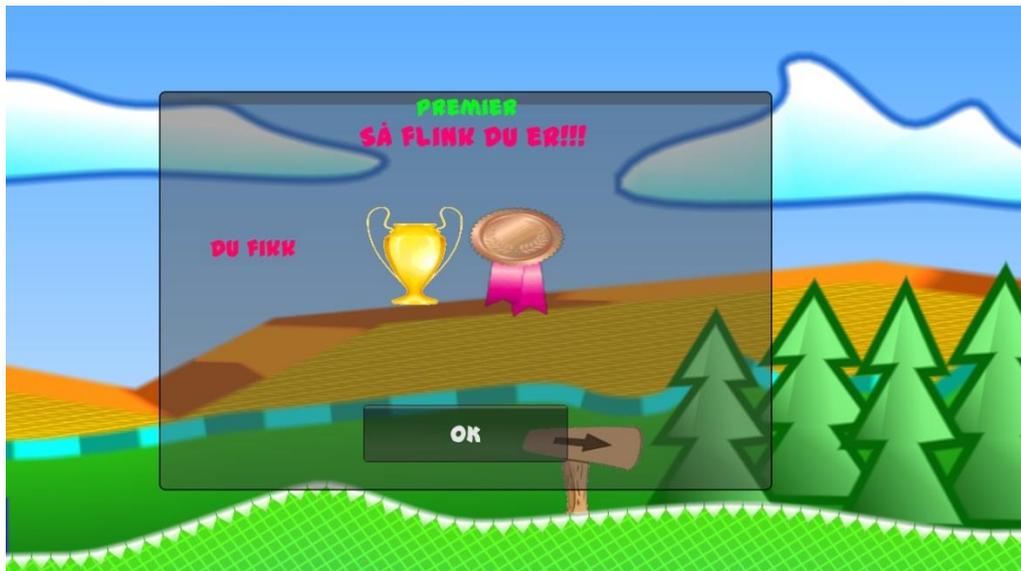


Figure 41. Rewards after finishing a level

In the final mission, a player is opposed to SuperBoss. This SuperBoss is a huge bucket of popcorn which shoots into a player with popcorn grains. It is not enough to hit him once, but more efforts are required. To beat him, a character should have a big arsenal of insulin pens, healthy food and sports equipment. Some other enemies are also in this level to intercept a character's win.

After a player's successful attempt to win the boss, we show the picture where all the enemies are running away in scare, and a character and his/ her friend are really happy that now everyone is free (Figure 42). Happy end!



Figure 42. Final page of the game

#### 5.4.4 Rewards System

Conditionally, there are several levels of rewards in the game.

The first level is obviously a score on each game level. It depends on a number of destroyed enemies and their types (cupcakes, lollipops, or others), whether a character has got hypoglycemia and/ or hyperglycemia during the level, and a correct or an incorrect answer to a diabetes-related question after the level.

Cups and medals can be considered as the second level of the game rewards (Figure 43 and Figure 44). A player is awarded with a gold/ silver/ bronze cup based on the level score. A big gold/ silver/ bronze cup is equal to ten gold/ silver/ bronze cups, respectively, regarding to all levels. The same is with medals. A player can get a medal (gold/ silver/ bronze) depending on a number of collected orange juice boxes which are missiles gathered for the final level. And, it is also possible to get big gold/ silver/ bronze medals under the same conditions as the cups.



Figure 43. Level rewards

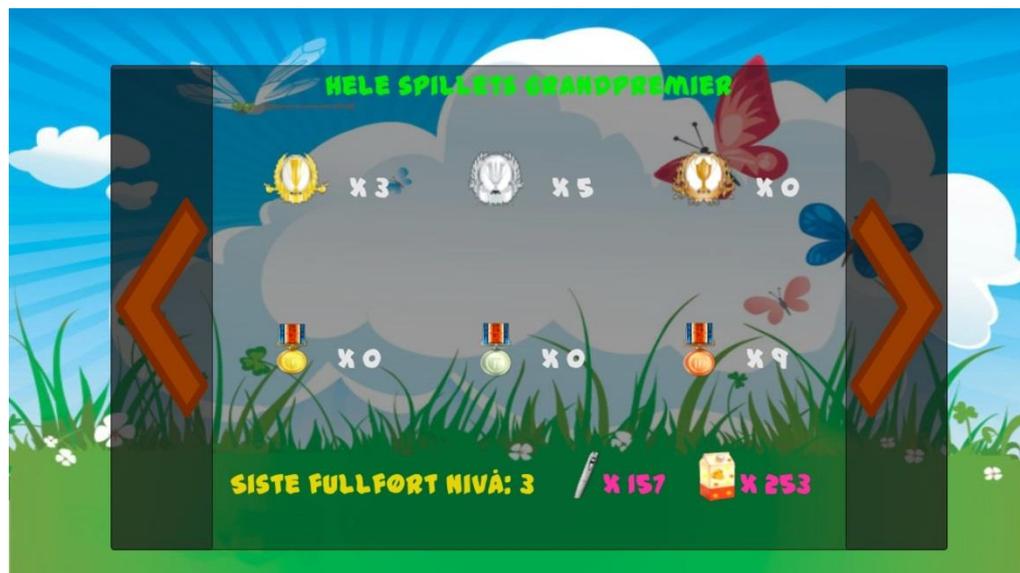


Figure 44. The whole game rewards

The next level of rewards is the progress scale on the main menu page with stars (Figure 45). Stars are awarded for higher user's progress in his/ her blood glucose monitoring: a certain number of measurements during a day, an interval between measurements, and measurements regularity. The higher percentage on the scale, the more stars a user gets (maximum three stars).

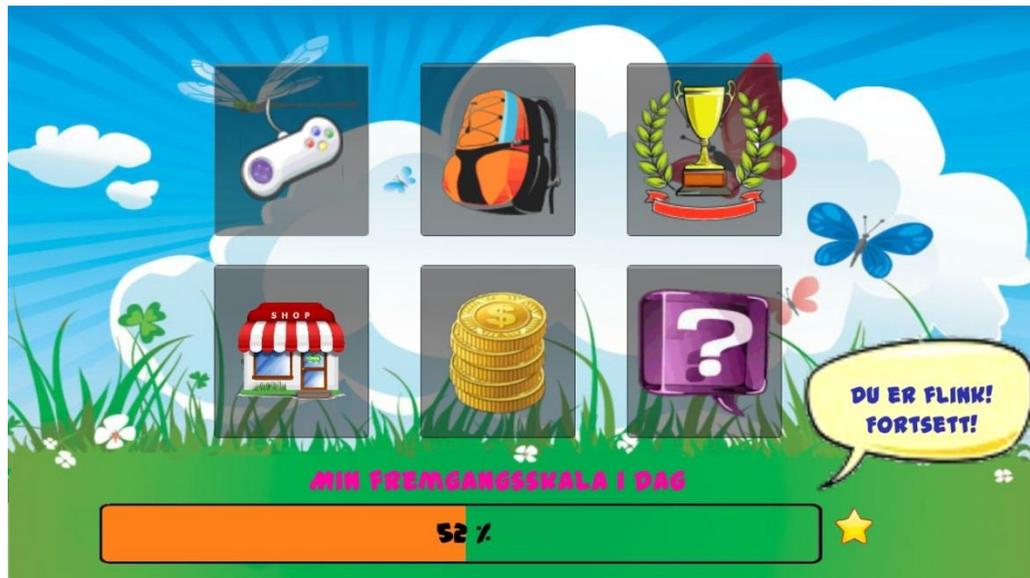


Figure 45. Progress scale

Moreover, for better progress in blood glucose monitoring, a user is awarded with a certain number of Goldpoints. If the user's average blood glucose level value is in a normal range during a month, a player also gets Goldpoints. These points can be spent for getting, for example, discounts on some goods, cinema tickets, or some other bonuses.

In addition, as a level of rewards, we can name a charge of Superpoints. A user gets 20 Superpoints every time he/ she measures his/ her blood glucose level. These points can be used for a purchase of required equipment in the game Shop.

Via all the described game rewards, we want a player to have higher intrinsic and extrinsic motivation to play the game and monitor his/ her blood glucose levels.

### 5.5 Versions of Application

Several versions (and subversions) of the game have been implemented until the game has satisfied the doctors from the University Hospital of North Norway and it has been approved by them for testing in children. Processing of game versions can schematically depicted as follows (Figure 46).

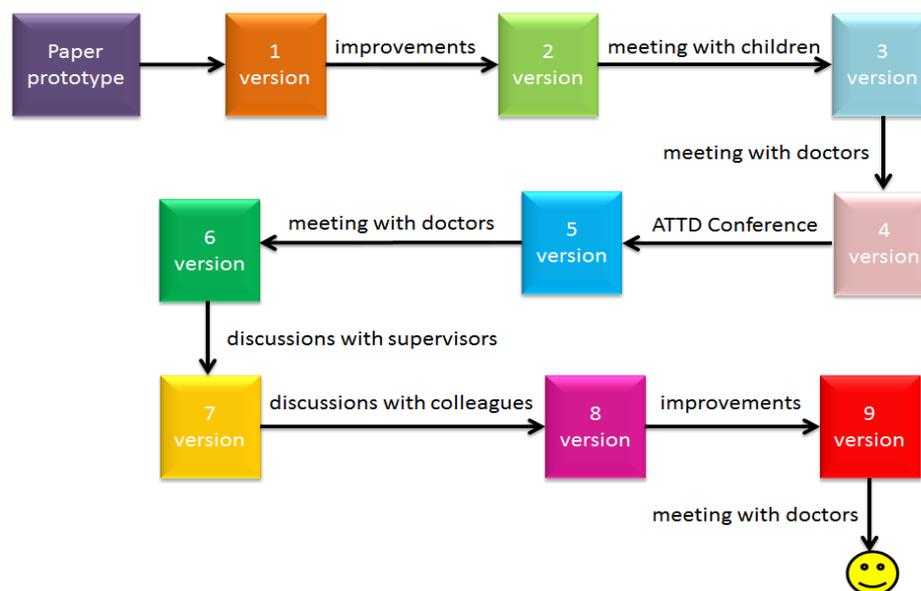


Figure 46. Version of the application

### 5.5.1 Paper Prototype

First of all, a paper prototype considering the project requirements and assumptions was created. The prototype should express main ideas of the design including basic redirections between windows within the application. In the beginning, the prototype was implemented on the paper. But then, to get more attractive appearance, the 10screens.com web site<sup>33</sup> tool was used, and afterwards, images were processed with FotoSketcher 2.2.5<sup>62</sup> to mimic a hand-drawn style. The paper prototype is presented on Figures 47-56.



Figure 47. Welcome display



Figure 48. Registration of a new user



Figure 49. Loading the application parameters



Figure 50. The user's BG measurements

<sup>62</sup> FotoSketcher web site <http://www.fotosketcher.com/> [Accessed 12.06.2013]



Figure 51. Loading the game parameters



Figure 52. Gameplay



Figure 53. Pause

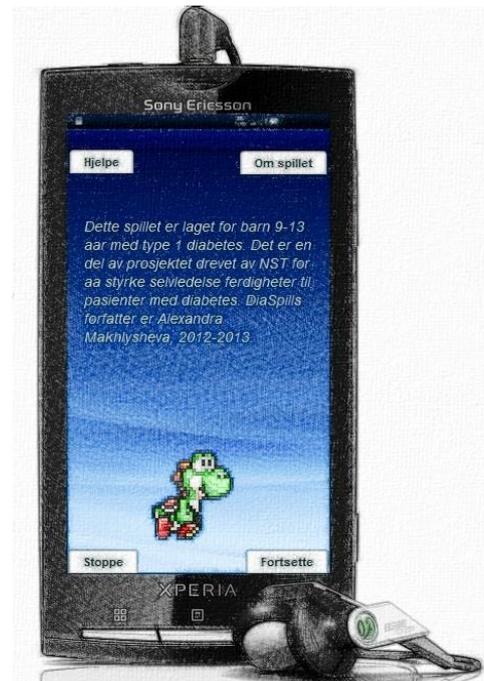


Figure 54. Information about the game

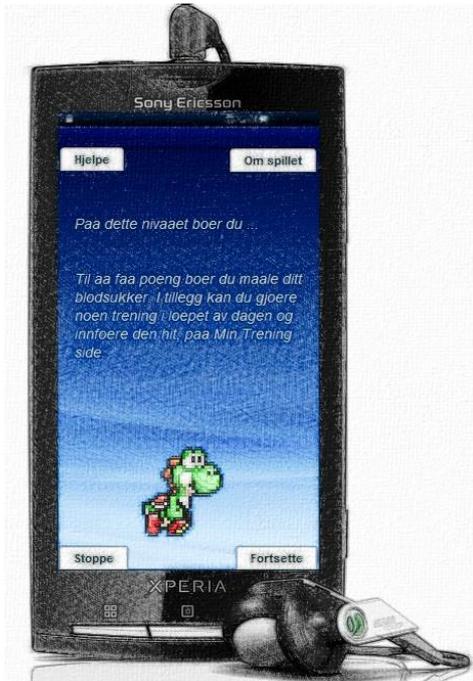


Figure 55. The tips window



Figure 56. Farewell window

The paper version of the application as a basis for further versions quite satisfied the project supervisors. Some suggestions for improvements were given (for example, exclude a presence of too much text to read, which could be recognized as too boring for children) which were considered in the later versions.

### 5.5.2 Android-Based Versions

The first Android-based version was quite simple (see Figures 57-60). Its main idea was to create a skeleton for further versions. It was the beginning of mastering the Unity 3D game engine. And, the game was initially tested on the PC in the Unity 3D editor.

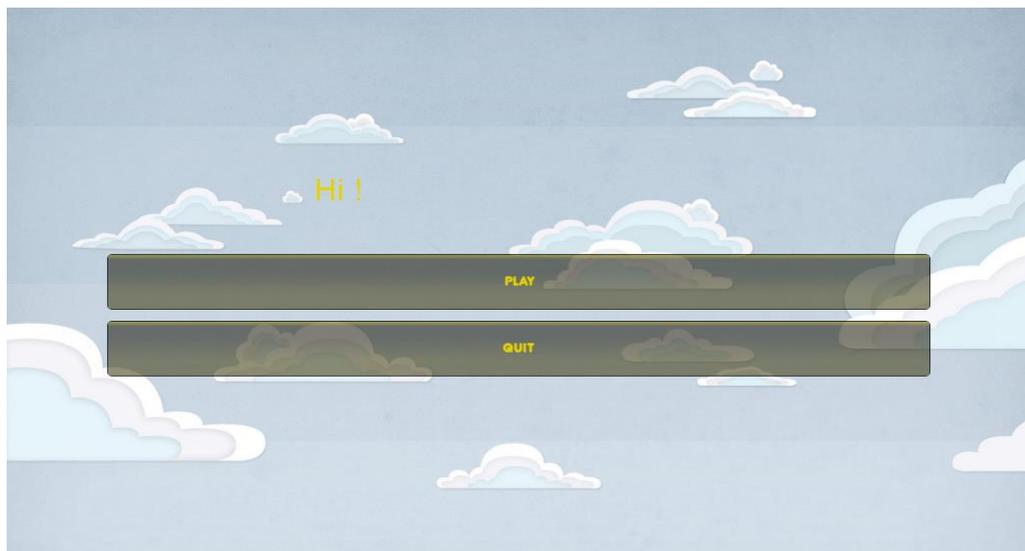


Figure 57. The game main page (version 1)



Figure 58. The main menu page (version 1)

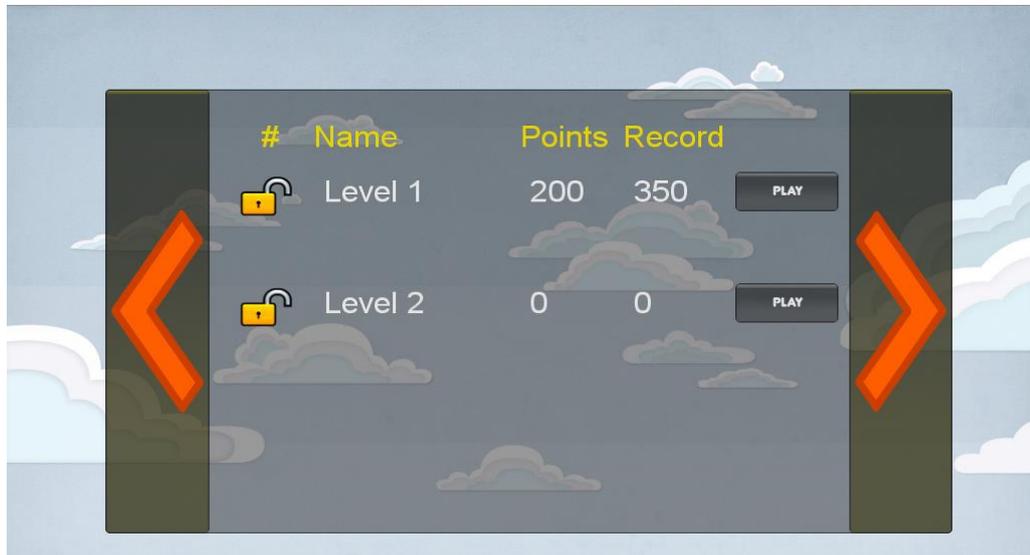


Figure 59. Levels menu (version 1)

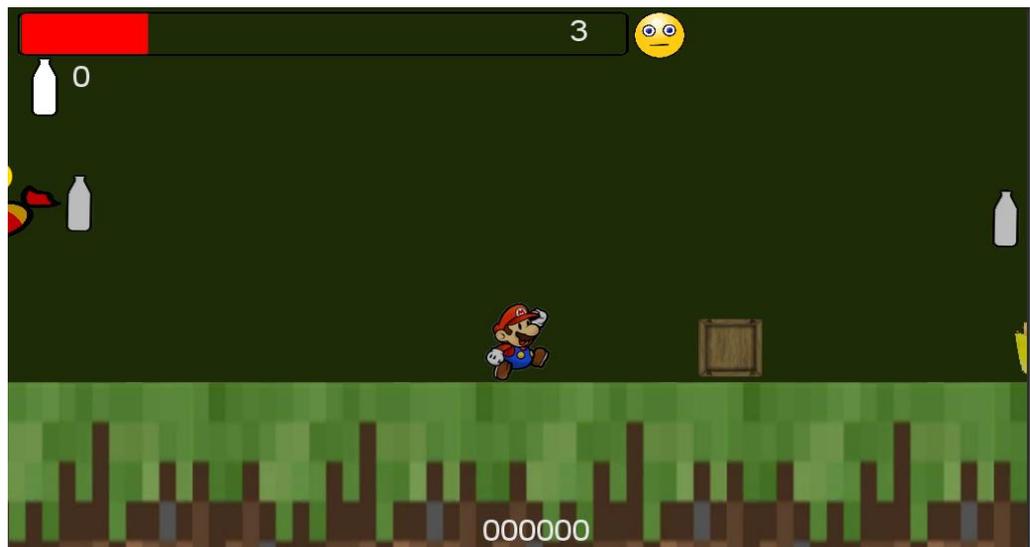


Figure 60. The first level gameplay (version 1)

After that, some improvements were made. This implied extensively improved game design, and additional functional and gameplay features (see Figure 61). Then, this version was demonstrated to children regardless having diabetes.

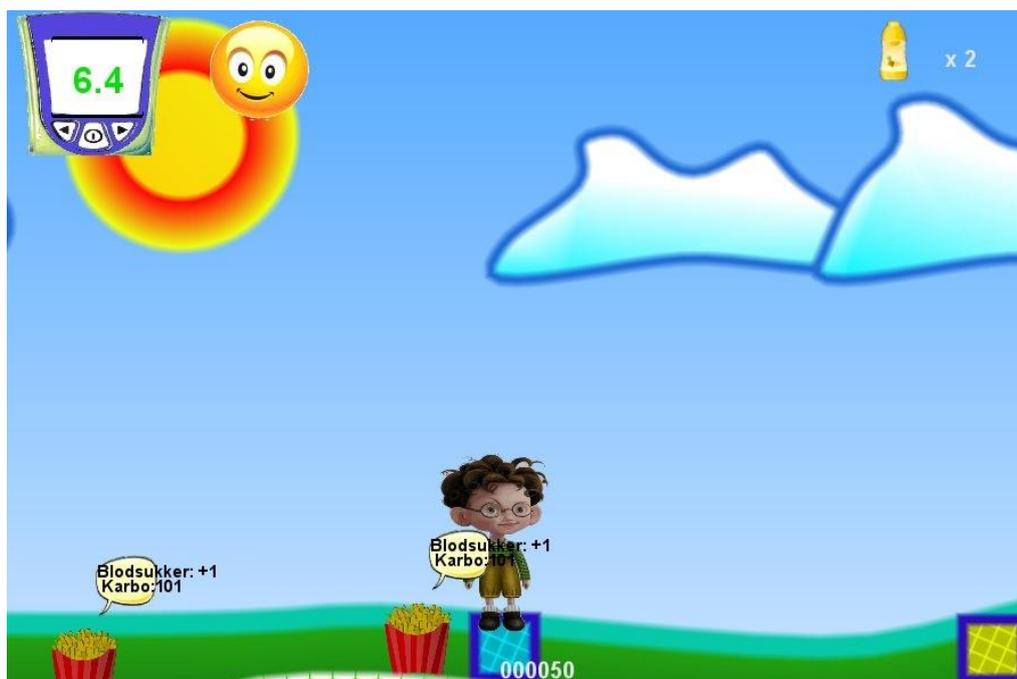


Figure 61. The first level gameplay (version 2)

For the first meeting with the end-users audience, children of the target age group were invited to participate. Before the meeting, the letter with the described meeting procedure, which was going to take place, was sent to children's parents.

After this meeting, more levels, items and other features, and as an overall requirement, more freedom (in a form of choice) were added to the game. In addition, game design was improved (see Figures 62-64).

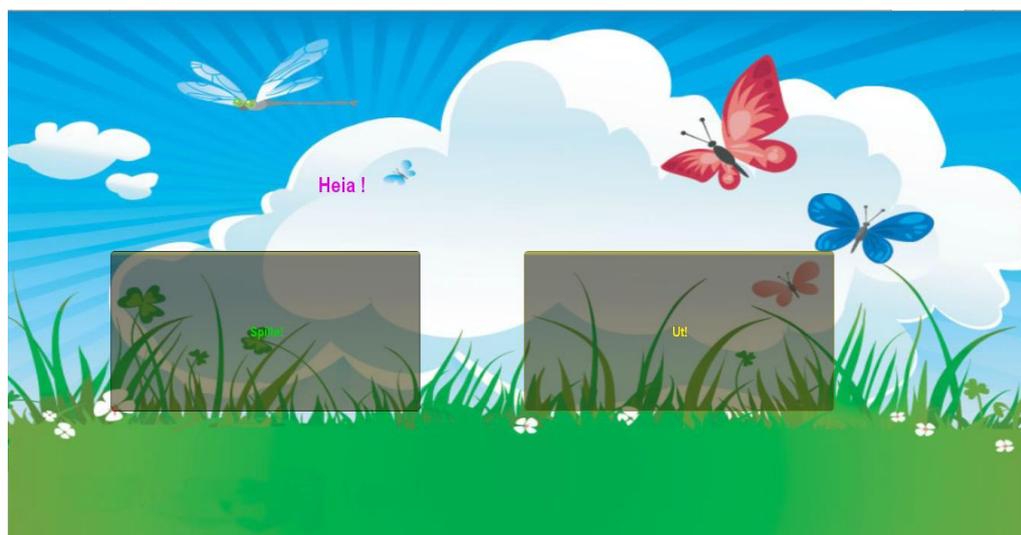


Figure 62. The first game page (version 3)



Figure 63. The main menu page (version 3)



Figure 64. Level gameplay (version 3)

Then, in the University Hospital of North Norway, we had a meeting with an endocrinologist and a diabetic nurse. Some errors were recognized in the game flow; in addition, it was decided to use player's age and weight in the game to make it more realistic.

The ATTD Conference inspired the project's author for the ideas about applying height instead of weight, two available languages, and the progress scale which is based on user's blood glucose monitoring as one more way for user's motivation. Moreover, wishes about 3D-effects in game design were taken into account.

As it was mentioned above, the data amount carbohydrate amounts in food items and burnt calories while different physical activity are extensively used in the game. After one of the meetings with doctors, for convenience of children who are going to use the application, volumes of carbohydrates were changed as follows: they were rounded up to the nearest number that can be divided by five (e.g. 0, 5, 10, etc.). It means that, for example, 21.5 g carbohydrates were replaced by 20 g, and 22.6 g were replaced by 25 g. Therefore, a column "Carbohydrate consumed/ expended" of Table 4 was changed as follows (see Table 5).

Table 5. Changes for the table of carbohydrates used in the application

Item	Carbohydrate consumed/ expended
water	0
tea	0
milk	10
apple	20
anasas	5
banana	30
paprika	5
carrot	5
cabbage	0
cheese	0
fish (codfish)	0
meat (beef)	10
skiing	35
skating	15
snowboarding	30
jogging	30
bicycling	25
ice cream	20
french fries	40
candy	10
burger	20
cake	35
pizza	30
orange juice	20
hot dog	50
cake	60
pop corn	10

Moreover, according to the doctors, among the main things that we want children to understand is the interconnections in the chain depicted on Figure 65.



Figure 65. Chain important for understanding by children while diabetes management

Therefore, we extensively developed the game features which could teach children to recognize these links in the game while concern after a character's blood glucose level and in real life while self-management of diabetes.

After discussion of the game features with the project supervisors, penalties for hypoglycemia and hyperglycemia were developed. Hypoglycemia was defined more critical both in the game and in reality. Therefore, it was decided to be penalized stricter than hyperglycemia.

In addition, a game design was reconstructed for the new testing mobile phone resolution (see Figures 66-69).

For testing of the application, Sony Xperia Acro with a 4.3'' HD Reality Display touch screen with a resolution of 1280x720 pixels was used. On mobile phones with other display resolutions, while graphics quality and proportionality of the objects is the same, texts look not very good because of font templates (additionally, they support Unicode) used for the application in the game engine.



Figure 66. The first game page (version 7)



Figure 67. The main menu page (version 7)



Figure 68. Level gameplay (version 7)

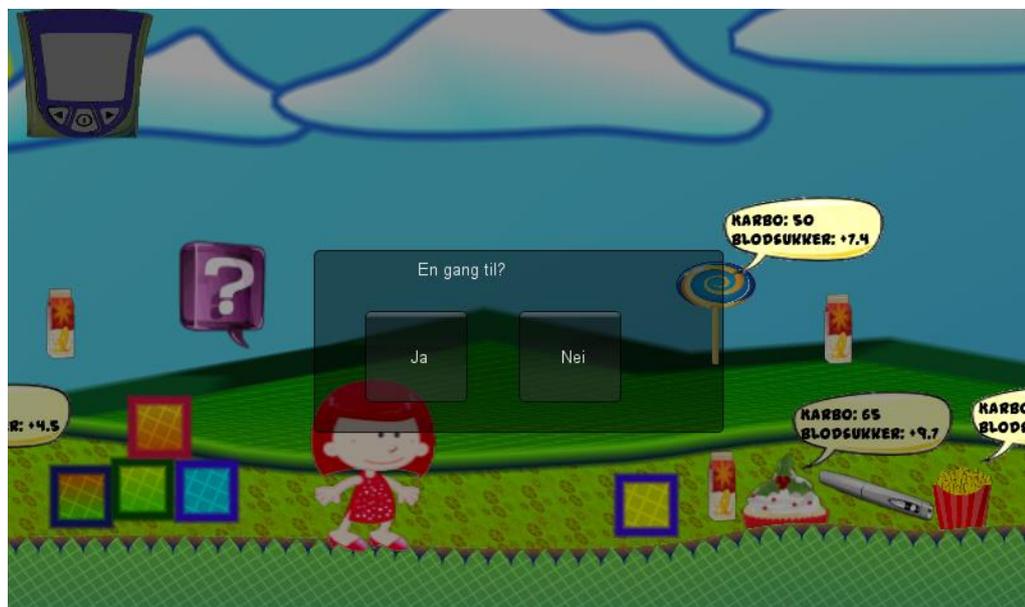


Figure 69. "Play one more time" window (version 7)

Afterwards, discussions and mini-testing of the game took place with IT developers from the NST. The following improvements such as additional language corrections, added backstory and final pages, and some corrections in the gameplay were made.

Also, some changes in game design (such as font sizes and colors) were implemented in the eighth version (Figures 70-73). This considered the fact that children with diabetes can have poor eyesight.



Figure 70. The first game page (version 9)



Figure 71. The main menu page (version 9)

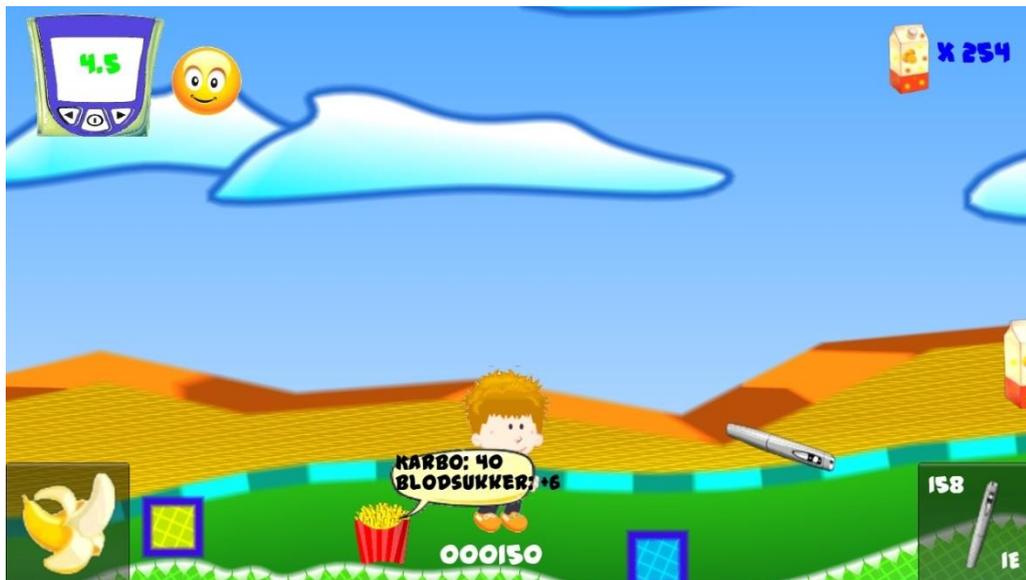


Figure 72. Level gameplay (version 9)



Figure 73. A diabetes-related question after completed level (version 9)

And, after all the mentioned above features were implemented, a new meeting with the endocrinologist and the nurse took place. The doctors were completely satisfied with the game prototype, and we were allowed to test the game in children registered in the Diabetic Registry at the UNN.

## 5.6 Summary

The history of the game title and logo is mentioned in the beginning of this chapter. Then, it is described how the game featured identified in the previous chapters should be used for game design. Next, a brief game scenario is given in the Chapter. After, different parts of game content are described in details. This includes start of the game, levels gameplay, and a rewards system of the game. This section contains numerous screenshots of the current version of the application. Lastly, the Chapter describes the project development process: from the very first paper prototype to the final Android-based version with detailed and illustrated transactions between versions.

## Chapter 6

# Implementation

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The chapter describes the implementation process of the application. Firstly, the choice of a target platform for implementation of the game is explained. Then, an introduction to the tools used in the project development is given. Lastly, the application structure is described via the application code examples and the most significant features.

### 6.1 Rationale for Choosing Android as a Development Platform

Mobile devices are so popular because of their availability and ubiquity. That is why, for development of the game prototype, mobile platform was chosen as a target.

Among existing mobile operating systems, Android was selected. There were several reasons for this. In author's opinion, there are four main ones. First of all, there is a slight prevalence of Android operating system devices on the market (see Figure 15). Therefore, a broad audience of potential end-users of the application built on this platform exists. Secondly, despite many people use smartphones and other devices based on Android OS, lack of Android-based serious games can be observed (see conclusions of the "State-of-the-art" part of the thesis). This tells us about an unfilled field where an additional work is required. In addition, Android platform is friendlier for developers in compare with iOS, for example, considering costs for game engines license, a thorny process of getting the applications validation, license for one's registration as a developer, license to be able to sell the developed products and use code parts afterwards elsewhere<sup>63,64</sup>. The last, but not least, reason was our plans of integration between the game and the Few Touch Application self-management tool (where the database of a diabetic patient's blood glucose data can be stored and afterwards used for further purposes in our application) which is built on the Android platform. Therefore, despite the mentioned above hitches are possibly easy to handle, Android seems to be one of the most attractive possibilities.

### 6.2 Android System Architecture

In a couple of words, Android is a package of software which includes an operating system, middleware and core applications<sup>65</sup> (see Figure 74).

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<sup>63</sup> AppStore. App Review Guidelines <https://developer.apple.com/appstore/guidelines.html> [Accessed 12.06.2013]

<sup>64</sup> Habrahabr IT Community web site. iOS Developer's thorny way <http://habrahabr.ru/post/132235/> [Accessed 12.06.2013]

<sup>65</sup> Android Development Community. Android Tutorials. Android - System Architecture <http://www.anddev.org/open-news-f1/android-system-architecture-in-words-t7.html> [Accessed 12.06.2013]



Figure 74. Android system architecture. Source<sup>32</sup>

Android is built on the Linux kernel (version 2.6), and uses Linux for memory management, process management, network stack, security, and driver model (Burnette, 2010). The core can also be viewed as an abstraction layer between applications and hardware. The Linux kernel runs a separate instance of the Dalvik VM (Virtual Machine) (which is a Java VM optimized for low memory requirements) for every launched application. This implies that each application runs in its own process. Moreover, the kernel supports threads and lowest-level memory management (Burnette, 2010).

In Android, most of the functionality in the core libraries is on Java programming language. All the framework APIs (Application Programming Interfaces) used by the core applications, are available for all developers. Any application can publish its capabilities and any other application may use these capabilities for its own issues with manageable security constraints enforced by the framework (it is so-called “publish/subscribe” communication policy). Moreover, every component can be replaced by the user. All these approaches make a reuse of all components possible and relatively simple.

For application development for the Android OS, Java is used as a scripting language. In Unity3D, which was chosen as a development environment for the implementation part of the application, C#, JavaScript, and Boo can be used for behavior scripts<sup>66</sup> which are originally are not supported in Android, but can be compiled by Unity3D for this platform.

### 6.3 Unity 3D Game Engine

Despite the name of this game engine contains “3D”, it is possible to develop 2D games, as well. When we deal with games for mobile platforms, we talk about 2D games because of obvious restrictions for the game control.

On Figure 75, the Unity 3D engine is ready for Android 2D games development. A standard scene includes an orthographic camera projection with a “back” camera view and standard mobile assets available in the application package.

<sup>66</sup> Unity Manuals. Using scripts <http://docs.unity3d.com/Documentation/Manual/Scripting.html> [Accessed 12.06.2013]

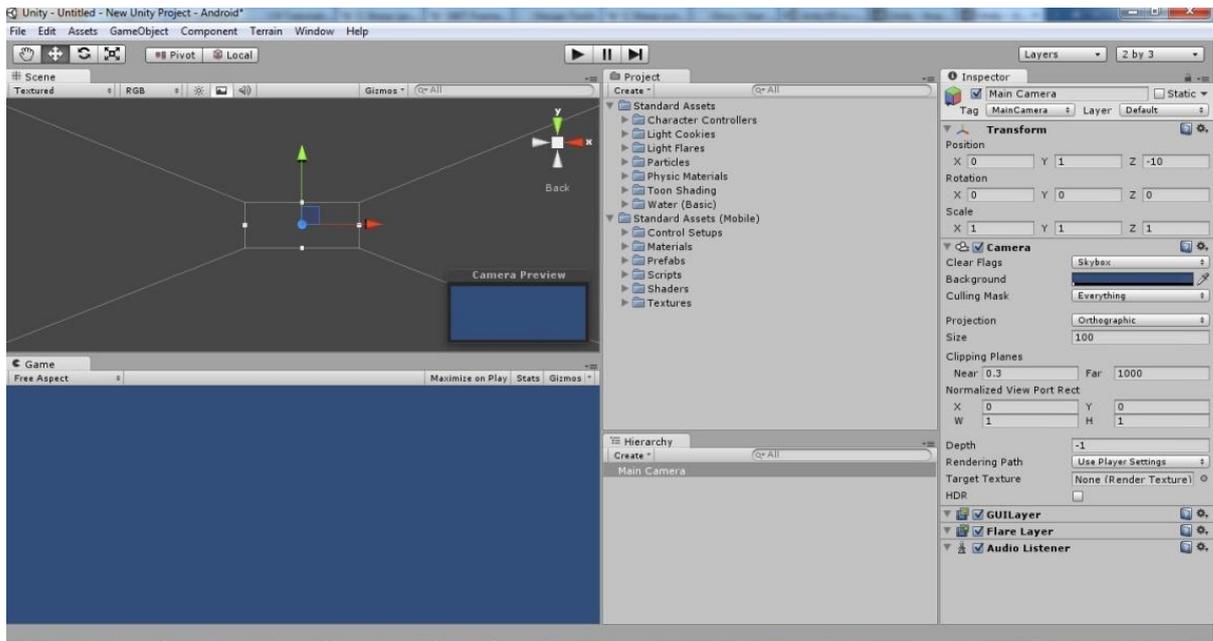


Figure 75. Unity 3D interface for Android 2D games

Each level in any game should be organized as a scene in the Unity 3D editor. One of the project scenes is presented on Figure 76.



Figure 76. Game scene in the Unity 3D editor

For the project, we assumed that users would have Android-based smartphones with touch screens and three basic sensor buttons (“Back”, “Home”, and “Menu”) for programming the game control elements.

While developing the prototype in this game engine, user manuals<sup>67</sup> and scripting reference<sup>68</sup> from the official Unity 3D web site were used for problem solving and better learning of the environment. Moreover, video tutorials from the YouTube web site<sup>69</sup> were watched.

<sup>67</sup> Unity Manual. Unity 3D web site <http://docs.unity3d.com/Documentation/Manual/index.html> [Accessed 12.06.2013]

<sup>68</sup> Scripting Overview. Unity 3D web site <http://docs.unity3d.com/Documentation/ScriptReference/index.html> [Accessed 12.06.2013]

The design of the application was changed to make it more attractive for users, considering the target audience, children. It was realized with Parallax, RageSpline, and some other Unity 3D assets (add-ons).

To implement the game, C# programming language for behavior scripts in the Unity 3D game engine was used.

#### 6.4 C# Programming Language

The content of this section of the Chapter is referenced to (Dietel and Dietel, 2006).

C# is an object-oriented programming language with syntax similar to syntax of most object-oriented languages with a few deviations and/ or additions. It was developed by Microsoft within its .NET framework project (for more details, see below). Later, European Computer Manufacturers Association (Ecma)<sup>70</sup> and The International Organization for Standardization (ISO)<sup>71</sup> approved it as a standard: ECMA-334 and ISO/IEC 23270:2006, respectively. The most recent version is C# 5.0, released in August, 2012. But there are no ECMA or ISO/IEC specifications for C# starting from version 3.0.

The .NET Framework is a software framework developed by Microsoft. The latest version is .NET Framework 4.5<sup>72</sup>. .NET Framework consists of the Common Language Runtime and the class library. The first component is a virtual machine which provides security, memory management, and exception handling. The second component provides user interface, data access, database connectivity, cryptography, web application development, numeric algorithms, and network communications. .NET Framework supports language interoperability which implies an ability of using the code written in one language by some other language. Therefore, programmers can combine their own source code with the .NET Framework and other libraries.

#### 6.5 Project Script Structure

As a standard, a main folder of each Unity 3D project contains the following sub-folders: “Assets”, “Library”, “ProjectSettings”, and “Temp”. Compiled .apk files are separately stored in the root of the project main folder. The folders “Library”, “ProjectSettings”, and “Temp” are completely maintained by the Unity 3D game engine while the sub-folders within the “Assets” folder are filled in by the developer.

The “Assets” folder has the following structure (see Figure 77).

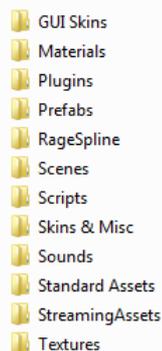


Figure 77. The project “Assets” folder content

<sup>69</sup> YouTube web site. Unity 3D 2D games video tutorials [http://www.youtube.com/results?search\\_query=unity3d+2d+game+tutorial+&fq=unity+3d+2d+&gs\\_l=youtube.1.0.0i10i10.2350.9468.0.13970.12.12.0.0.0.0.303.1740.4j4j3j1.12.0...0.0...1ac.1.11.youtube.p\\_o5DqmQ7bI](http://www.youtube.com/results?search_query=unity3d+2d+game+tutorial+&fq=unity+3d+2d+&gs_l=youtube.1.0.0i10i10.2350.9468.0.13970.12.12.0.0.0.0.303.1740.4j4j3j1.12.0...0.0...1ac.1.11.youtube.p_o5DqmQ7bI) [Accessed 12.06.2013]

<sup>70</sup> Ecma International web site <http://www.ecma-international.org/> [Accessed 12.06.2013]

<sup>71</sup> The International Organization for Standardization <http://www.iso.org/iso/home.html> [Accessed 12.06.2013]

<sup>72</sup> MSDN. Microsoft web site <http://msdn.microsoft.com/en-us/library/w0x726c2.aspx> [Accessed 12.06.2013]

The content of each “Assets” sub-folder is intuitively clear from their titles. Only a few details can be added. In the current project, in the “Plugins” folder, one can find an SQLite database plugin which is used for database connection capability of the application.

All the project scripts in the corresponding folder “Scripts” were sorted into smaller sub-folders: “Classes”, “Gameplay”, “GUI”, and “Static” (see Figure 78). Such order is, in author’s point of view, more ergonomic for bigger projects.

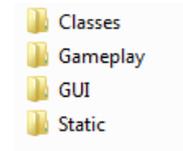


Figure 78. The project scripts

### 6.5.1 “Classes” Group of Scripts

The first folder contains eight scripts, e.g. eight classes are used in the project (see Figure 79).

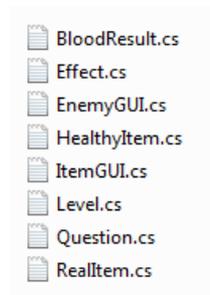


Figure 79. The project classes

The `BloodResults` class is used for work with user’s blood glucose measurements: blood glucose value and a date when this measurement was done.

```
public class BloodResult {
    public float bloodGlucose;//measurement
    public int date;//date

    public BloodResult(float _bg, int _d)
    {
        bloodGlucose = _bg;
        date = _d;
    }
}
```

Dates are stored as timestamps in seconds from the start of UNIX epoch (i.e. the 1<sup>st</sup> of January 1970). Therefore, to write SQL queries to the Few Touch Application database, we have to work with time first:

```
dtEpochStartTime = System.Convert.ToDateTime("1/1/1970 00:00:00");
System.TimeSpan ts = System.DateTime.Today.Subtract(dtEpochStartTime);
todayInt = (((((ts.Days * 24) + ts.Hours) * 60) + ts.Minutes) * 60) +
ts.Seconds);
```

where `System.DateTime` is 00:00:00 of the current day. Blood glucose values are stored in mg/dl in the Few Touch Application database while we need to present it in mmol/l. To do this, we just divide the blood glucose database values by 18.

The `Effect` class is a class for the enemies' effects for the character's behavior in a case of their collision.

```
public class Effect {
    public float time; //effect duration
    public float speed; //slowdown coefficient
    public float healthPoison; //damage per second
    public Color color; //character's color
    public Effect(float _t,float _s,float _h,Color _c)
    {
        time = _t;
        speed =_s;
        healthPoison =_h;
        color =_c;
    }
}
```

The next class, `EnemyGUI`, represents the information about enemies.

```
public class EnemyGUI {
    public int count;//how many enemies was eaten
    public float glucose;//their damage to glucose
    public int carbo;//carbo
    public Texture2D icon;//picture of the enemy
    public EnemyGUI(int _count,Texture2D _icon,float _glucose, int
    _carbo)
    {
        count = _count;
        icon = _icon;
        glucose =_glucose;
        carbo = _carbo;
    }
}
```

Similar to the `EnemyGUI` is the `ItemGUI` class which was created for the equipment used in the game.

For levels in the game, we have the `Level` class where we store: level id, name, points collected on the level, record, locally collected orange juice boxes, locally collected insulin pens, and rewards: cups for level score and medals for collected orange juice boxes.

The equipment to be used during the game can be bought in the game Shop. All the items are representatives of the `HealthyItem` class. Thus, they all have id, name, its price in the Shop, icon, some description, information about carbohydrates amount, its effect to the character's blood glucose level, and whether it can neutralize negative enemies' effects or not.

Also, similar class to the previous one is the `RealItem` class that is applied to real-life bonuses items, but its representatives have fewer properties (they do not need carbohydrates amount information, glucose effects, and a neutralizing property).

And the last class is the `Question` class.

```
public class Question {
    public string question; //the question
    public string[] answer = new string[2]; //2 possible answers
    public int rightAnswer; //correct answer
}
```

```

        public Question(string _question, string _answer1, string
_answer2, int _rightAnswer)
    {
        question = _question;
        answer[0] = _answer1;
        answer[1] = _answer2;
        rightAnswer = _rightAnswer;
    }
}

```

The questions which a user gets after completing each level are from this class. Each of them has a following structure: the question to be asked, two alternative answers, and an id of the correct answer. All the questions in the game are in English and Norwegian languages and are written in the `QuestionList` script. In addition, a method for the random generation of one question from the list is presented in this script.

### 6.5.2 “Gameplay” Group of Scripts

The next group of scripts is Gameplay scripts. They work when the game on each level is running. They are quite numerous: 18 scripts are in this folder. Among the most important scripts that can be discussed here, in author’s point of view, are `PlayerScript`, `EnemyScript`, and `FinishScript` scripts.

In the `PlayerScript`, all the game character’s behaviors and GUI while each level is being played are described. The GUI includes buttons for insulin pens and food items and sports equipment bought in the game Shop, glucometer, smiles, level score, and orange juice boxes (see Figure ??). Also, on GUI, symptoms of hypoglycemia and hyperglycemia are visualized. For too low blood glucose level, or hypoglycemia, symptom effects in the game are tremor, the message about the hungry character, flashing glucometer, red blood glucose level digits on the glucometer, and blinking healthy food items icons. In the case of too high blood glucose level, or hyperglycemia, the game character get the following symptoms: lower character’s movement speed, the message about the thirsty character, flashing glucometer, yellow blood glucose level digits on the glucometer, and blinking drinks and insulin pen icons.

The `EnemyScript` was developed for enemies’ behavior and GUI elements in the game. The enemies’ GUI include bubbles with the information about the enemy’s carbohydrate amount and its damage to a character’s blood glucose level which depends on the user’s parameters input while registration (formulas for calculation of different user’s parameters are given below).

For healthy and unhealthy food and sports activities in the game, the data about carbohydrate amounts in food items and burnt calories while different physical activity from reliable sources<sup>34,60</sup> were used.

But in those sources, carbohydrate amounts were decimal numbers. This, in endocrinologists’ opinion, is quite difficult for people with diabetes, and, moreover, is out of practice. For ease of carbohydrate calculation, patients with diabetes use integer numbers that can be divided by five. For example, instead of 21.5 g carbohydrates in some food, they consider it as 20 g, and instead of 12.6 g, 15 g carbohydrates are counted.

Therefore, changes in the code concerning carbohydrates in the game were made.

```

itemCarboInt = (int)(itemCarbo/100*mass);
if ((itemCarbo/100*mass)%5!=0)
{
    if (((itemCarbo/100*mass)%5)<2.5f)

```

```

        itemCarboInt = (itemCarboInt/5)*5;
    else
        itemCarboInt = (itemCarboInt/5)*5+5;
}

```

In the end of each level, the `FinishScript` works. It provides a question after each level, a level results page (with level score, points for a correct answer, information about whether a character has got hypoglycemia and/ or hyperglycemia, collected orange juice boxes and insulin pens, eaten enemies and used equipment), and the rewards according to user's achievements on the level. A question after each level is randomly generated from the list of available questions.

### 6.5.3 “GUI” Group of Scripts

In the GUI folder there is only one script: it is `MainMenuScript`. As it is clear from its title, it constructs the GUIs for the game main menu. The script is quite big. Therefore, only some comments about the code are given.

As it was mentioned before, there are eight levels in the game. The main menu has 13 pages (levels). In the case of the first use of the game, a user sees the language choice page (since the game is available in two languages). Then the prehistory page is shown to the user. If a user is willing to play, he/ she can choose a character to play on the respective menu level. Then, as it is in the case of ordinary use of the game, the main menu page with different alternatives is available.

There (see Figure ??) a user can go to the game rules to read about how the game should be played for better results, or to the game Shop to buy some food items or sports equipment to use them in the game (when some shop items have been bought, a user can find them on a separate page). From the main menu page, a user can check if it is enough Goldpoints to get some bonus in real life, or see his/ her game achievements, or go to the Levels page to play the game. When all levels are complete, the final page is shown to a user.

Moreover, as you have seen on the Figure ??, on the main page, there is a user's progress scale that works in integration with the Few Touch Application. More details are given below in the thesis part dedicated to integration with the Few Touch Application. Also, different comments about the progress here as feedback messages are shown to a user depending on the progress scale value.

### 6.5.4 “Static” Group of Scripts

The scripts in this group mostly work with databases: either with the internal game database or the Few Touch Application database. Again, details about the integration with the Few Touch Application are given below. More attention here is paid to the internal database.

The internal database is not a database in a standard view to databases: there is no a database file. Here it implies that certain data are stored in some format in the game.

To do this, the `GameSettings` script is extensively used. The script is global. It is available all the time at all levels and never is set to 0 while the game is functioning. All the parameters in the script are directly or indirectly are stored in the game database.

In the script, there are several “pairs” of functions: first component in this pair loads certain game parameters as a default; the second one saves them into the database. For example, `LoadUser()` and `SaveUser()`, `LoadLevels()` and `SaveLevels()`, `LoadInventory()` and `SaveInventory()`. In addition, there are also `AddCollectedEnemy(GameObject obj)` and `CheckEnemy(EnemyGUI eg)`, and `AddUsedItem(ItemGUI ig)` and `CheckItem(ItemGUI ig)` which add an item/ enemy used/ eaten during the level and check whether this item/ enemy was used/ eaten several times during the level, respectively.

Hereby, for the user, we store: last level completed by a user, user's name, age and height, id of the chosen character, a number of collected orange juice boxes and number of collected insulin pens, Goldpoints, Superpoints, a language chosen for the game, a number of hypoglycemia incidents, and a number of hyperglycemia incidents, progress scale state, time of last blood glucose measurement, last time of Goldpoints charge, a date when a game was started, and information about awarded cups and medals. Last score, record score, locally collected insulin pens and locally collected orange juice boxes, and locally achieved rewards are stored for each level in the internal database.

In the `dbAccess.cs` file, all the methods used for work with the external database are described. Here we use the plugin for SQLite database connection; therefore, in the top of the script is written

```
using Mono.Data.SqliteClient;
```

Moreover, for a connection capability of the application, we need some special components:

```
private IDbConnection dbcon;  
private IDbCommand dbcmd;  
private IDataReader reader;  
private StringBuilder builder;
```

A component `IDbConnection` is an open connection to some data source<sup>73</sup>; `IDbCommand` is an SQL statement for execution while a connection<sup>74</sup>; `IDataReader` executes a command in the database and then reads the result sets from one or more forward-only streams<sup>75</sup>; and, `StringBuilder` builds mutable strings of characters<sup>76</sup>. All components are .NET Framework data components for an access to relational databases.

To open the FTA database, we check if the database file exists in the `Application.persistentDataPath` which is a cross-platform directory path to persistent data (these data are available to different users over multiple sessions and to external applications<sup>77</sup>). If a required database is not in this folder, we open a `StreamingAssets` directory and load the database, and then save it to `Application.persistentDataPath`. When we have a database, we can open a database connection.

```
public string OpenDB(string p, bool toggle){  
    string filepath = Application.persistentDataPath + "/" + p;  
    if(toggle)  
        filepath = p;  
    if(!File.Exists(filepath)){  
        WWW loadDB = new WWW("jar:file://" + Application.dataPath +  
"!/assets/" + p);  
        while(!loadDB.isDone) {}  
        File.WriteAllBytes(filepath, loadDB.bytes);  
    }  
    connection = "URI=file:" + filepath;
```

---

<sup>73</sup> MSDN web site. `IDbConnection` <http://msdn.microsoft.com/en-us/library/system.data.idbconnection.aspx> [Accessed 12.06.2013]

<sup>74</sup> MSDN web site. `IDbCommand` <http://msdn.microsoft.com/en-us/library/system.data.idbcommand.aspx> [Accessed 12.06.2013]

<sup>75</sup> MSDN web site. `IDataReader` <http://msdn.microsoft.com/en-us/library/system.data.idatareader.aspx> [Accessed 12.06.2013]

<sup>76</sup> MSDN web site. `StringBuilder` <http://msdn.microsoft.com/en-us/library/system.text.stringbuilder.aspx> [Accessed 12.06.2013]

<sup>77</sup> Novell web site. extend Director 5.0. Working with Scoped Paths and XPath <http://www.novell.com/documentation/extend5/Docs/help/Director/books/cdScopedPaths.html> [Accessed 12.06.2013]

```

        dbcon = new SqliteConnection(connection);
        dbcon.Open();
        return connection;
    }

```

To close a database connection, we close the reader and the connection components, and clean everything after work.

```

public void CloseDB(){
    reader.Close();
    reader = null;
    dbcmd.Dispose();
    dbcmd = null;
    dbcon.Close();
    dbcon = null;
}

```

For different standard SQL queries, separate methods are written in this script. One of the methods in use is

```

public List<string[]> SingleSelectWhere(string tableName, string
itemToSelect, string conditions)

```

where we select records from the database according to the query, temporary add them one by one to a dynamic result list of strings, and then, write them one by one into a dynamic list of `BloodResult` class.

These SQL queries to the Few Touch Application database are called from the `LoadDB` script.

```

        resultToday = db.SingleSelectWhere("bloodglucose", "*", "WHERE ((date
>="+todayInt.ToString()+") AND (date<="+(todayInt+86399).ToString()+") AND
(mgdl>0)) ORDER BY date DESC");
        numberToday = resultToday.Count;
        if(numberToday>0) {
            for(int i=0;i<numberToday;i++){
                resultToday = db.SingleSelectWhere("bloodglucose",
                "*", "WHERE ((date >="+todayInt.ToString()+") AND
                (date<="+(todayInt+86399).ToString()+") AND (mgdl>0)) ORDER BY date DESC");
                RealGlucose.resultsToday.Add(new
                BloodResult(float.Parse(((string[])resultToday[i])[2]),int.Parse(((string[])r
                esultToday[i])[1])));
            }
        }
}

```

For different rewards in the game, we need to have data about the user's blood glucose measurements during the current day, his/ her measurements the day before and measurements during the whole month.

Further, in the `RealGlucose` script, we work with the user's real data from the Few Touch Application database. Also, here the user's input while registration is processed. More details are given below.

## 6.6 Most Significant Gameplay Features

The most interesting feature of the game, in author's point of view, is embedding of real player's data. This implies (a) user-dependent parameters in the gameplay and (b) user's blood

glucose measurements data. These elements are involved into the application for the enhanced educational effect of the game and higher player' intrinsic motivation to play it.

### 6.6.1 User-Dependent Parameters in Gameplay

When a player opens the game for the first time, he/ she is asked to input the following information: his/ her name, gender (for further choice of a character to play), age and height. The user's age and height are used further in different parameters calculated specifically for this user. According to the Breitman's formula, an ideal body mass (IBM) for a user can be found as follows:

```
IBM = 0.7f*GameSettings.height-50;
```

Using user's ideal body mass and age, we can calculate a daily insulin dosage (DID). Since the application is for 8-12-years-old children, the formulas for daily insulin dosage in the code are applied only for this age:

```
if (GameSettings.age>=8 & GameSettings.age<10)
    DID = 0.6f*IBM;
else if (GameSettings.age>=10 & GameSettings.age<=12)
    DID = 1.0f* IBM;
```

Further, we can find an insulin sensitivity factor (ISF) for the user which implies that one insulin unit (IU) decreases person's blood glucose level by the ISF number of mmol/l. It is calculated as 100 divided by DID. Then, we can find a portion of bolus insulin dosage (BoIID) which is approximately 75% of daily insulin dosage. This, in turn, can be used to calculate CCM, a carbohydrate compensate measurement, which means that one insulin unit (IU) compensates the CCM grams of carbohydrates consumed by a person.

```
CCM = 500/BoIID;
```

In the gameplay, insulin sensitivity factor and carbohydrate compensate measurement are used. This implies effects to the character's blood glucose level from enemies, healthy food items and sports equipment, and defines how much one insulin unit can decrease the blood glucose level and, herewith, how many insulin units are required to compensate the overall effect. For example, we calculate how much the user's blood glucose level can be increased by each food and sports equipment item as follows.

```
itemGlucose = itemCarboInt*RealGlucose.ISF/RealGlucose.CCM;
```

Moreover, as it happens in real life, the more carbohydrates some food item contains, the higher blood glucose level and the more insulin is required to compensate it. The same principal is working in the game. For example, if some food contains 40 g carbohydrates and another one 27 g, they can in average require four and 3 insulin units to be injected, respectively.

### 6.6.2 Integration with the Few Touch Application

The integration with the Few Touch Application (FTA) includes an access to the FTA database in order to work with the user's blood glucose measurements and date when they were made.

In general, in Android, applications are not able to work with data created by another application because of security issues within the Android operating system. In the current version of the game, the Few Touch Application makes back-ups of its database in the internal storage of the mobile phone where the application is installed by push-notifications. To get the newest data about user's blood glucose measurements can take up to 10 minutes. The same capability can be implemented via Content Provider. It is one or more classes in an Android

application with elements in the manifest file that provides an access to central data storage and makes data available to other applications<sup>78</sup>.

In the FTA blood glucose database, we need only one table, “bloodglucose” that contains the user’s data about blood glucose measurements. In this table, blood glucose values are in mg/dl while we are interested to have measurements in mmol/l. As it was mentioned before, to convert the values, we just divide the existing blood glucose values by 18.

Some explanations are required. First of all, mmol/l is the world standard unit designated by SI (System International) for measuring glucose in blood. The US and a number of other countries use mg/dl instead of mmol/l as it is preferred in Norway, for example. To convert mmol/l of glucose to mg/dl, we should multiply by 18. And vice versa, to convert mg/dl of glucose to mmol/l, division by 18 or multiplication by 0.055 is required<sup>79</sup>.

Additional calculations required for time of measurements stored in the FTA database were also described before.

These data are further used in the game. First of all, in the beginning of each game level on the game glucometer is the user’s last blood glucose level value. Moreover, the game reward system is built on the user’s blood glucose measurements. It includes Superpoints, Goldpoints and a progress scale with stars.

### **Superpoints**

The application charges extra 20 Superpoints to a user every time he/ she measures blood glucose. These points can be used in the game to buy different equipment to control the character’s blood glucose on each level.

### **Progress Scale**

The progress scale, which is available on the main menu page of the game, considers many factors for percentage calculation and stars award. We control regularity, periodicity and a number of the user’s blood glucose measurements.

If there are user’s blood glucose measurements from the current day and the day before in the Few Touch Application, the system checks if measurements of this day are made approximately in the same time as the day before (+/- 15 minutes) and counts a number of matches. If times of all current day blood glucose measurements match times of the previous day measurements, a user gets additional 20% to the progress scale; if only one measurement does not match +15%; if two measurements of this day and the day before were done in different time, a user still can get additional points for the scale: +10%. Hereby, we want to motivate a user to regularly measure blood glucose.

Also we check periodicity of the user’s blood glucose measurements: if a user measures blood glucose every 2-4 hours, he/ she additionally gets 15% to the progress scale. We want to teach a user to do measurements in an appropriate time interval.

A user gets approximately 5% to the progress scale every time he/ she measures blood glucose. It is recommended by endocrinologists to do measurements 5-8 times a day. If a user manages this number of measurements, additionally 15% are charged to the progress scale. For more than 10 measurements during a day, a user does not get any points.

---

<sup>78</sup> Android Developers. Content Providers <http://developer.android.com/guide/topics/providers/content-providers.html> [Accessed 12.06.2013]

<sup>79</sup> Diabetes FAQ: general (part 1 of 5). Section - What are mg/dl and mmol/l? How to convert? Glucose? Cholesterol? <http://www.faqs.org/faqs/diabetes/faq/part1/section-9.html> [Accessed 12.06.2013]

In regard to the final percentage, stars are awarded. One star is given for 51-75%, two stars for 75-90%, and three stars are gotten in the case of the almost full progress scale.

### **Goldpoints**

In the end of each day from 20:30:00 till 23:59:59, a user gets Goldpoints if he/ she has achieved a certain percentage on the progress scale during a day. If numbers on the scale are from 25% to 50%, a user gets three Goldpoints; if there are 51-75%, five Goldpoints are charged; for 76-90%, a user is awarded with seven Goldpoints; and if a user has achieved more than 90% on the progress scale, he/ she deservedly gets ten Goldpoints.

Moreover, in the end of each month of game playing, additional 20 Goldpoints can be charged if an average value of the user's blood glucose measurements during this month has been in a recommended range (4-7 mmol/l).

Goldpoints are supposed to be used for real life bonuses, such as getting free cinema tickets, some discounts in shops, gift cards for sports equipment, or similar. By now, there have not been signed any contracts for the implementation of this idea.

### **6.7 Summary**

This chapter describes the process of the application implementation. First, the choice of Android as a target platform for implementation of the game was substantiated. Then, an introduction to the Android operating system, the Unity 3D game engine and a used programming language is given. After, the application structure is explained with different code examples and the most significant gameplay features are described. Full scripts texts are not presented in the text of the Chapter, but they are available in the project source code.



This chapter deals with the performed application testing procedure and the results from this testing. The test consisted of three parts. Before the game testing, a questionnaire for parents and a questionnaire/ verbal questions for children were conducted. Then, a demonstration of the game content with a detailed explanation of game rules and game testing itself took place. And, afterwards, an interview of a child about his/ her impression about the game as a whole and game content with elements of usability testing was held. This all is described in this chapter.

#### 7.1 Testing Procedure

The final version of the application satisfied the doctors from the University Hospital of North Norway (Children's Department) and it was approved to be tested in children with diabetes registered in the UNN Diabetes Registry.

In Tromsø County, according to the data from the UNN doctors, there are 18 children of 8-12 years old with type 1 diabetes. Invitation letters with a description of the testing procedure were sent by Astrid, a nurse from the UNN, to parents of these children (a letter sample is available in Appendix 7). Only one tester contacted us to participate in testing.

The meeting with a 10-years-old boy, a child with type 1 diabetes, and his parents was held as follows.

In the beginning, the overall tasks of the current and subsequent research were briefly discussed. Then, the main features of the DiaSpill game were described. It was aimed to convince participants that we wanted to provide diabetes-related knowledge to children and teach them diabetes self-control and, first of all, to perform it in an interesting and understandable for children form. Also, it was explained in details why and how the user's blood glucose measurements registered in the Few Touch Application (DiabetesDagboka) are used in the game flow. After that, parents were asked to fill in a questionnaire about the child's diabetes-related self-management, and then, they discussed some questions about the NST (the Norwegian Center for Integrated Care and Telemedicine) subsequent project with one of the researchers from the NST meanwhile we continued talking with a child.

In the beginning, the boy was interviewed about his game preferences in general and his knowledge about diabetes. In particular, the questions for the child were as follows.

1. Do you like to play and why, or why not?
2. Which games do you play now, or what have you played recently? On the PC, mobile phone, game console, etc.
3. Do you play most often alone, or play together with others (or against others)? How much?
4. What do you think is funny in these games and why do you continue to play them? Graphics, sound, story, earn points, or something else? Any other things?
5. Do you measure your blood glucose or do your parents do it for you?
6. How often (how many times a day) do you (or your parents) measure your blood glucose?
7. Do you know how to calculate an insulin dose?
8. Do you know what the symptoms of low blood glucose level are?
9. Do you know how to behave while you have low blood glucose?

10. Do you know what the symptoms of high blood glucose level are?

11. Do you know how to behave while you have high blood glucose?

Then, the game backstory, all the possibilities and functions within the game, and the rules for better game progress were explained in details. After that, the boy was left for playing the DiaSpill game.

Testing lasted approximately for 30 minutes. Then, several interview questions were asked to the tester. Those questions were:

1. What do you think about the game? What is good and what is bad?

2. How often do you think you would play it?

3. How much time per dag do you think you would play it?

4. How do you think about the game? Can you try to give a rating for these parts of the game: 😞 = “I don’t like”, 😐 = “It’s quite good”, 😊 = “I like it very much”?

a. Colors: what do you think of the colors we have chosen? 😞 😐 😊

b. The background to the game 😞 😐 😊

c. Sounds like game use 😞 😐 😊

d. Character 😞 😐 😊

e. Enemies, equipment and healthy food at every level and in store 😞 😐 😊

5. Did you like rewards you got?

6. Was it difficult to play the game?

a. It was difficult to move the player

b. It was hard to jump with player

c. It was hard to throw Cokes

d. It was difficult to use insulin pens

e. It was difficult to use equipment and healthy food

7. Were the questions after each level difficult to answer?

8. Was it hard to understand how you could get points for what you did in the game?

a. Was it okay to understand how you could get points on every level?

b. Did you understand how you could get super points to buy anything in the game?

c. Did you understand how you could get gold points that can be used in real live?

d. Was it okay to understand how progress scale during the day work?

9. Do you find that you have better knowledge about diabetes from the game? Can you give some examples?

10. What did you like in the game and what did not?

11. What did you like most?

12. What was the most difficult for you in the game?

13. Was it fun to play game?

14. Would you like to play this game with your friends? Or against your friends?

15. Want to share your results with others in the game?

16. Do you have suggestions about what we can add to the game? Was there something you missed?
17. What do you think about the game uses the data (information) about your blood glucose measurements from the Few Touch Application? Do you like it?
18. Do you have suggestions about what we can add to this connection?
19. Have you anything more to say?

Finally, the participants, the boy and his parents, were sincerely thanked for their willing to participate in the test and research.

Afterwards, the participants' answers to questionnaires before the testing and to the interview after the testing were considered as the testing results and analyzed. The logs of game progress were additionally used for the results analysis.

## **7.2 Test Results**

### **7.2.1 Results from the Questionnaires**

Out of the parents' answers to the questionnaire about children's self-monitoring, we can extract the following data. The child is 10 and has got diabetes relatively recently (for 1-3 years). By this time, the boy can measure his blood glucose and inject insulin himself when he is at school and in other places, but not at home: his mother is used to control it when he is at home. At the same time, calculation of insulin dose is done by the child only at home under parents' control; in other places, boy's mother does it for him. The boy confirms this in his answers to the children's questionnaire.

Parents report also that the child's blood glucose is measured before and after each meal, in the morning, before the boy goes to bed, and before he is going to have some physical activity. As additional reasons for measuring blood glucose, the child's feeling unwell is named. In total, they measure blood glucose 8-15 times a day. According to the child's answers, he measures blood glucose himself and does it 5-8 times a day.

Parents know about carbohydrate counting, and do it for the child. But to evaluate an insulin dosage which should be injected they use their previous experience with the food and food portion which is going to be eaten.

In addition, parents claim that both they and the child know the symptoms and further actions while hypoglycemia and hyperglycemia conditions. This is agreed with the boy's answers. The child also added that he has had hypoglycemia symptoms before.

As for the game experience, the child is used to play a lot: on PC, XBOX 360, mobile phones, and other platforms. He plays mostly because it is fun. Most often he plays online in a team with his friends. In games, the boy likes to get points and rewards.

### **7.2.2 Game-log results**

Based on the game-log file, the following information was extracted.

In the game, during this 30-minutes testing period, a user managed to complete the last, final level, e.g. win the game. The maximum level score was 1040. It was reached on the fifth level. The minimum score was 300 points for the completed first level. Two times the user had to play a level once again because of too high blood glucose level (over 18 mmol/l). Also, the level score was decreased three times for the same reason (it gives -20 points to the level score). Hypoglycemia reduced the user's level points once. The statistics of the score on each level is available in Table 6.

Table 6. Test level results

Level	Score	Record
Nivå 1	300	480
Nivå 2	570	590
Nivå 3	670	670
Nivå 4	850	910
Nivå 5	980	1040
Nivå 6	750	750
Nivå 7	700	740
Nivå 8	610	650

In total, the player got 8 gold cups, 2 silver cups and 1 bronze cup; also, 3 silver medals, 8 bronze medals, and 0 gold medals were awarded for the whole game (see Table 7). In the game, cups are given for the score on a level, and medals are rewards for a number of collected orange juice boxes.

Table 7. Test rewards

Level	Gold rewards	Silver rewards	Bronze rewards	
Nivå 1	1	1	0	Cups
	0	0	2	Medals
Nivå 2	1	1	0	Cups
	0	1	1	Medals
Nivå 3	1	0	0	Cups
	0	1	0	Medals
Nivå 4	1	0	0	Cups
		1	0	Medals
Nivå 5	1	0	1	Cups
	0	0	2	Medals
Nivå 6	1	0	0	Cups
	0	0	1	Medals
Nivå 7	1	0	0	Cups
	0	0	1	Medals
Nivå 8	1	0	0	Cups
	0	0	1	Medals

No insulin pens and orange juice boxes were left by the end of the game.

In the beginning of the game, the user had 140 Superpoints: 120 Superpoints were charged in the beginning of the game to help the user to go further in the game flow, plus 20 points the user got for one blood glucose measurement before starting the game. Out of this sum of points, no Superpoints were left. It means that 140 Superpoints were spent in the game Shop to buy some equipment to be used in the game. No Goldpoints were awarded to the player during the playing period.

### **7.2.3 Results from the Interview**

According to the player's answers to the interview questions after the testing, the user's overall impression about the DiaSpill game was rather good. He really liked playing the game and would like to play it often when it becomes available in the Google Play.

The most interesting thing in the game flow, in the player's opinion, was the fact that his personal data (the blood glucose levels registered in the Few Touch Application) influences the gameplay: a game character, enemies and the rewards. Also, he liked that a game character can be chosen out of several alternatives. The boy considered the game backstory, graphics colors and sounds quite friendly.

He mentioned that questions after each level were quite simple for him, but at the same time, he considered this to be good since then he could get additional level points. He would like to have more questions (because during the game testing the questions were often the same). Among the knowledge acquired from the game, at least, differences in insulin units' effects for different people were mentioned.

The interviewed boy found a bit difficult to jump over the blocks on game levels. The most difficult feature, in the user's opinion, was to control the character's blood glucose since "you have to counteract to the enemies and simultaneously take care over these numbers on the glucometer". In the game, the boy sought to get more points and get the better cups and medals. He supposed that playing this game together with the others against the Cake enemies (when there are much more levels in the game) would make the game as "the super cool" one. He suggested summing up the levels points to share it with his friends as the game achievements.

Finally, he concluded that it was "cool and fun" to play the game. Parents added that they were impressed that the game was implemented specially for children with type 1 diabetes.

### **7.3 Summary**

The Chapter describes the application test and presents the results of this test. Firstly, the whole testing procedure is explained in details. The test consisted of three parts: a pre-testing part with questionnaires for parents and children, playing the game as a testing part, and after-testing with an analysis of game logs and an interview to get a child's feedback about the game. Lastly, this chapter presents the results from all these test parts.



All the major test findings and their interpretation are discussed in this chapter. Firstly, the findings from answers to the questionnaires before the testing, game testing and game logs, and answers to the feedback interview will be presented. Then, project ethical issues are discussed. Lastly, the identified points to improve the project are described.

#### 8.1 Findings from Testing

Testing procedure was held in the end of the project. Out of 18 potential users, we managed to get only one tester in the end. The whole testing procedure was divided into three parts (questionnaires for parents and children before the testing, game testing by the child, and the child's interview after the testing). After the procedure, the test results were thoroughly analyzed.

First of all, it should be noticed that it was too short period of testing which could not show significant results. Moreover, because of the test duration, the main motivational gameplay features were not properly tested. This includes a rewards system of the application: awards of Superpoints and Goldpoints for the user's blood glucose measurements registered in the Few Touch Application, and the glucose-monitoring progress scale. These are key elements of the educational effect of the game. Moreover, this could influence the overall impression of the user about the game.

According to the parents' answers, the child is 10 years old and has got diabetes recently. This explains the parents' control over child's diabetes management. At the same time, the diabetes-related questions after each level did not cause too big difficulties for the child. In fact, there are not too many questions in the DiaSpill database and they are quite simple since the main goal of such questions was to consolidate the existing basic knowledge about diabetes.

In the parents' and the child's answers to the questionnaires, we found no contradiction, except one thing. The difference in answers to the question about a number of blood glucose measurements daily can be possibly explained by too big high limit of measurements in the alternative chosen by the parents (parents answered "8-15 times per day" while the child said "5-8 times per day").

The child was quite experienced in game-playing. This can explain his plan to finish the game as fast as possible which was carried out within the testing period (approximately 30 minutes). Herewith, the fast user's progress can be explained both by the user's previous game-playing experience and the DiaSpill attractive and moderately difficult game flow that was noticed by the tester.

In average, there were 1,375 cups and 1,375 medals in average for each level. This means that each level was played 1,375 times. Moreover, level scores on some levels were different from the level record scores. This also shows that the user returned to some levels either to play them better to compete with himself or because he just liked them.

The percentage of the user's awarded rewards separately for cups and medals are given in Table 8.

Table 8. The user's rewards in %

	Gold rewards	Silver rewards	Bronze rewards
Cups	72,73%	18,18%	9,09%
Medals	0,00%	27,27%	72,73%

If we consider that cups are awarded for a certain number of points on a level, and medals are rewards for a certain number of collected orange juice boxes, then the Table tells us that it was quite simple for the user to earn points on each level while gathering the orange juice boxes was onerously. This can be explained either by the difficult process of collecting these artifacts, or possibly, it was unclear for the user why he needs orange juice boxes in the game. Therefore, the game awards criteria should be reviewed and/ or the role of the orange juice should be more carefully explained to players.

The fact that no insulin pens and orange juice boxes were left by the end of the game tells us they all were fully utilized on the last, final and, therefore, the most difficult level which was completed from the second attempt with quite a good score.

The user was not able to get any bonuses in real life (which can be got for an enough sum of Goldpoints) because of too short testing duration. In the game, Goldpoints are charged in the end of the day for the sufficient glucose-monitoring progress and in the end of each game-play month. In the interview, the user admitted that he would like to get a gift card for sports equipment.

For the same reason, the player could not get many Superpoints which are awarded in the DiaSpill for each user's blood glucose measurement. Therefore, 120 Superpoints were charged in the beginning of the game to help a user to go further in the game flow. 20 Superpoints were charged for the user's blood glucose measurement before he had started the game. In the end of the test, no Superpoints were left. All the points were spent to buy the equipment in the game Shop (4 bottles of water, an apple and a banana). Since nothing was left in the player's backpack by the end of the game, the bought items were used in the game flow.

According to the original evaluation, 140 Superpoints are quite a small sum for the game. It does not allow a user to buy all the Shop items and, hereby, he/ she is not able to try all of them "in action" for a game character's blood glucose control. The connection between Superpoints deficit and the appropriate control over a character's glucose level is confirmed by the user's two re-plays of some levels and four reductions of the level score because a character's got hyperglycemia or hypoglycemia.

While the user's game progress can be considered as quite good, more attention should be paid by him to monitoring a game character's blood glucose level. The user's insufficient control over these parameters could be affected by the novelty of the game story. This could be changed while the next game attempt. However, this may to some extent correspond to the level of the user's self-management skills. Then, the game can gradually improve this.

## **8.2 Ethical Issues**

As it was mentioned in the Requirements chapter, there could not be any personal data transmission over non-secure channels without proper authorization in the application; this, a fortiori, includes health-related data which is confidential.

During the process of gathering the requirements for the project and the application testing, no personal information were used. Audio records, which were done while meetings with children, were listened to only by the project author and removed after their analysis. Invitation letters for potential users were sent by a diabetic nurse from the Children's Department of the UNN. Hereby, no personal information was available to the application developer.

One of the assumptions for the project is that the child using the DiaSpill is the owner of the mobile phone where the application is installed. Thereby, we do not provide any authorization and authentication services since it could become an encumbrance for the target audience (quite young children) and decrease the tool usability. The DiaSpill application has an access to the Few Touch Application blood glucose database (this application is assumed to be

installed on the same mobile phone), thus, the prototype does not require transmitting the patient's data of any form outside the mobile phone. Therefore, there was no breach of users' confidentiality.

The intercommunication of two applications is implemented in a secure way. The FTA database is not corrupted or changed by the DiaSpill since only the results from SQL-queries from the game application to the FTA database (as integer values with no personal identification) are stored internally in the application.

The application uses the real personal data about blood glucose measurements in the gameplay in the form of the latest user's blood glucose level as an initial blood glucose level on the start of each level and as a basis for the rewards system in the game: Superpoints, Goldpoints, and the progress scale are based on these data. Moreover, we provide the information about amount of carbohydrates and the corresponding potential effect from all the food and sports equipment items. In addition, in the gameplay, the character's blood glucose level slightly decreases over time and changes by unhealthy and healthy food, sports equipment, and insulin injections via the insulin sensitivity factor value calculated for this particular user as all this happens in real life. Hereby, a user follows the character's blood glucose fluctuation and gets a certain understanding about his/ her personal changes in blood glucose, and learns basics of diabetes self-management.

In regard to the described game features, we had to be very careful and prevent the DiaSpill application misuse. One possible form of inappropriate behavior is too often measurements of personal blood glucose level in order to get more Superpoints (since they are charged for each new blood glucose measurement) and to get higher percentage on the glucose-monitoring progress scale. To avoid this, we have limited a number of blood glucose measurements per day which can be awarded with Superpoints or higher score on the progress scale. Moreover, the conditions of getting points on the progress scale consider not only a number of measurements, but their periodicity and regularity: without a combination of these three factors it is impossible to progress well, both in the game and in real life.

Another potential ethical issue is a use of game items (which includes food, sports equipment, and insulin pens). First of all, this concerns insulin injections. The need for insulin for a game character is calculated in the game algorithm and considers the user's personal parameters. To avoid misuse of insulin in the game and further applying this behavior in real life, a player is not able to use more insulin than it is needed for a game character according to the calculations in regard to a character's blood glucose level. In addition, a number of other items used in the gameplay cannot be used by a player as a concrete guide for action in diabetes management. The medications and insulin injections, and duration of physical activity depend on person's weight, age, personal conditions of the disease flow, and other factors. Therefore, we warn users about the fact that the application gameplay should not be used as concrete recommendations for diabetes management: in this question, the endocrinologist's advice is strongly required.

### **8.3 Points to Improve**

In regard to the discussed test results, several points for further improvement were identified.

#### **8.3.1 Duration of Testing**

The test lasted for a very short period of time which could not show significant results. Moreover, because of the test duration, the main motivational gameplay features were not properly tested. This includes a reward system of the application: charge of Superpoints and Goldpoints for the user's blood glucose measurements registered in the Few Touch Application,

and the glucose-monitoring progress scale. These are key elements of the educational effect of the game. Moreover, this could influence the overall impression of the user about the game.

To test all the game features and identify the project points of improvements, 1-2-weeks testing could be enough. This, in addition, would show whether the game is immersive enough to attract children for a quite long game-playing period. But to reach the overall goal which is to make children more independent in diabetes self-control (in particular, in blood glucose monitoring), longer test should take place. This could be a 3-months test since an HbA1c (glycated hemoglobin) test can be performed for this aim. This test shows how well a patient is controlling his/ her diabetes via the patient's average level of blood glucose over the previous 3 months<sup>80</sup>.

### **8.3.2 Recruitment of Testers**

As it was mentioned earlier, recruitment of testers was conducted, in fact, by medical personnel of the University Hospital of North Norway (Children's Department). In particular, to recruit users, invitation letters were sent out to the parents of children of 8-12 years old with type 1 diabetes who are registered in the UNN Diabetes Registry. Therefore, we could not get any information about patients. It was done in order to not violate the patients' personal confidentiality. But, at the same time, this makes us unable to facilitate the process. This could become a reason for a paucity of the application testers.

Possibly, more extensive promotion of the project by the UNN medical personnel could convince patients to participate in the research. More testers of the application would give us more objective test results and could contribute to further improvements of the project.

### **8.3.3 Improvements of Game Content Features**

Based on the test results, the following points for potential improvements were identified.

First of all, game-control should be slightly revised since it caused some difficulties for user's playing the game. In addition, the most part of texts in the game rules could be replaced by the "cartoons"-style pictures not to bore the young audience.

The next version of the game should have more levels with a gradually growing difficulty (with more enemies and challenges) which should require a team play against the enemies. Therefore, the improvements should also imply the multiplayer functionality. In addition, an ability to share the game achievements can become an additional attraction for the players.

According to the user's rewards results, the game awards criteria can be possibly changed and the role of the orange juice boxes collected on each level should be better clarified to players in the beginning of the game.

More diabetes-related questions should be added to the game questions list. Moreover, their difficulty should vary. But it can be very hard to define the questions optimal difficulty level. Possibly, the questions should depend on the user's age and/ or the user's level of knowledge before the game (which could be check, for example, via some quiz while the registration for the application).

### **8.3.4 Real-Life Bonuses**

As an additional attraction and motivation of children to play the game, and, as an overall goal, to adhere to treatment regimens (first of all, a control of blood glucose level values and regularity of blood glucose measurements are considered), Goldpoints are used. They can be spent for getting some bonuses (prizes) in real life. A player gets Goldpoints for having an

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<sup>80</sup> The U. S. National Library of Medicine. Medline Plus  
<http://www.nlm.nih.gov/medlineplus/ency/article/003640.htm> [Accessed 12.06.2013]

average blood glucose level during a month of game playing in a normal range. The bonuses can include, for example, discounts on some goods in supermarkets, or cinema tickets or tickets to museums, gift certificates for sports equipment, tickets/ season tickets to the swimming pool. But also, this can be T-shirts, pens, notebooks with the game logo, etc. All these bonuses should not contradict the main goal of the application to teach children diabetes self-management and show them good behavior while having diabetes. Consequently, bonuses should not promote a violation of the treatment regimen or involve children into unhealthy lifestyle.

By the end of the project, any contracts or agreements with the Tromsø municipality or other possible partners have not been signed. Therefore, this question can be considered in the future work.

#### **8.4 Summary**

This chapter discusses the results of the research as a whole and the game testing, in particular. Firstly, the findings from the whole testing process (which includes questionnaires before testing, testing itself and an interview and a game-log analysis after testing) are discussed. Then, ethical issues of the project are discussed. Later, the points to improve (which include different alternatives for getting real life bonuses in the game, test duration, the way of testers' recruitment, and some game content improvements) are described in the Chapter.



## Chapter 9

### Concluding Remarks and Future Work

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#### 9.1 Conclusion

The main research problem formulated in the beginning of the project was to design an educational game able to help children with type 1 diabetes improve their diabetes-related self-management skills. The major goal was to attract children with a game that could give them knowledge they need for proper self-management of the disease which, in turn, can help them avoid short-term and long-term disease complications in future. In addition, this should be given in an unobtrusive way and be always available. Therefore, a mobile phone-based game, DiaSpill was developed to address these problems.

The application was designed in accordance to identified significant game features and psychological behavior features of the target group. Moreover, requirements and suggestions formulated by children of the target age group, doctors and experts in diabetes were considered.

Diabetes-related knowledge was seamlessly embedded into the DiaSpill. For example, to teach children understand the interconnections within the chain “carbohydrate in food - blood glucose level - insulin to be injected”, this process happening in a human body in real life was included into the gameplay. Moreover, knowledge about diabetes was delivered through questions after each level and information about food items and sports equipment in terms of carbohydrate amount and effects to blood glucose level in the game flow. In addition, the user’s real data about blood glucose measurements and user’s parameters such as age and height were embedded into the game to create a user-dependent gameplay and a multi-level rewards system, and therefore, make a user to be even more motivated in game results.

The game was tested on the final stage of the project. Despite of too short testing period which could not show significant results, the test demonstrated an attractive and moderately difficult game flow which did not cause big difficulties for the game-play experienced child. According to the tester, the most impressive game feature was an ability of a user to influence the gameplay and the game progress via personal blood glucose data. In addition, the player mentioned a provided choice of characters in the beginning of the game, game backstory, used graphics colors and sounds in the game. Herewith, the user showed insufficient control over a game character’s blood glucose level which could be affected by the novelty of the game story. This could be changed while the next game-playing attempt. But also, to some extent this might correspond to the user’s self-management skills level which, in turn, can be gradually improved by DiaSpill. Real-life bonuses suggested in the game scenario showed a potential to be highly demanded in the game. It was concluded that the next version of the game should include certain improvements in game content, have more levels with a gradually growing difficulty (with more enemies and challenges) with abilities to team-play and sharing the player’s game achievements with other users.

The inferences regarding sub-questions claimed in Chapter 1 are presented below.

<i>Question 1: What makes an application attractive for children?</i>
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The relevant literature studied serious games and self-management tools developed specifically for children was systematically reviewed. Four the most significant gameplay features corresponding to the reviewed psychological behavior theories (social cognitive theory, self-determination theory, behavior inoculation theory, and elaboration likelihood model) were identified: (1) a player learns some skill by playing a character empathetically related to the player and improves the skill by learning the subtleties of the game and further planning of strategy (goal setting, goal review); (2) a player gets rewards; some virtual trophies for the

player's achievements, and new game content were used (referred to feedback and extrinsic motivation); (3) a player faces challenges; either he/ she can compete with other players or surpass one's own score or record, or resist time constraints or gradually increasing difficulty of levels, or locked context (seen as intrinsic rewards being a part of self-regulatory behavior); and (4) games had attractive design including graphics, sounds, animations. The features (2)-(4) make the game immersive and motivate players to continue playing, while (1) composes an educational component of games. In addition, an easy game access, understandable gameplay, novelty of game scenario, an ability of team-play, and an attractive colorful design are additional attractions for children audience. These features were considered while game designing.

*Question 2: How to create an application easy to master by children?*

To create an easy-to-play game, an experience from the relevant literature should be applied, first of all. In addition, a user-centered cyclic development process should take place. The application should meet the requirements and suggestions for improvements gathered via numerous meetings with end-users, specialists and experts in the field. In our case, these included meetings with children of the target age group, endocrinologists and experts in diabetes. The check whether the final product meets the expectations and identified requirements, the testing procedure took place.

*Question 3: What can help children in improvement of their diabetes-related self-management skills?*

To help children in improvement of diabetes-related self-management skills, we can explain children the basics of diabetes. This can be, for example, in a form of questions about the disease. But also, we can show the processes happening in human body an understandable form, suggest the actions to influence these processes and show the consequences of these actions.

In our case, we exploit the following process. When a person with diabetes eats something, a blood glucose level rises and if nothing is done, hyperglycemia symptoms appear. To decrease a glucose level, a person should inject a certain insulin dose dependent on the food type and its size. Moreover, this dose depends on bolus insulin dose calculated for the user which, in turn, is defined by the user's age and the body mass ideal for the user's height (often, other parameters should be also taken into account). When a person's blood glucose level is too low (for example, after physical activity), simple carbohydrates should be consumed. Otherwise, hypoglycemia symptoms will occur.

These critical situations with too low blood glucose or too high blood glucose in real life can lead to short-term and long-term complications. We wanted a child to see the consequences of his/ her action on a game character in the game to avoid critical situations in real life and improve his/ her diabetes-related self-management skills.

*Question 4: How to embed knowledge about diabetes and the elements able to help children in improvement of diabetes-related self-management skills into the application?*

Knowledge about diabetes and the elements able to help children in improvement of diabetes-related self-management skills into the application should be seamlessly embedded into the gameplay. It was identified from the relevant literature and discussions with doctors and experts in diabetes that an empathetically related game character can motivate a user to be immersed into the game. This, in turn, can help a user follow the game scenario where an educational component is embedded.

In our case, a character was decided to be a small boy or a girl (which depends on a user's gender) who as a player has type 1 diabetes and has the same processes in his/ her body. Thereby, a user has two goals in the game: 1) to reach the final level, win SuperBoss, and

complete the mission of a world free, and 2) to take over a character's blood glucose level. Hereby, the first goal cannot be reached without the second one. Simultaneously, we show that the enemies in the game are food that contains big amounts of carbohydrate and has a great effect on a user's blood glucose level in real life. Moreover, a rewards system of the application depends on the user's progress in learning and blood glucose monitoring.

*Question 5: How can the user's real data be used in the gameplay?*

The user's real data about blood glucose measurements can be stored and accumulated in the Few Touch Application, a self-help tool for people with diabetes. We can use these data to motivate a user in a game. In the DiaSpill, we embed it into the game scenario and gameplay. The user's real data about blood glucose measurements and user's parameters such as age and height were embedded into the game via a multi-level rewards system dependent on user's blood glucose-monitoring progress in real life, and a provided information about healthy food items, sports equipment, and enemies (unhealthy food) in terms of carbohydrate amount and their effects to blood glucose level. We use actual data about carbohydrate amounts in different items and calculate the items effects on a user's blood glucose level specifically for this user. In fact, a user's blood glucose level is represented in the game as a character's glucose level on the glucometer that in the beginning of each level, has the same value as a user during the last measurement.

## **9.2 Thesis Contribution**

### **First mobile phone-based game for children with type 1 diabetes in Norway**

The project was the first attempt to develop a game for children with type 1 diabetes for the Android mobile platform in Norway. In game design, the features identified from the state-of-the-art in the field and behavioral theories were considered. Herewith, the age of the target audience was taken into consideration. Moreover, users were extensively involved in development: the requirements and suggestions for improvements were collected on meetings with end-users, doctors, specialists and experts in diabetes. In addition, the age and nationality of the end-users audience who was going to test the game (young Norwegians) defined a choice of a language the game content is available for a user. In a current version, two languages (Norwegian and English) were implemented. On the final stage of the thesis, the game testing was conducted in a target group of end-users.

### **Use of real personal data as an additional motivational factor**

According to the reviewed literature, only exergames use person's data directly for one's motivation. People with diabetes have to document their conditions to manage the disease flow. It implies records of blood glucose measurements, insulin and medication doses, carbohydrate intake and physical activity. This all can be registered in the Few Touch Application. Therefore, we may use the user's real self-management data in order to teach people understand their conditions better and improve their self-management skills. In our case, these data were embedded into the attractive shell of gameplay. The user's progress in the game directly depended on the user's progress in blood glucose monitoring in real life with considered frequency, periodicity and regularity of blood glucose measurements.

### **Educational component as an integral part of the application**

The implemented game combines the entertainment and educational roles. On one hand, it is a colorful attractive for children game. But on the other hand, it introduces basic knowledge about diabetes and promotes children's diabetes-related self-management skills development. Education is given in a form of questions about the disease, but also in a form of the seamlessly embedded in a character who as a player has type 1 diabetes and has the same processes in his/her body. Therefore, a user has two goals in the game. First of all, a player wants to reach the

final level to complete the mission. But simultaneously, he/ she should monitor a character's blood glucose level. Hereby, the first goal cannot be reached without the second one.

### **Positive test results**

On the final stage of the research, testing took place. The test consisted of three parts. First of all, a questionnaire for parents and a questionnaire/ verbal questions for children before the game testing were conducted. Then, a demonstration of the game content with a detailed explanation of game rules and game testing itself took place. And, afterwards, an interview of a child about the impression of the game as a whole and game content with elements of usability testing was held.

The test results demonstrated an attractive and moderately difficult game flow which did not cause big difficulties for the game-play experienced child. The most interesting thing in the game flow, in the player's opinion, was the fact that his personal blood glucose data influences the gameplay: a game character, enemies and the rewards. Also, a provided choice of characters in the game, game backstory, colors and sounds were positively noticed by the tester. Real-life bonuses suggested in the game scenario showed a potential to be highly demanded in the game.

Suggestions for the next game version included some improvements in game content, have more levels with a gradually growing difficulty (with more enemies and challenges), multiplayer and an ability to share the game achievements with other users.

However, too short testing period could not properly demonstrate a rewards system of the application that introduces the key motivational and educational gameplay features. Moreover, because of a limited number of the application testers, the results should not be considered as undisputed, and a new more numerous research is required.

### **Reusable project results**

The research (including the described design process, the test results and a source code) can become a basis for other research in the field of Games for Health. Here, in Norway, for example, it can be partly used for the subsequent NST project "Spill og lær med diabetesvenner"<sup>81</sup>.

### **9.3 Future Work**

First of all, in the next game version, some game content features mention in the Discussion chapter should be revised. This includes game-controls, the awards criteria which should be revised. Also, the next version should contain more levels with a gradually growing difficulty. This implies adding more enemies and challenges into the game. Possibly, a difficulty level could be regulated by a user. In addition, the game should allow a team play against the enemies. This means the multiplayer functionality which can, in addition, make the game more social. Moreover, an ability to share the game achievements can become an additional attraction for the players.

Also, the list of diabetes-related questions should be extended. Herewith, the questions asked after each game level should depend on the user's age and/ or the user's level of knowledge before the game, and some other factors.

Real-life bonuses seemed as really attractive for children (both on the requirements gathering and the testing stages of the project) should be also fully implemented in the future game versions. This can become an additional incentive in the game.

Moreover, we can use other capabilities of the Few Touch Application which is able to store durations of physical activity, volumes of consumed carbohydrates and injected insulin

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<sup>81</sup> Norwegian Center for Integrated Care and Telemedicine. Project "Spill og lær med diabetesvenner"  
<http://www.telemed.no/spill-og-laer-med-diabetesvenner.5207848-247953.html> [Accessed 12.06.2013]

doses in addition to blood glucose level measurements. Also, the FTA can visualize the accumulated blood glucose measurements data during a certain period of time as a graph. These features could be used, for example, by parents and/ or endocrinologists to monitor the child's diabetes self-management. On the current stage of the DiaSpill application implementation, these capabilities were not applied because all of them are required manual input of the information. Hereby, it was decided that for 8-12 years-olds children with type 1 diabetes, who are just on their way to manage the disease independently, following all of them could become too complicated and constrained. Therefore, we were concentrated on promoting children basic knowledge about diabetes. We wanted to convey the idea of how it is important to control the blood glucose via showing them what influences the blood glucose level by visualization of its fluctuations and causes. Herewith, we tried to provide this in a children's favorite learning form: a game, with an attractive design which considers the experience of previous research works, both psychological behavior principles and game development practices.

To extend the target auditory, a game version can be implemented on the iOS platform. In addition, support for some other languages (not only Norwegian and English) can be organized. This can include Swedish, Danish, and Russian, for example. Then, the real-life bonuses feature should be "localized": the contracts or agreements with local partners which would provide these bonuses should be signed in each country separately.

To test all the implemented game features, 1-2-weeks testing can be conducted. This will show whether the game can attract and immerse children for a quite long game-playing period. Moreover, the health outcomes observations can take place in the future in order to test the long-term effects of the application. In this case, a 3-month test can be conducted since an HbA1c test (a glycosylated hemoglobin test which shows the patient's average level of blood glucose over a previous 3-months period) is measured every quarter of the year. This test dedicated to evaluation of the game efficacy and the game validation would be conducted in accordance with a guidance provided by Kato (Kato, 2012).

According to the researcher, there are several main features of the appropriate research. A coherent theoretical basis for a game is one of them. Also, for the research results objectivity, a research for efficacy evaluation should conduct a randomized trial (which is the gold standard for research aimed to identify the interconnections between interventions and outcomes) with an appropriate number of participants and an adequate control group where participants are randomly assigned. Moreover, the research evaluations ideally combine self-report of participants with objective measures of health outcomes. In addition, Kato suggested monitoring and reporting potential the game negative side effects, and publishing even null results (which makes future meta-analyses biased to show positive effects). To these integral components of such a research, I would add an adequate testing duration which should correspond to the aimed outcomes.



## Appendix 1

**Table: Detailed list of reviewed relevant literature**

Author	Group of articles	Target disease	Game type	Development platform	Target population	Findings/ Significant features
(Kanstrup et al., 2008)	1	Diabetes		Not specified	Children (3-5 years old)	Game-based learning with positive learning and motivational attitudes in children. Less time to complete awareness tasks. Learning with more fun
(Aoki et al., 2005)	2	Diabetes		Cell phone	Children (age is not specified)	Efficient and enjoyable learning tool that combines fun and learning
(Arteaga et al., 2010)	2	Obesity		Mobile phone	Children (age is not specified)	Theory of meaning behavior, and theory of planned behavior are used. 5 factors model of personality: Openness to Experience; Conscientiousness; Extroversion; Agreeableness; Neuroticism
(Baranowski et al., 2008)	2	Games are included into the final list (see Appendix 2)				25 health-related videogames. SDT, intrinsic motivation provided by fun
(Baranowski et al., 2010)	2	Games are included into the final list (see Appendix 2)				Games use behavior change components: modeling, skill development, self-regulatory behaviors, rewards, immediate feedback, and personalization
(Baranowski et al., 2011)	1	T2DM Obesity		Not specified	Not specified	Mediating/moderating variable model, psychological aspects should be used in VG for behavior changing
(Bassilious et al., 2012)	2	Games are included into the final list (see Appendix 2)				Various educational strategies to enhance learning and transfer knowledge and skills are used
(Boren et al., 2006)	1	Diabetes		Not specified	Children Adults	Knowledge is necessary but not sufficient to change health behaviors and improve health status. Goal setting and feedback are important
(Boren et al., 2008)	1	Diabetes		Not specified	Children Adults	Education content in diet and nutrition, exercise and physical activity, blood glucose monitoring and recording, prevention and management of complications. Goal setting and feedback are also important
(Brown et al., 1997)	1	Games are included into the final list (see Appendix 2)				Relative to the control group, the treatment group showed gains in self-efficacy, communication with parents about diabetes, and diabetes self-care behaviors
(Brown, 1998)	2	Diabetes Asthma		Not specified	Not specified	Psychological aspects employed for the user's self-management
(Buday et al., 2012)	2	Games are included into the final list (see Appendix 2)				Fun serious games. Educational aim + entertainment
(Cafazzo et al., 2012)	2	Games are included into the final list (see Appendix 2)				User-centered design process, including simple, automated transfer of glucometer readings; the use of a social community; and the concept of gamification; rewards (iTunes music and apps). The daily average frequency of blood glucose measurement increased by 50%
(Scott, 2004)	1	Diabetes		Internet	Adults, Pre-Teens, Teens, Young Adults	Relevant increase in knowledge about diabetes, higher perceived self-efficacy; improved emotional well-being of children with diabetes, by providing them with a "virtual friend" with the same lifestyle regimen. Novelty effect is attraction
(Chen et al., 2011)	1	Diabetes		PC	Children (age is not specified)	Design strategies: Structure Enhancement, Feedback Enhancement, Challenge Enhancement. A novel game, using an open

			source 2D game design
(Hieftje et al., 2012)	1	Games are included into the final list (see Appendix 2)	The DIDGET BGMS provided accurate test results across all age ranges in children, teens, and young adults with diabetes
(Watters et al., 2006)	2	Games are included into the final list (see Appendix 2)	11 video games for diabetes education. Only two games explicitly referenced theoretical constructs. Video games hold great potential as an alternative modality for diabetes education
(Errickson et al., 2012)	1	Games are included into the final list (see Appendix 2)	Numerous developmental motor and sports-specific skills for children and adolescents. Taken together in this exergame, they present a notable opportunity to develop eye-foot coordination and promote kinesthetic, proprioceptive, and tactile exploration experiences.
(Frederico, 2012)	2	Games are included into the final list (see Appendix 2)	Although only 4% of respondents played nutrition games, 79% thought they could be of benefit, and 21% felt that “maybe” they could be beneficial educational tools. Games on all nutrition topics were welcome, with preference for computers and smartphone apps.
(Chen et al., 2011)	1	Games are included into the final list (see Appendix 2)	Game character likeability increased with participant’s perceived similarity to the character. The presence of diabetes context facilitated the diabetes-management procedural knowledge, leading to self-efficacy. A longitudinal study would deliver stronger results
(Fujiki et al., 2008)	1	Games are included into the final list (see Appendix 2)	Design principles: simple, informative, discreet, motivating. NEAT-o-Games, unlike others, run for hours, days, or for life: a part of people’s everyday routines.
(Gao and Mandryk, 2012)	1	Games are included into the final list (see Appendix 2)	Significantly improved performance on 2 cognitive tests that require focus and concentration and in participants’ affective states after playing the casual exergame. Also casual exergame produces similar exertion levels to treadmill exercise, but is perceived as more fun.
(Gerling et al., 2011)	2	Games are included into the final list (see Appendix 2)	The results of an empirical study revealed a generally high acceptance of the health game among young patients, while parents and medical staff highlighted the educational potential of health games addressing cancer
(Getchell et al., 2012)	1	Games are included into the final list (see Appendix 2)	Videogame systems may increase daily physical activity and help alleviate the growing rates of obesity
(Glasemann et al., 2010)	1	Games are included into the final list (see Appendix 2)	5 important aspects when designing a mobile learning game scenario prototype for young diabetics: foster active participation; use the environment and foster mobility; facilitate dialogue; use technology to enrich the learning experience; prepare for real life
(Gorgu et al., 2010)	2	Games are included into the final list (see Appendix 2)	Gaming environment should be mobile, adaptive, augmented, and collaborative.
(Graf et al., 2009)	1	Games are included into the final list (see Appendix 2)	Energy expenditure during active video game play is comparable to moderate-intensity walking. Children who spend considerable time playing electronic screen games for entertainment, physically active games seem to have a safe, fun, and valuable means of promoting energy expenditure.
(Heston and Lazar, 1980)	2	Games are included into the final list (see Appendix 2)	5 subjects showed an initial increase in knowledge, but without reinforcement, demonstrated minimal retention. 6 control subjects showed no increase in knowledge

(Derryberry, 2007)	1	Games are included into the final list (see Appendix 2)			Adolescents reported protective factors and facilitators to engaging in risk behaviors, including (1) their personal ability to balance the tension between individuation and group membership, (2) the presence of stable mentor figures in their life, and (3) the neighborhood in which they live
(Hong et al., 2010)	2	Games are included into the final list (see Appendix 2)			Design requirements: 1. Helping community health workers provide education, support for behavior change, and resources to control triggers effectively. 2. Helping parents control environmental asthma triggers and minimize children's exposure to indoor triggers. 3. Supporting children's experimental learning about asthma triggers in real-world environments
(Hyde et al., 2011)	2	Games are included into the final list (see Appendix 2)			Measurements of usability (alpha testing), user adoption and effectiveness as future steps
(Kahol, 2011)	2	Games are included into the final list (see Appendix 2)			Identified 3 groups of games: Games for Nutrition, Games for Exercise, Games Focused on Teaching Compliance
(Kanstrup et al., 2008)	2	Games are included into the final list (see Appendix 2)			Participatory design: real problem+ designer's share. Main functions of games for diabetes: motivation, training and performance
(Mulvaney et al., 2012)	2	Cancer		Not specified	Teenager, young adults (13-25 years old) An action video game could be useful to nurses as a tool to improve understanding and self-care of adolescent and young adult cancer patients
(Kato et al., 2008)	1	Cancer		Not specified	Teenager, young adults (13-29 years old) The video-game intervention significantly improved treatment adherence and indicators of cancer-related self-efficacy and knowledge in adolescents and young adults who were undergoing cancer therapy.
(Kharrazi and Faiola, 2010)	1	T1DM		Not specified	Children (age is not specified) Health Belief Model is applied. Empowerment adolescents for positive changes in health behavior both now and into full adulthood
(Kharrazi et al., 2009)	2	Games are included into the final list (see Appendix 2)			Health Belief Model, Planned Behavioral Model are applied. 2 phases: Gaming Pilot Design and Testing Stage; Gaming Pilot Testing Stage
(Kharrazi et al., 2012)	2	Not specified		Not specified	Not specified 6 types of games: (1) educational games; (2) behavioral games; (3) cognitive games; (4) exercise games; (5) rehab games; and (6) hybrid games. Computer-based videogames: 67.8 % of the health games, console-based: 31.5 % of them, for mobile devices: 5%
(Kim et al., 2011)	2	Games are included into the final list (see Appendix 2)			All the children enjoyed using it and thought that it would benefit them by helping them make informed decisions while they were shopping with their parents. The game helps under such circumstances by keeping the user focused on the nutritional perspective of all the items in the store.
(Koivisto et al., 2011)	2	Games are included into the final list (see Appendix 2)			Sufficient flow experience since the audience, other players, game graphics etc. did not play major role in the game experience of the players. In addition, the players did not consider the game as hard exercise. The physical actions the players perform are not at the focal point
(Deeb et al., 2011)	1	Games are included into the final list (see Appendix 2)			Visual feedback and variable reinforcement through scoring points are tangible benefits provided to patients by DiaBetNet. Increased frequency of monitoring, reduced occurrences of hyperglycemia, improved diabetes knowledge, and possibly optimized

						glycemic control.	
(Toscos, 2011)	2	T1DM		Not specified	Children (age is not specified), adolescents	Combining beneficial social media integrated gameplay mechanics with serious games as a valuable tool for educating children and adolescents with T1DM	
(Lauritzen et al., 2012)	2	T1DM		Not specified	Children (age is not specified)	3 characteristics of the social games: (1) involve learning skills and planning actions/ activities to achieve the best results; (2) reward the player; (3) use status sharing for other purposes. 4 types of mini-games: counseling; avatar; mixed reality; quiz	
(Lee, 2012)	2	Games are included into the final list (see Appendix 2)					Lessons from users' feedback: 1. Independent play is the most important. 2. Children prefer high-quality interaction just as adults do. 3. Play first, and learning will follow.
(Lehmann, 1997)	2	Games are included into the final list (see Appendix 2)					The need for improved graphical user interfaces, and for further efforts to evaluate such programs and demonstrate an educational benefit from their use are identified as hurdles to their more widespread application
(Lewis, 2007)	2	Not specified		Not specified	Children (age is not specified)	Questions to be answered while developing serious games for children: Theory based? Approved best practices? Time on task? How assessed?	
(Lieberman, 2006)	2	Games are included into the final list (see Appendix 2)					Research is finding that exergames are highly appealing, motivating, and fun, and they offer compelling game challenges, a chance to perform athletically or expressively for others, and a way to meet and interact with others in friendships and in communities
(Lu et al., 2012)	2	Games are included into the final list (see Appendix 2)					Ethnic similarity between videogame characters and players enhanced immersion and several health outcomes, motivating children to adopt obesity prevention behaviors
(Macvean and Robertson, 2012)	1	Games are included into the final list (see Appendix 2)					It is possible to facilitate moderate to vigorous - yet enjoyable - exercise in adolescents using a pervasive exercise game. A successful design could be one in which the exertion mechanics involved repetitions of a task interspersed with rest periods but an additional mechanic increased the cognitive challenge for the player during the rests
(Macvean, 2012)	2	Obesity		Not specified	Not specified	Game appealed to both boys and girls; Players were not affected by game outcome; Different players found motivation from different areas; When given the opportunity to manually override difficulty levels, a wide variety of behavior was observed	
(Fuchslocher et al., 2010)	2	Games are included into the final list (see Appendix 2)					In Ego-Involved games individuals at the lower end of the performance spectrum will become demotivated, while in Task-Involved games, individuals of all standards have been shown to flourish with those at both ends of the spectrum motivated to improve on previous performances
(Mansour et al., 2009)	2	Games are included into the final list (see Appendix 2)					The game should (1) teach heuristics about food that will actually be remembered and used when making eating decisions, (2) design a game that adolescents would like to play multiple times, (3) be entertaining and, by virtue, increase the likelihood of continued playing. It allows for collaboration and increases the excitement in the game. The division of players into teams also pulls the players' existing knowledge together

(Kumar, 2004)	1	T1DM		Mobile phone	Adolescents	Mobile phones provide a feasible method to measure glucose monitoring and insulin administration. The method provided novel insights regarding patterns of adherence
(Nikkila et al., 2012)	2	Games are included into the final list (see Appendix 2)				Design principles: social gaming features, detailed reports/ statistics, added value through expansions. Contributions of the game are the incorporation of social gaming features and the medical regimen itself into the game, thus providing additional incentive for children and adolescents to adhere to the regimen.
(Patterson et al., 2011)	2	Games are included into the final list (see Appendix 2)				ERCA principles: 1) create a tight marriage among content, game play, and valued ways of thinking and acting; 2) motivate learning through social engagement; 3) assess learning through game play; 4) provide cutting-edge content that integrates new medical technologies. + 3 scenarios for serious games
(Kato and Beale, 2006)	2	Games are included into the final list (see Appendix 2)				Games should be fun. By providing incremental rewards, the game will promote a stronger relationship between children and their pet, thereby increasing their desire to eat healthily
(Rizzo et al., 2011)	2	Games are included into the final list (see Appendix 2)				VR and interactive digital game technology. Computing, display, and interaction can promote health-relevant activities, and provide another essential ingredient for positive attitude and behavior change
(Ruppert, 2011)	2	Games are included into the final list (see Appendix 2)				More realistic and immersive game play. The ability to convey emotion plays an important role in games effectiveness. With a virtual environment, individuals perceive less stigma, and it does not seem as clinical
(Gorgu et al., 2010)	1	Diabetes		Not specified	Children 7-14 years old, >14 years old	Self-monitoring wireless tools for blood glucose control are effective for the management of diabetes, diabetes self-care, and lifestyle modification
(Scheider et al., 2012)	1	Obesity T2DM		Internet	Children 8-12 years old	Significant increases in positive attitudes toward healthy eating and healthy eating self-efficacy and marginally significant increases in nutrition knowledge
(Stinson et al., 2009)	1	Not specified		Not specified	Children (age is not specified)	Symptoms improved in internet interventions compared to control conditions in seven of nine studies
(Thai et al., 2009)	2	Not specified		Not specified	Children (age is not specified)	Well-designed digital games show significant potential to promote children's growth and healthy development. They can foster skills and knowledge that help children with academic learning, as well as habits which contribute to better health
(Thompson et al., 2007a)	2	T2DM		Not specified	Children (9-11 years old)	Alpha testing identifies problems with possible negative effects on functionality, usability, and comprehension during development, provides an opportunity to correct these issues prior to final production
(Thompson et al., 2010)	2	T1DM		Not specified	Children (age is not specified)	Characters should include both protagonists and antagonists. Goal setting and goal review should be embedded in the gameplay. Character modeling and dialogue can convey knowledge, demonstrate skills, and enhance self-efficacy. Providing choice, connecting goals to personal values, providing immediate performance-related feedback, and structuring the game in levels with challenges that gradually increase in difficulty would enhance competence, self-efficacy, and internal motivation.

(DeShazo et al., 2010)	2	T1DM		Not specified	Children (8-19 years old)	Barriers: BG logging, engage children. Emotions: fear, social rejection. Regardless of how enticing and fun it may be, if a technology does not help a person make sense of health data in a way that maps to their values it is likely to be abandoned over time
(Gao and Mandryk, 2012)	2	Not specified		Not specified	Children (age is not specified)	Gaming world for children: (a) easy and continual gaming access; (b) games are personalized and adaptable based on the child's interests or specific illness; and (c) maintain novelty and interest in the treatment over time. Patients will be more engaged in the management of their treatment using the game. User profile information is stored for each player, so that the game content and play style can be tailored to the needs of individual players

## Appendix 2

**Table: Videogames for chronic diseases mentioned in relevant literature and elsewhere**

#	Source	Game title	Platform	Game type	Game Internet link	Target group
1	(Frederico, 2012)	<i>Food Focus: Fruits</i>	iPhone		<a href="https://itunes.apple.com/us/app/food-focus-fruits/id413089696?mt=8">https://itunes.apple.com/us/app/food-focus-fruits/id413089696?mt=8</a>	Children (age is not specified)
2		<i>Max's Plate</i>	iPhone		<a href="https://itunes.apple.com/us/app/maxs-plate/id471761180?mt=8">https://itunes.apple.com/us/app/maxs-plate/id471761180?mt=8</a>	Children (age is not specified)
3	(Getchell et al., 2012)	<i>Wii Sports</i>	Nintendo Wii		<a href="http://www.nintendo.com/games/detail/1OTtO06SP7M52gi5m8pD6CnabhW8CzxE">http://www.nintendo.com/games/detail/1OTtO06SP7M52gi5m8pD6CnabhW8CzxE</a>	General Audience
4		<i>Fit</i>	Nintendo Wii		<a href="http://www.nintendo.com/games/detail/hoiNtus4JvIcPtP8LQPyud4Kyy393oep">http://www.nintendo.com/games/detail/hoiNtus4JvIcPtP8LQPyud4Kyy393oep</a>	General audience. Obesity
5		<i>Dance Dance Revolution</i>	Xbox Kinect		<a href="http://www.ddrgame.com/">http://www.ddrgame.com/</a>	General Audience
6	(Errickson et al., 2012)	<i>Dance Dance Revolution</i>	duplicate			
7	(Hyde et al., 2011)	<i>Go.Me</i>	iPhone		Unknown	Children and Adolescents. T1D
8	(Lee, 2012)	<i>Injini</i>	iPad		<a href="http://www.injini.net/">http://www.injini.net/</a>	Children with Special Needs
9	(Derryberry, 2007)	<i>Unknown</i>	Unknown		Unknown	Adolescents (10-15 years old). HIV prevention
10	(Scheider et al., 2012)	<i>Fitter Critter</i>	Web		<a href="http://appsforhealthykids.com/submissions/6134-fitter-critters">http://appsforhealthykids.com/submissions/6134-fitter-critters</a>	Children 8-12 years old
11	(Bassilious et al., 2012)	<i>Power Defence</i>	PC		<a href="http://www.youtube.com/watch?v=iKUSfBRv_JI">http://www.youtube.com/watch?v=iKUSfBRv_JI</a>	Adolescents. T1D
12		<i>Ketones Attack</i>	Web		<a href="http://www.jdrft1.org.uk/games/attack.html">http://www.jdrft1.org.uk/games/attack.html</a>	Children (age is not specified). T1D
13		<i>Diabetes Dash</i>	Web		<a href="http://www.jdrft1.org.uk/games/dash.html">http://www.jdrft1.org.uk/games/dash.html</a>	Children (age is not specified). T1D
14		<i>The Diabetic Dog</i>	Web		<a href="http://www.nobelprize.org/educational/medicine/insulin/game/insulin.html">http://www.nobelprize.org/educational/medicine/insulin/game/insulin.html</a>	Adults, Pre-Teens, Teens, Young Adults
15		<i>Packy &amp; Marlon</i>	Super Nintendo		<a href="http://www.comm.ucsb.edu/faculty/lieberman/">http://www.comm.ucsb.edu/faculty/lieberman/</a>	Children (age is not specified). T1D
16		<i>The Magi and the Sleeping Star</i>	PC		<a href="http://themagigame.net/">http://themagigame.net/</a>	Pre-Teens, Teens, Young Adults. Diabetes
17	(Heston and Lazar, 1980)	<i>OK Insulin</i>	Unknown		Unknown	Children 7-12 years old. T1D
18	(Lehmann, 1997)	<i>BG Pilot</i>	PC		Unknown	Children (age is not specified)

19		<b>Captain Novocare</b>	PC		Unknown	Children (age is not specified)
20		<b>Captain Novolin</b>	Super Nintendo		<a href="http://coolrom.com/roms/snes/1821/Captain_Novolin.php">http://coolrom.com/roms/snes/1821/Captain_Novolin.php</a>	Children (age is not specified)
21		<b>Packy &amp; Marlon</b>	duplicate			
22		<b>Fit</b>	duplicate			
23	(Ruppert, 2011)	<b>Dance Dance Revolution</b>	duplicate			
24		<b>Tamagoya</b>	Handheld device		<a href="http://www.trademarkia.com/tamagoya-76654349.html">http://www.trademarkia.com/tamagoya-76654349.html</a>	Children (age is not specified)
25	(Kahol, 2011)	<b>Tantei (Detective)</b>	Handheld device	Unknown	Unknown	Children (age is not specified). Diabetes
26		<b>Magic Toom (Buildup Blocks)</b>	Handheld device	Unknown	Unknown	Children (age is not specified)
27		<b>MetaKenKoh</b>	Web		<a href="http://www.metakenkoh.com/">http://www.metakenkoh.com/</a>	Children 9-11 years old. Obesity
28	(Glasemann et al., 2010)	<b>Dragon Quest</b>	Nintendo DS	Unknown	<a href="http://vgsales.wikia.com/wiki/Dragon_Quest">http://vgsales.wikia.com/wiki/Dragon_Quest</a>	General Audience
29		<b>Dance Dance Revolution</b>	duplicate			
30	(Lieberman, 2006)	<b>In the Groove</b>	PC, PlayStation 2		<a href="http://www.giantbomb.com/in-the-groove/61-23832/">http://www.giantbomb.com/in-the-groove/61-23832/</a>	General Audience
31		<b>EyeToy (video game series)</b>	PlayStation 2		<a href="http://en.wikipedia.org/wiki/EyeToy_%28video_game_series%29">http://en.wikipedia.org/wiki/EyeToy_%28video_game_series%29</a>	General Audience
32	(Rizzo et al., 2011)	<b>Dance Dance Revolution</b>	duplicate			
33		<b>Wii Sports</b>	duplicate			
34		<b>Re-Mission</b>	PC		<a href="http://www.re-mission.net/">http://www.re-mission.net/</a>	Young adults (13-29 years old). Cancer
35	(Brown et al., 1997)	<b>Packy &amp; Marlon</b>	duplicate			
36		<b>Packy &amp; Marlon</b>	duplicate			
37	(Gerling et al., 2011)	<b>Bronkie the Bronchiasaurus</b>	Nintendo		<a href="http://www.comm.ucsb.edu/faculty/lieberman/">http://www.comm.ucsb.edu/faculty/lieberman/</a>	Children (age is not specified). Asthma and Respiratory Health
38		<b>Re-Mission</b>	duplicate			
39		<b>Cytarius</b>	Unknown		<a href="http://www.youtube.com/watch?v=ghJv3eDxVF8">http://www.youtube.com/watch?v=ghJv3eDxVF8</a>	Children (age is not specified). Cancer
40	(Baranowski et al., 2008)	<b>Store</b>	Unknown		Unknown	Children (school age, 3rd-5th graders)
41		<b>Guess Who</b>	Unknown		Unknown	Children (school age, 3rd-5th graders)

42		<b>Granny Smith</b>	Unknown		Unknown	Children (school age, 3rd-5th graders)
43		<b>The Restaurant</b>	Unknown		Unknown	Children (school age, 3rd-5th graders)
44		<b>Squire's Quest!</b>	Web		<a href="http://clinicaltrials.gov/ct2/show/NCT01004094">http://clinicaltrials.gov/ct2/show/NCT01004094</a>	Children (age is not specified)
45		<b>Boy Scout 5A Day Badge</b>	Web		<a href="http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=198453">http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=198453</a>	Children, Pre-Teens, Teens. Obesity
46		<b>Dance Dance Revolution</b>	duplicate			
47		<b>EyeToy</b>	duplicate			
48		<b>MetaKenKoh</b>	duplicate			
49		<b>Escape from Diab!</b>	PC		<a href="http://www.escapefromdiab.com/">http://www.escapefromdiab.com/</a>	Children (age is not specified). Diabetes
50		<b>Nanoswarm: Invasion from Inner Space</b>	PC, Videogame console		<a href="http://www.archimage.com/portfolio-screeningroom-nanoswarm.cfm">http://www.archimage.com/portfolio-screeningroom-nanoswarm.cfm</a>	Children, Pre-Teens. Obesity, T2D
51		<b>Watch, Discover, Think &amp; Act</b>	PC		<a href="http://www.eric.ed.gov/ERICWebPortal/search/detailmini.jsp?_nfpb=true&amp;_ERICExtSearch_SearchValue_0=EJ617537&amp;ERICExtSearch_SearchType_0=no&amp;accno=EJ617537">http://www.eric.ed.gov/ERICWebPortal/search/detailmini.jsp?_nfpb=true&amp;_ERICExtSearch_SearchValue_0=EJ617537&amp;ERICExtSearch_SearchType_0=no&amp;accno=EJ617537</a>	Children, Pre-Teens. Asthma and Respiratory Health
52		<b>Wee Willie Wheezie</b>	PC		<a href="http://www.bio.net/bionet/mm/immuno/1996-July/008110.html">http://www.bio.net/bionet/mm/immuno/1996-July/008110.html</a>	Children, Pre-Teens. Asthma and Respiratory Health
53		<b>The Astma Files</b>	PC		<a href="http://www.childtrends.org/Lifecourse/programs/asthmafiles.htm">http://www.childtrends.org/Lifecourse/programs/asthmafiles.htm</a>	Children (7-14 years old). Asthma
54		<b>Packy &amp; Marlon</b>	duplicate			
55		<b>Insulot</b>	Cell phone		<a href="http://www.changemakers.com/competition/healthgames/entries/insulot-cellular-phone-based-edutainment-learning-tool">http://www.changemakers.com/competition/healthgames/entries/insulot-cellular-phone-based-edutainment-learning-tool</a>	Children (age is not specified). Diabetes
56		<b>Tamagoya</b>	duplicate			
57		<b>Detective</b>	duplicate			
58		<b>Buildup Blocks</b>	duplicate			
59		<b>Re-Mission</b>	duplicate			
60	(Kato et al., 2008)	<b>Re-Mission</b>	duplicate			
61	(Baranowski et al., 2010)	<b>Escape from Diab!</b>	duplicate			
62		<b>Nanoswarm: Invasion from Inner Space</b>	duplicate			
63		<b>Fun, Food &amp; Fitness!</b>	Web		<a href="http://pbskids.org/itsmylife/body/eatingdisorders/article6">http://pbskids.org/itsmylife/body/eatingdisorders/article6</a>	General Audience

				<a href="#">html</a>		
64		<i>Squire's Quest!</i>	duplicate			
65		<i>Packy &amp; Marlon</i>	duplicate			
66	(Kharrazi et al., 2009)	<i>Glucoboy</i>	Ninten do Advanc e, Ninten do Game Boy		<a href="http://www.joystiq.com/2005/12/06/glucoboy-game-boy-glucose-meter/">http://www.joystiq.com/2005/12/06/glucoboy-game-boy-glucose-meter/</a>	Children (age is not specified). T1D
67		<i>Escape from Diab!</i>	duplicate			
68		<i>Nanoswarm: Invasion from Inner Space</i>	duplicate			
69		<i>MyPyramid Blast Off</i>	Web		<a href="http://teamnutrition.usda.gov/resources/game/blastoff_game.html">http://teamnutrition.usda.gov/resources/game/blastoff_game.html</a>	Children (age is not specified)
70		<i>Insulot</i>	duplicate			
71		<i>Fatworld</i>	PC, Mac		<a href="http://www.fatworld.org/">http://www.fatworld.org/</a>	Children (age is not specified). Obesity. Diabetes
72		(Aoki et al., 2005)	<i>Insulot</i>	duplicate		
73	(Lu et al., 2012)	<i>Family Eats</i>	Web		<a href="http://www.familyeats.net/">http://www.familyeats.net/</a>	General Audience
74		<i>Escape from Diab!</i>	duplicate			
75		<i>Nanoswarm: Invasion from Inner Space</i>	duplicate			
76		<i>Fun, Food &amp; Fitness!</i>	duplicate			
77		<i>Squire's Quest!</i>	duplicate			
78		<i>Boy Scout 5A Day Badge</i>	duplicate			
79	(Patterson et al., 2011)	<i>Asthma Command</i>	PC		<a href="http://www.childtrends.org/Lifecourse/programs/asthma_command.htm">http://www.childtrends.org/Lifecourse/programs/asthma_command.htm</a>	Children (7-12 years old). Asthma
80		<i>Bronkie the Bronchiasaurus</i>	duplicate			
81		<i>Insulot</i>	duplicate			
82		<i>Detective</i>	duplicate			
83		<i>Buildup Blocks</i>	duplicate			
84		<i>Escape from Diab!</i>	duplicate			
85		<i>Nanoswarm: Invasion from Inner Space</i>	duplicate			
86		<i>Glucoboy</i>	duplicate			

87		<i>Packy &amp; Marlon</i>			duplicate		
88		<i>Captain Novolin</i>			duplicate		
89		<i>Didget</i>	Ninten do DS, Ninten do DS Lite		<a href="http://www.bayerdidget.ca/Home">http://www.bayerdidget.ca/Home</a>	Children (age is not specified). Diabetes	
90		<i>The Magi and the Sleeping Star</i>			duplicate		
91		<i>The Diabetic Dog</i>			duplicate		
92		<i>Tamagoya</i>			duplicate		
93		<i>Re-Mission</i>			duplicate		
94	<a href="http://www.healthgamesresearch.org/">http://www.healthgamesresearch.org/</a>	<i>Alimentary My Dear Joe</i>	Unkon own		Unknown	Children (age is not specified). Diabetes	
95		<i>Build a Healthy Kid</i>	Web		<a href="http://web.diabetes.org/video/youth/healthykid.swf">http://web.diabetes.org/video/youth/healthykid.swf</a>	Children (age is not specified). Diabetes	
96		<i>Build a Healthy Plate</i>	Web		<a href="http://web.diabetes.org/video/youth/plate.swf">http://web.diabetes.org/video/youth/plate.swf</a>	Children (age is not specified). Diabetes	
97		<i>Community Clash</i>	Web		<a href="http://www.meyouhealth.com/clash/">http://www.meyouhealth.com/clash/</a>	General Audience	
98		<i>dbaza's Diabetes Education for Kids</i>	PC		<a href="http://www.dbaza.com/dek/index.html">http://www.dbaza.com/dek/index.html</a>	Children (age is not specified). Diabetes	
99		<i>Didget</i>				duplicate	
100		<i>Escape from Diab!</i>				duplicate	
101		<i>Fatworld</i>				duplicate	
102		<i>Fix Frank</i>	Web		<a href="http://web.diabetes.org/video/youth/frank.swf">http://web.diabetes.org/video/youth/frank.swf</a>	Children (age is not specified)	
103		<i>Glymetrix</i>	PC, handheld device		<a href="http://www.changemakers.com/competition/healthgames/entries/improving-diabetes-self-management">http://www.changemakers.com/competition/healthgames/entries/improving-diabetes-self-management</a>	General Audience	
104		<i>Glymetrix Diabetes Game: Quiz Game</i>	Web		<a href="http://www.diabetesgame.com/">http://www.diabetesgame.com/</a>	General Audience	
105		<i>Glymetrix Diabetes Game: Solitaire</i>	Web		<a href="http://www.diabetesgame.com/">http://www.diabetesgame.com/</a>	General Audience	
106		<i>GRIP</i>	PC		<a href="http://www.ranj.com/content/werk/grip">http://www.ranj.com/content/werk/grip</a>	Children (age is not specified). Diabetes	
107		<i>HealthSeeker</i>	Web, Android, iPhone		<a href="http://apps.facebook.com/healthseeker/">http://apps.facebook.com/healthseeker/</a>	General Audience. Diabetes	
108		<i>Insulot</i>				duplicate	
109		<i>Juice Jumble</i>	Web		<a href="http://www.playnormous.com/games/juice-jumble">http://www.playnormous.com/games/juice-jumble</a>	Children (age is not specified)	
110		<i>Lunch Crunch</i>	Web		<a href="http://www.playnormous.com/games/lunch-crunch">http://www.playnormous.com/games/lunch-crunch</a>	Children (age is not specified)	

111		<b>Lunch Crunch 2</b>	Web		<a href="http://www.playnormous.com/games/lunch-crunch-2">http://www.playnormous.com/games/lunch-crunch-2</a>	Children (age is not specified)
112		<b>Nanoswarm: Invasion from Inner Space</b>	duplicate			
113		<b>Packy &amp; Marlon</b>	duplicate			
114		<b>The Diabetic Dog</b>	duplicate			
115		<b>The Kore: Fitness Challenge, Move Mixer</b>	Web		<a href="http://www.kidnetic.com/">http://www.kidnetic.com/</a>	Children (age is not specified). Diabetes
116		<b>The Magi and the Sleeping Star</b>	duplicate			
117		<b>Zamzee</b>	Handheld device, Web		<a href="https://www.zamzee.com/">https://www.zamzee.com/</a>	General Audience, Pre-Teens, Teens
118		<b>Bronkie the Bronchiasaurus</b>	duplicate			
119		<b>Dance Dance Revolution</b>	duplicate			
120		<b>Free Dive</b>	Unknown		<a href="http://www.breakawaygames.com/serious-games/solutions/healthcare/free_dive.html">http://www.breakawaygames.com/serious-games/solutions/healthcare/free_dive.html</a>	Children (age is not specified). Cancer, pain
121	<a href="http://www.google.com">http://www.google.com</a>	<b>Time Out</b>	Web		<a href="http://www.gluciweb.com/timeout/en/">http://www.gluciweb.com/timeout/en/</a>	Teenagers, young adults. T1D
122		<b>bant</b>	iPhone		<a href="http://www.bantapp.com/">http://www.bantapp.com/</a>	Teenagers. T1D
123	Eli Lilly Norge A.S.	<b>Equilize</b>	Web		<a href="http://www.equalize.no/">http://www.equalize.no/</a>	Children, teenagers
124	Google Market	<b>Go Fish! SugarKidsClub</b>	Android		<a href="https://play.google.com/store/apps/details?id=org.games4all.android.games.gofish_dvn.prod&amp;feature=search_result">https://play.google.com/store/apps/details?id=org.games4all.android.games.gofish_dvn.prod&amp;feature=search_result</a>	Children (age is not specified). Diabetes
125		<b>Tina the Cat</b>	Android		<a href="https://play.google.com/store/apps/details?id=air.tinaTheCat&amp;feature=search_result">https://play.google.com/store/apps/details?id=air.tinaTheCat&amp;feature=search_result</a>	Children (age is not specified). Diabetes
126		<b>HealthSeeker</b>	Android, iPhone		<a href="http://apps.facebook.com/healthseeker/">http://apps.facebook.com/healthseeker/</a>	General Audience. Diabetes
127	iTunes Store	<b>Da hunger</b>	iPhone, iPad		<a href="http://www.feeddahunger.com/">http://www.feeddahunger.com/</a>	General Audience. Diabetes. Obesity
128		<b>Da hunger Lite</b>	iPhone, iPad		<a href="https://itunes.apple.com/us/app/da-hunger-lite-for-ipad/id491261177?mt=8">https://itunes.apple.com/us/app/da-hunger-lite-for-ipad/id491261177?mt=8</a>	General Audience. Diabetes. Obesity
129		<b>Jake Gets Diabetes</b>	iPhone, iPad		<a href="https://itunes.apple.com/hk/app/jake-gets-diabetes/id429948204?mt=8">https://itunes.apple.com/hk/app/jake-gets-diabetes/id429948204?mt=8</a>	Children (age is not specified). Diabetes
130		<b>iDiabetesKids</b>	iPhone		<a href="https://itunes.apple.com/hk/app/idiabeteskids/id364758905?mt=8">https://itunes.apple.com/hk/app/idiabeteskids/id364758905?mt=8</a>	Children (school-aged). Diabetes

131	(Buday et al., 2012)	<i>Nanoswarm: Invasion from Inner Space</i>	duplicate			
132		<i>Escape from Diab!</i>	duplicate			
133	(Cafazzo et al., 2012)	<i>bant app</i>	duplicate			
134	(Hieftje et al., 2012)	<i>Didget</i>	duplicate			
135	(Watters et al., 2006)	<i>Packy &amp; Marlon</i>	duplicate			
136		<i>Insulot</i>	duplicate			
137		<i>Tamagoya</i>	duplicate			
138		<i>Detective</i>	duplicate			
139		<i>Buildup Blocks</i>	duplicate			
140		<i>Glucoboy</i>	duplicate			
141		<i>Escape from Diab!</i>	duplicate			
142		<i>Captain Novolin</i>	duplicate			
143		<i>dbaza's Diabetes Education for Kids</i>	duplicate			
144			<i>DiaBetNet</i>	PC		<a href="http://slie.dyndns.org/projects/DiaBetNet/webpage/">http://slie.dyndns.org/projects/DiaBetNet/webpage/</a>
145		<i>Starbright Life</i>	PC		<a href="http://www.muehlmatt.com/eric/starbright.html">http://www.muehlmatt.com/eric/starbright.html</a>	Children (5-18 years old). Diabetes
146	(Deeb et al., 2011)	<i>DiaBetNet</i>	duplicate			
147	(Kato and Beale, 2006)	<i>Time to Eat!</i>	iPhone		<a href="https://itunes.apple.com/us/app/time-2-eat/id383695571?mt=8">https://itunes.apple.com/us/app/time-2-eat/id383695571?mt=8</a>	General Audience
148	(Graf et al., 2009)	<i>Dance Dance Revolution</i>	duplicate			
149	(Chen et al., 2011)	<i>Balance</i>	Web		Unknown	Teenagers. T1DM
150	(Fuchslocher et al., 2010)	<i>Fit</i>	duplicate			
151		<i>Dance Dance Revolution</i>	duplicate			
152		<i>iFitQuest</i>	iPhone		<a href="http://www.macs.hw.ac.uk/~apm8/University_Site/pubSub.html">http://www.macs.hw.ac.uk/~apm8/University_Site/pubSub.html</a>	Adults. Obesity
153		<i>Fish'n'Steps</i>	PC		<a href="http://www.informatics.uci.edu/research/research_highlight_view.php?id=38">http://www.informatics.uci.edu/research/research_highlight_view.php?id=38</a>	General Audience
154		<i>NEAT-o-Games</i>	Mobile phone		<a href="http://www.webmd.com/fitness-exercise/video/computer-game-weight-loss">http://www.webmd.com/fitness-exercise/video/computer-game-weight-loss</a>	General Audience. Obesity
155	(Gao and Mandryk, 2012)	<i>GrabApple</i>	iPhone		<a href="http://hci.usask.ca/publications/view.php?id=233">http://hci.usask.ca/publications/view.php?id=233</a>	Children (age is not specified). Obesity
156	(Gorgu et al., 2010)	<i>Freegaming Mobile Application</i>	Mobile phone		Unknown	Young adults. Obesity

157	(Hong et al., 2010)	<b>TriggerHunter</b>	Mobile phone		<a href="http://www.prism.gatech.edu/~hhong31/triggerhunter.html">http://www.prism.gatech.edu/~hhong31/triggerhunter.html</a>	Children (age is not specified). Asthma
158	(Kanstrup et al., 2008)	<b>Packy &amp; Marlon</b>	duplicate			
159		<b>DiaBetNet</b>	duplicate			
160		<b>Glucoboy</b>	duplicate			
161	(Kim et al., 2011)	<b>Grocery Hunter</b>	Mobile phone		<a href="http://www.anyakogan.com/portfolio/grocery_hunter/grocery_hunter.php">http://www.anyakogan.com/portfolio/grocery_hunter/grocery_hunter.php</a>	Children (7-11 years old). Obesity
162	(Koivisto et al., 2011)	<b>Bug Attack</b>	Mobile phone		<a href="http://www.agame.com/game/bug-attack.html">http://www.agame.com/game/bug-attack.html</a>	Children (age is not specified). Obesity
163	(Mansour et al., 2009)	<b>MunchCrunch</b>	PC		Unknown	Young adults. Obesity
164	(Nikkila et al., 2012)	<b>Wind Runners</b>	Mobile phone		Unknown	Children (8-14 years old). Asthma

## Appendix 3

# Letter to Children's Parents (Focus Group Meeting)

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Nasjonalt senter for samhandling og telemedisin  
Postboks 35  
9038 Tromsø  
Telefon 07766  
Telefaks 77 75 40 98  
info@telemed.no

Tromsø, 21. januar 2013

### Informasjon til barn og deres foreldre angående hjelp til forskning innen seriøse spill:

En del av Universitetssykehuset i Nord Norges oppgaver er forskning, og veiledning av studenter. En forskningsgruppe ved Telemedisin, ledet av Eirik Årsand, veileder en student som skal utvikle opplærende spill for barn med Type 1 diabetes, og for å gjøre dette, trenger hun hjelp/input fra barn generelt om hvilke spill som vil være motiverende. Dersom deres barn vil bidra til dette, ville det være kjempenyttig for studenten. Nedenfor beskriver studenten litt om hennes masteroppgave og hva hun trenger hjelp til. Bare ring dersom dere trenger mer informasjon.  
Vennlig hilsen Eirik Årsand (tlf. 992 43 592)

Heil Jeg heter Alexandra. Jeg er andre års master student i telemedisin og elektronisk helse på Universitetet i Tromsø. Nå jobber jeg med min mastergradsoppgave og utvikler spill til mobiltelefon for barn med type 1 diabetes. Nå har jeg jobbet fram en prototype og trenger hjelp til å vurdere denne: jeg er interessert i barnas meninger og ønsker om dette spillet, og til å forbedre det. Også jeg vil prøve å skjønne hvor mye barna spiller og hvilke spilletyper de foretrekker.

Jeg vil gjerne møte barna på torsdag 24. januar etter skoletid – ca. 14:30. Møtet vil foregå på Nasjonalt senter for samhandling og telemedisin sitt møterom. Det vil ta cirka en time. Barna får servert litt mat og vi blir å diskutere.

Jeg vil ta opp vår diskusjon på min mobiltelefon for mer lettvin registrering av ønsker og meninger. Ingen, unntatt meg, vil kunne høre dette opptaket: verken andre forskere, og heller ikke foreldre. Ingen navn eller andre personlige data vil bli brukt. Etter analyse vil opptaket bli fjernet.

Etter møtet vil barna bli kjørt hjem av Eirik Årsand (Grys far), og eventuelle bussbilletter hit vil bli betalt.

Med vennlig hilsen,

Alexandra Makhlysheva





## Appendix 4

### Plan for Meeting with Children

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#### Meetings with children to collect requirements for design of the application

I am going to meet with small groups of children (for example, 4-6 children). Meetings will be recorded for more convenient further analysis. The record will not be available for anyone else, except me, and will be removed after processing. Parents were notified about the meeting procedure.

In the beginning, I will introduce myself and explain what we are going to do during the meeting.

*Hei! Jeg heter Alexandra. Jeg studerer på Universitetet i Tromsø. Nå driver jeg med min mastergradsoppgave og utvikler spill til mobiltelefon for barn med type 1 diabetes. Nå har jeg jobbet fram en prototype og trenger hjelp til å vurdere denne: jeg er interessert i deres meninger og ønsker om dette spillet, og til å forbedre det.*

First, children can eat something to relax a bit and get energy for further discussion. After that, I will notify children about recording of the discussion in the beginning of the meeting.

*Vår diskusjon skal opptas på min mobiltelefon, bare for mer lettvin registrering og lettere analyse av ønsker og meninger. Ingen, unntatt meg, vil kunne høre dette opptaket: verken andre forskere, og heller ikke foreldre. Ingen navn eller andre personlige data vil bli brukt. Etter analyse vil opptaket bli fjernet.*

Meetings will consist of three parts.

The first part: **Answers and Questions (Spørsmål og svar).**

Here I am going to ask children several questions about their game playing experience. Following questions are preliminary.

1. *Hvor gammel(le) er du(dere)?*
2. *Har du (dere): PC, mobiltelefon og/eller en eller flere spillkonsoller?*
3. *Eventuelt hvilken type mobiltelefon og hvilken spillkonsoll(er)?*
4. *Hvor gammel(le) var du (dere) da du fikk din første mobiltelefon?*
5. *Hvor ofte bruker du (dere) mobiltelefon?*
6. *Hvordan bruker du (dere) mobiltelefon? Hvilke programmer/apper på din mobiltelefon er de mest brukte?*
7. *Liker du (dere) å spille?*
8. *Hvilke spill spiller du (dere) nå, eller hvilke har du (dere) spilt i det siste? På PC, mobiltelefon, spillkonsoll, osv.*

*Here I will ask children to show their favorite games on mobile phones if they have ones. I am going to bring some snapshots of popular games.*

9. *Spiller du som oftest for deg selv (deres selv), eller spiller du (dere) i lag med andre? Evt. hvor mange?*
10. *Hvilke sosiale media bruker du? Facebook? Twitter? Instagram? Snapshot? Andre?*
11. *Spiller du noen spill fra disse sosial media? Evt. hvilke?*

The second part: **The game you would like to play (Det spillet som du ville spille).**

Here I would like to discuss with children features of the best game they would like to play if they could create a game themselves.

12. *Hva tiltrekker deg i dine (deres) favorite spillene og hvorfor fortsetter du å spille dem? Grafikk, lyd, historien, tjene credits, eller noe annet? Eventuelt andre ting?*

*Here children can demonstrate something that attracts them in the games they play on mobile phones.*

13. *Forestille at du (dere) kan implementere et spill for deg selv (deres selv). Kan du (dere) beskrive hvilket spill kunne være det spennende for deg (deres)? Evt. grafikk stil, design, former for oppgaver, tegn, noe annet.*

*There will be paper sheets. So participants can draw something.*

14. *Ville du (dere) få noen virkelige premier i et spill? Hva kunne du tenke deg å få som slike premier? For eksempel rabatter på noen varer, kinobilletter, billetter til museer (for eksempel til Polaria), gavekort på idrettsbutikken, bilett/ abonnement til svømmehallen, T-skjorter / penner / notatblokker med spillets logo (logo som et bilde med protagonist(er) (Kari og Per) eller med antagonist (Sint Kakesjefen)), DVD med noen ting (for eksempel med tegnefilmer), osv. Eventuelt andre ting?*

15. *Kan et spill opplære eller motivere noen? Hvilke opplærende eller motiverende spill har du (dere) spilt?*

16. *Ut fra din (deres) mening, hva kan motivere barn med diabetes : å måle blodsukker, spise sunn mat, være fysisk aktive? Kan noe spill gjøre det? Hvorfor eller hvorfor ikke?*

The third part: **The prototype demonstration (Prototypens demonstrasjon).**

Here I will show the current stage of the game prototype to children to see if it can attract them. Stress that they have to tell their honest meaning and feelings about these questions!

17. *Liker du (dere) det?*

18. *Hva liker du (dere) i det spillet?*

19. *Hva bør forandres?*

20. *Ville du (dere) spille det når det er ferdig?*

Then, our meeting ends. I will thank children for attention and active participation and tell them how I will use their input, so that they get a feeling of having been important in an important work and field of research.

### A Poster Presented at the 6<sup>th</sup> International Conference on Advanced Technologies & Treatments for Diabetes (27.02.2013-02.03.2013, Paris, France)

# A Review of Serious Games for Diabetic Patients



Authors: Alexandra Makhlysheva<sup>1</sup>, Eirik Årsand<sup>2,3</sup>, Gunnar Hartvigsen<sup>2</sup>, Jonas Lauritzen<sup>3</sup>

<sup>1</sup>University of Tromsø, Department of Computer Science, Tromsø, Norway  
<sup>2</sup>University Hospital of North Norway, Norwegian Centre for Integrated Care and Telemedicine, Tromsø, Norway  
<sup>3</sup>Aarhus Universitetshospital, Denmark

## Background

The market of serious games is growing rapidly. Nowadays it is a huge industry which revenue totaled about 1.5 billion EUR in the global market in 2010 [1]. Serious games are so popular because of accessibility and ubiquity of devices, easy-to-use interfaces, attractive highly motivating graphics and sounds, and ability of self-paced and entertaining learning through role playing and simulation. Among numerous serious games, there are many games related to diabetes. Thus, the purpose of the following study was to identify: (1) motivational, educational games for behavior changes and self-management skills development, (2) self-management tools specifically developed for children with diabetes, and (3) studies of serious games' effects reported in the literature. Moreover, we wanted to identify (4) significant features of serious games successful among children.



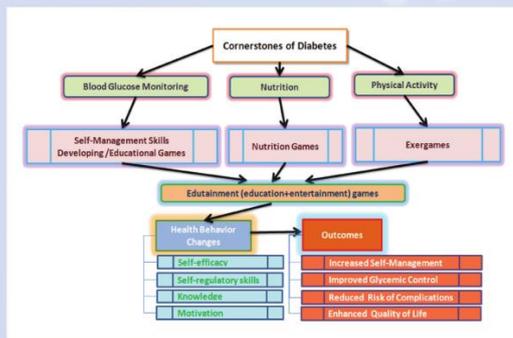
Prototype of the authors' serious game for children with diabetes

## Methods

Relevant studies were systematically searched for in the following databases: PubMed, ACM Digital Library, IEEE Xplore, Google Scholar, Google Books, Google, SAGE journals, and Games For Health Journal. Besides identified literature, the HealthGamesResearch, iTunesStore, and GoogleMarket web sites were searched to find games for children with diabetes.

## Discussion

According to the analyzed content, we identified few serious games built for Android and Windows mobile platforms and an increased use of psychological theoretical frameworks (such as social cognitive theory, self-determination theory, behavior inoculation theory, elaboration likelihood model, and some other theories) in game development. Diabetes related games can be structured as follows, regarding diabetes cornerstones aimed for:

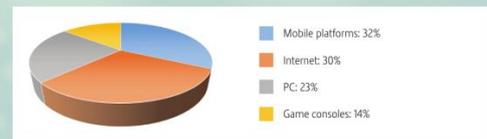


Cornerstones of diabetes, serious videogames and their goals

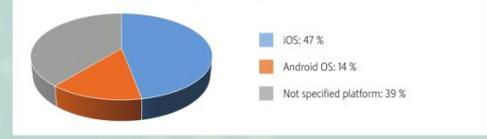
Almost all identified literature affirms that games for health should be enjoyable and fun while being educational, thus so-called "edutainment" tools. Considering serious games for children, an easy game access and understandable gameplay, novelty of game backstory, ability of team play, and an attractive colorful, "cartoons" design style are identified as additional attractions.

## Findings

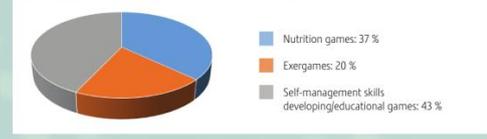
66 papers were selected as relevant and divided into two groups: studies of clinical effects of serious games (25) and papers identifying serious games success criteria (41). Herewith, 89 serious games were found. The following data was extracted from this literature.



Identified serious games platforms



Mobile platforms for serious games



Serious games for diabetes

The following significant features were identified: (1) skill learning by playing a character empathetically related to the player and skill improvement by planning the strategy, (2) getting rewards, (3) facing and solving challenges, (4) attractiveness of game design (such as graphics, sounds, and animations). The features (2)-(4) make the game immersive and, at the same time, enjoyable, while (1) defines the games aimed to educate users. Both groups should be equally considered in development of games for children.

## References

[1] IDATE Report. Serious Games. A 10 billion euro market in 2015, 2010. Available at <http://seriousgamesmarket.blogspot.no/2010/08/idade-serious-games-10-billion-euro.html> [Accessed 07.02.2013]

This study has been supported by:





## Appendix 6

### Questionnaire for Experts at the ATTD Conference 2013

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PLEASE, TAKE A LOOK AT SCREENSHOTS OF THE AUTHORS' PROTOTYPE OF THE SERIOUS GAME FOR CHILDREN WITH TYPE 1 DIABETES AND ANSWER SOME QUESTIONS BELOW ABOUT THE SERIOUS GAMES TOPIC.

1. *Do you believe it is a good idea to build games for "serious" topics, such as chronic diseases, conditions, rehabilitation, surgery/dentistry/etc. training? Why do you think so?*

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2. *Game is a natural activity for people, and especially for children. Therefore, we consider children are an appropriate audience for serious games. Does the children's age matter?*

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3. *If we talk about children with type 1 diabetes, is it the same situation with the "age" - dependency/independency? Why? In a case of dependency, what age is the most susceptible?*

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4. *What features from everyday life of children with type 1 diabetes would you use in a game for them?*

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5. *What can motivate children to adhere to treatment regimens? Which of these motivational factors could be included into the game for children with diabetes?*

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6. *Any comments to the screenshots of the game prototype*

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# Appendix 7

## Invitation Letter to Children's Parents (Meeting for Testing)

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Til barn med Type 1 diabetes og deres foreldre

Nasjonalt senter for samhandling og telemedisin  
Postboks 35  
9038 Tromsø  
Telefon 07766  
Telefaks 77 75 40 98  
info@telemed.no

VÅR REF.:

DERES REF.:  
Alexandra Makhlysheva

Tromsø, 8. mai 2013

### Spill for å lære mer om Type 1 diabetes

Som del av Universitetssykehuset Nord-Norge driver vi også utdanning i samarbeid med Universitetet i Tromsø. Jeg heter Alexandra Makhlysheva og er siste års master student i telemedisin og elektronisk helse hvor jeg utvikler et spill til mobiltelefon for 8-12 års gamle barn med Type 1 diabetes.

Jeg trenger nå hjelp til testing av spillet for å få tilbakemelding på om det passer krav og behov for målgruppen, og for å samle barnas meninger, ønsker og forslag for forbedringer, som kan brukes for fremtidige prosjekter.

Jeg vil i den forbindelse gjerne møte barn og foreldre. Møtet vil foregå etter skoletid på Nasjonalt senter for samhandling og telemedisin i Forskningsparken, 3 etg. – rett nederfor sykehuset. Møtet vil ta mellom 1 og 2 timer, og foregå etter skoletid/arbeidstid etter avtale.

På møtet vil foreldre bli forespurt om å fylle inn et spørreskjema om barnas egenkontroll. I løpet av møtet skal vi snakke litt generelt om spill og diabetes egenkontroll. Deretter vil jeg forklare et spesifikt spill og dets regler, og be barna prøve dette spillet. Deretter vil vi diskutere barnas inntrykk av dette – inkludert om dette kan hjelpe til med barnets forståelse av sykdommen Type 1 diabetes.

Det vil bli gjort lydopptak av diskusjonen for mer lettvin registrering av ønsker og meninger om spillet. Ingen, unntatt meg vil kunne høre dette opptaket: verken andre forskere, og heller ikke foreldre. Ingen navn eller andre personlige data vil bli brukt. Etter analyse vil opptaket bli slettet.

Dersom dere kan tenke dere å delta på dette – vennligst ta kontakt med meg (telefon/ sms) på 969 50 475 for å avtale tidspunkt. Ønskes snarlig tilbakemelding, siden studien min avsluttes i slutten av mai.

Med vennlig hilsen,

Alexandra Makhlysheva





## Appendix 8

### Plan for a Test Meeting

---

#### Test av smarttelefonspill for barn med type 1 diabetes

Til barnets foreldre,

Tusen takk for at dere er villige til å delta i denne testen og forskningen.

Noen ord om meg:

Jeg heter Alexandra Makhlysheva. Jeg er siste års mastergradsstudent i telemedisin og elektronisk helse (e-helse) ved Universitetet i Tromsø. I mitt mastergradsprosjekt har jeg utviklet et spill til mobiltelefon/smarttelefon for barn med type 1 diabetes, hovedsakelig i alderen 8-12 år.

På dette møtet ønsker jeg å få tilbakemelding på om spillet oppfyller de krav som denne aldersgruppen stiller til et slikt spill. Jeg er interessert i alle synspunkt som barnet måtte ha om spillet, samt ønsker og forslag til forbedringer som kan brukes i fremtidige versjoner av spillet, og øvrige prosjekter.

Spillet mitt har jeg kalt for DiaSpill. Det bruker reelle opplysninger om barnets blodsuktermålinger fra en annen app som heter Diabetesdagboka (utviklet av NST/UNN her i Tromsø). Det innebærer at hver gang barnet måler blodsukkeret sitt med en blodsuktermåler med Bluetooth tilkobling (eller blodsukkerverdien skrives inn manuelt), så får spillet (appen) overført dette fra Diabetesdagbokas database. Målingen benyttes så i spillet.

DiabetesDagboka er et selvhjelpsverktøy for personer med diabetes, utviklet ved Nasjonalt senter for samhandling og telemedisin (NST), Universitetssykehuset Nord-Norge (UNN). Diabetesdagboka gir brukeren mulighet til å registrere og lagre blodsuktermålinger, insulindosering, karbohydratinntak og fysisk aktivitet. Alt som registreres i dagboka bygger opp en database over hendelser og situasjoner, og kan dermed være med på å veilede ved valg av mat og medisinerings.

Nåværende versjon av spillet bruker imidlertid kun informasjon om blodsuktermålinger fra dagboka. Dette ble gjort for å gjøre det så realistisk som mulig, og for å øke opplæringseffekten. Målet med et slikt system er å gi barna grunnleggende kunnskap om diabetes og lære dem om sammenhengene mellom karbohydratmengden i mat som de spiser, blodsukkernivået deres etter måltidet og insulindosen som må settes. I møtet skal vi bare simulere at barnet har brukt Diabetesdagboka, og fokusere mest på spillet.

Nå ville jeg spørre foreldrene å fylle inn et spørreskjema om barnets egenkontroll først og etterpå diskutere med en av forskerne på NST om et påfølgende prosjekt de skal i gang med snart, mens jeg prater med barnet om hvordan det er å bruke spillet.

*Jeg antar at noen snacks (frukt eller noe annet) kan serveres.*

Jeg vil starte med å stille deg noen spørsmål (*spørreskjemaet til barn med diabetes: antall spørsmål vil variere avhengig av situasjonen*).

Historien om dette spillet er som følger. Den Onde Kake stammen med deres leder, SuperBoss, har angrepet vår planet. De vil gjøre alle mennesker fete. De har stjålet vennene dine. Du må kjempe mot stammen for å frigjøre vennene og resten av verden. Jeg håper du kan hjelpe til med å bli kvitt de Onde

Kakene. Kakene er redde for Cola. SuperBoss, som du kun møter i siste nivå av spillet, tåler Cola, men han er til gjengjeld redd for appelsinjuice. Derfor bør du også samle appelsinjuice til å bekjempe han.

Litt om hvordan fremgangsskalaen på inngangssiden fungerer. For å få høyere prosent her, så må du kontrollere blodsukkeret. Det er best om du måler blodsukkeret 5-8 ganger per dag, og med cirka 2-4 timer mellom målingene. Når du har fått mer enn 50 % her, får du en stjerne; når du har over 75 %, får du to stjerner; og tre stjerner får du hvis skalaen er nesten full (90 % og mer). I tillegg får du forskjellige kommentarer om din fremgang her.

Hver gang du måler blodsukkeret, får du Superpoeng som kan brukes til å kjøpe forskjellige typer sunn mat og treningsutstyr til å passe på spillkarakterens blodsukker. Dette kan du handle i butikken. Her finner du litt informasjon om hva du kan kjøpe. Når du har kjøpt noe, finner du dette igjen her. Alt kan brukes i spillet.

Her kan du se premier du har fått i løpet av det spillet. Her finner du de store pokalene og medaljene for hele spillet, og premiene for hvert nivå. På denne siden får du også informasjon om det siste nivået du har spilt og hvor mange insulinpinner og appelsinjuicepakker du har samlet.

På slutten av dagen får du Gullpoeng hvis du har klart å ha nok poeng på fremgangsskalaen i dag. I tillegg får du Gullpoeng på slutten av hver måned hvis ditt blodsukker i gjennomsnitt har vært innen det anbefalte området (omtrent 4-7 mmol/l). Du kan bruke Gullpoeng til å få premier i det virkelige liv, f.eks. kinobilletter, gavekort på sportsutstyr, osv. Premier kan velges avhengig av Gullpoeng du har fått.

Hvis du har glemt noe, så finner du spillets regler her.

Jeg skal nå vise hvordan du kommer deg fram i spillet: slikt løper du (bare dra på skjermen), slikt hopper du (dra opp på skjermen), og slikt kaster du Cola flasker mot fiender, de Onde Kakene (bare trykk på spilleren).

Her på skjermen har du blodsuktermåleren med din siste blodsukkermåling i begynnelse av hvert nivå. Og verdiene endres her hvis du har blitt overfalt av fiender eller bruker insulinpinner eller utstyret som du har kjøpt i butikken. Her er insulinpinner som du samler på hvert nivå. De må brukes hver gang spilleren treffes av Kakene eller dersom blodsukkeret er for høyt (bare trykk på insulinpenn ikon). Da blinker dette ikonet. Her er utstyret som du har kjøpt. Utstyrselementenes ikoner blinker også når noe trengs å bli brukt. Utstyr brukes til å holde spillerens blodsukkernivå i anbefalt området (mellom 4 og 7 mmol/l). Hvis blodsukkernivået er lavere enn 2 eller høyere enn 18, får du en melding om å spille dette nivået en gang til. Blodsukkernivå som er lavere enn 4 er for lavt og merkes rød på denne blodsuktermåleren. Og hvis spillerens blodsukkernivå øker til 10 og høyere, er det for mye og er tallene gule på blodsuktermåleren. Hvis spilleren får for lavt blodsukkernivå 5 ganger eller for høyt blodsukker 8 ganger, bør du spille det forrige nivået på det du spiller nå. Hver gang du treffer fiender med Cola får du poeng.

Også du samler appelsinjuicepakker på hvert nivå. De skal brukes for å kjempe mot SuperBoss på det siste nivået.

Nå, hvis du vet blodsukkernivået ditt så kan du skive dette i Diabetesdagboka. Hvis ikke så kan du måle blodsukkeret og da registrere det i Diabetesdagboka. Det kan gjøres på denne måten. Du må gjøre det samme hver gang du måler blodsukkeret. Som det ble sagt før, får du Superpoeng og poeng på fremgangsskalaen hver gang du måler ditt blodsukker, men når du gjør det oftere enn 10 ganger per dag, kan du ikke få mer poeng.

Nå tror jeg du er klar til å spille! Lykke til og ha det gøy! Hvis du har noen spørsmål, så er det bare å spørre meg.

Etter barnet er ferdig å spille (cirka en halv time), vil jeg spørre ham/henne om spillet (*spørreskjemaet til barn om spillet*).

**Tusen takk for at du ville delta!!**



## Appendix 9A

### Questionnaire for Parents (English version)

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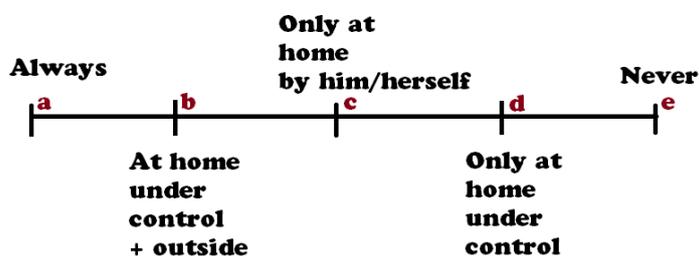
#### Questionnaire about children's self-monitoring for parents of children with diabetes

To be filled in before the meeting

*Tick the most appropriate answer to each question*

1. How old is your child?
  - a. 8
  - b. 9
  - c. 10
  - d. 11
  - e. 12
2. How long has your child had diabetes?
  - a. He/she has got it recently (less than one year)
  - b. For 1-3 years
  - c. For 3-5 years
  - d. For more than 5 years
3. What is your child able to do by him/herself considering the disease management?
  - Bloodglucose measurements

Child's self-monitoring scale:



- a. Child always measures bloodglucose by him/herself
  - b. Child measures bloodglucose by him/herself at school and other places, but measurements at home are under my control
  - c. Child measures bloodglucose by him/herself only at home
  - d. Child measures bloodglucose by him/herself only at home when I can control it
  - e. Child is not able to do bloodglucose measurements by him/herself, I do it for him/her
- Insulin injections

Child's self-monitoring scale:



- a. Yes, I use it for my child
  - b. Yes, my child can count carbohydrates by him/herself
  - c. Yes, but neither I nor my child count carbohydrates
  - d. No, but I would like to get more information about it
  - e. No, I don't think it's useful for my child
  - f. Alternatively, what training in carbohydrate counting have you got?
- 7. What is under your (or your child) consideration when insulin dose is calculated?**
- a. Bloodglucose before a meal
  - b. Carbohydrates in forthcoming food
  - c. Carbohydrates in eaten food
  - d. Forthcoming physical activity
  - e. Experience of what is needed to the food that is eaten
  - f. Other things: \_\_\_\_\_
- 8. Do you (and your child) know what symptoms of low bloodglucose are?**
- a. Yes, I know and my child too
  - b. Yes, I know, but my child doesn't
  - c. Yes, I know and I will explain them to my child
  - d. No, neither I nor my child know about them
- 9. Do you (and your child) know how to behave while a child has low bloodglucose?**
- a. Yes, I know and my child too
  - b. Yes, I know, but my child doesn't
  - c. Yes, I know and I will explain it to my child
  - d. No, neither I nor my child know about it
- 10. Do you (and your child) know what symptoms of high bloodglucose are?**
- a. Yes, I know and my child too
  - b. Yes, I know, but my child doesn't
  - c. Yes, I know and I will explain them to my child
  - d. No, neither I nor my child know about them
- 11. Do you (and your child) know how to behave while a child has high bloodglucose?**
- a. Yes, I know and my child too
  - b. Yes, I know, but my child doesn't
  - c. Yes, I know and I will explain it to my child
  - d. No, neither I nor my child know about it

**Thank you for participation in the research!**



## Appendix 9B

### Questionnaire for Parents (Norwegian version)

#### Spørreskjema om barnas egenkontroll til foreldre til barn med diabetes

Fylles inn før møtet

*Kryss av for det svaret du mener passer best til hvert spørsmål*

1. Hvor mange år er barnet?

- a. 8
- b. 9
- c. 10
- d. 11
- e. 12

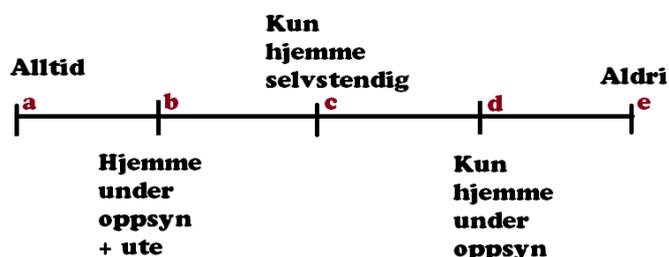
2. Hvor lenge har ditt barn hatt diabetes?

- a. Han/hun har nylig fått påvist diabetes (i mindre enn ett år)
- b. 1-3 år
- c. 3-5 år
- d. Mer enn 5 år

3. Hva kan barnet selv foreta seg i forhold til sin diabetes?

- Blodsuktermåling

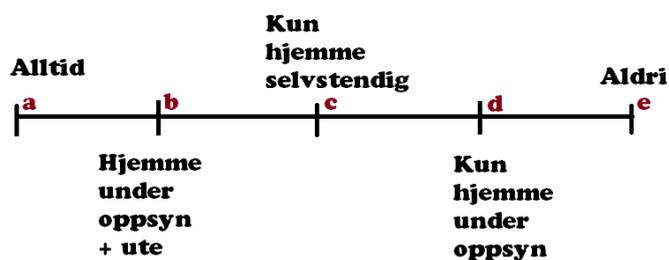
Barnets egenkontrollskala:



- a. Barnet måler alltid selv blodsukker
- b. Barnet måler selv blodsukker når han/ hun ikke er hjemme, men hjemme måler han/hun alltid blodsukker under mitt oppsyn
- c. Barnet måler selv blodsukker kun hjemme
- d. Barnet måler selv blodsukker kun hjemme når jeg kan kontrollere det
- e. Barnet er ikke selv i stand til å måle blodsukker, jeg gjør alltid det for ham/henne

- Insulinsetting

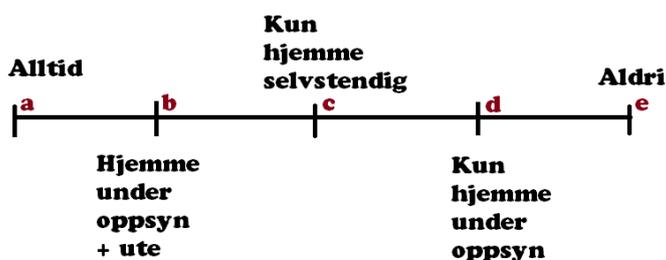
Barnets egenkontrollskala:



- a. Barnet setter selv alltid insulin
- b. Barnet setter selv insulin når han/ hun ikke er hjemme, men hjemme setter han/hun insulin alltid under mitt oppsyn
- c. Barnet setter selv insulin kun hjemme
- d. Barnet setter selv insulin kun hjemme når jeg kan kontrollere det
- e. Barnet er ikke selv i stand til å sette insulin, jeg gjør alltid det for ham/henne

- Beregning av insulindose

**Barnets egenkontrollskala:**



- a. Barnet beregner selv alltid insulindosen
- b. Barnet beregner selv insulindosen når han/ hun ikke er hjemme, men hjemme gjør han/hun alltid det under mitt oppsyn
- c. Barnet beregner selv insulindosen kun hjemme
- d. Barnet beregner selv insulindosen kun hjemme når jeg kan kontrollere det
- e. Barnet er ikke selv i stand til å beregne insulindose, jeg gjør alltid det for ham/henne

**Spørsmål om diabetes**

**4. Når måler du (eller barnet) blodsukker?**

- a. Før hvert måltid
- b. Etter hvert måltid
- c. Om morgenen
- d. Før barnet skal legge seg
- e. Før trening
- f. Andre ganger: \_\_\_\_\_

**5. Hvor ofte måler du (eller barnet) blodsukkernivå?**

- a. 1-2 ganger per dag
- b. 3-4 ganger per dag
- c. 5-8 ganger per dag
- d. 8-15 ganger per dag
- e. >15 ganger per dag

**6. Kjenner du (og barnet) til effekten av karbohydrattelling for bedre blodsukkernivåkontroll?**

- a. Ja, jeg foretar det for barnet
- b. Ja, barnet kan selv telle karbohydrater
- c. Ja, men verken jeg eller barnet teller karbohydrater
- d. Nei, men jeg ønsker mer informasjon om dette
- e. Nei, jeg tror ikke er dette er nyttig for barnet
- f. Eventuelt hvilken opplæring i karbohydrattelling har dere fått? \_\_\_\_\_

**7. Hva inngår i din (eller barnets) grunnlag for beregning av insulindosen?**

- a. Blodsukkerverdi før mat
- b. Karbohydrater i den maten som skal spises

- c. Karbohydrater i den maten som nettopp er spist
- d. Kommende fysisk aktivitet
- e. Erfaring med hva som trenges til maten som spises
- f. Andre ting: \_\_\_\_\_

**8. Kjenner du (og barnet) symptomene for lavt blodsukker?**

- a. Ja, både jeg og barnet kjenner til disse
- b. Ja, jeg kjenner til disse, men barn kjenner ikke til disse
- c. Ja, jeg kjenner til disse og har planer om å forklare dette for barnet
- d. Nei, verken jeg eller barnet kjenner til disse

**9. Vet du (og barnet) hva som må gjøres om barnet har for lavt blodsukker?**

- a. Ja, både jeg og barnet kjenner til dette
- b. Ja, jeg hva som må gjøres, men barnet vet ikke hva han/ hun må gjøre
- c. Ja, jeg kjenner til dette og har planer om å forklare dette for barnet
- d. Nei, verken jeg eller barnet kjenner til dette

**10. Kjenner du (og barnet) symptomene for høyt blodsukker?**

- a. Ja, både jeg og barnet kjenner til disse
- b. Ja, jeg kjenner til disse, men barn kjenner ikke til disse
- c. Ja, jeg kjenner til disse og har planer om å forklare dette for barnet
- d. Nei, verken jeg eller barnet kjenner til disse

**11. Vet du (og barnet) til hva som må gjøres om barnet har for høyt blodsukker?**

- a. Ja, både jeg og barnet kjenner til dette
- b. Ja, jeg hva som må gjøres, men barnet vet ikke hva han/ hun må gjøre
- c. Ja, jeg kjenner til dette og har planer om å forklare dette for barnet
- d. Nei, verken jeg eller barnet kjenner til dette

**Takk for deltakelse i forskningen!**



## Appendix 10A

### Questionnaire for Children (English version)

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#### Questionnaire about diabetes self-monitoring for children with diabetes

1. Do you like to play and why, or why not?  
\_\_\_\_\_
2. Which games do you play now, or what have you played recently? On the PC, mobile phone, game console, etc.  
\_\_\_\_\_
3. Do you play most often alone, or play together with others (or against others)? How much?  
\_\_\_\_\_
4. What do you think is funny in these games and why do you continue to play them? Graphics, sound, story, earn points, or something else? Any other things?  
\_\_\_\_\_
5. Do you measure your bloodglucose or do your parents do it for you?
  - a. I do it myself
  - b. My parents do it for me
6. How often (how many times a day) do you (or your parents) measure your bloodglucose?
  - a. 1-2 times per day
  - b. 3-4 times per day
  - c. 5-8 times per day
  - d. 8-15 times per day
  - e. >15 times per day
7. Do you know how to calculate an insulin dose?
  - a. Yes
  - b. No
8. Do you know what the symptoms of low bloodglucose level are?
  - a. Yes
  - b. No
9. Do you know how to behave while you have low bloodglucose?
  - a. Yes, I know and I have had it
  - b. Yes, I know but I haven't had it
  - c. No, I don't know
10. Do you know what the symptoms of high bloodglucose level are?
  - a. Yes
  - b. No
11. Do you know how to behave while you have high bloodglucose?
  - a. Yes, I know and I have had it
  - b. Yes, I know but I haven't had it
  - c. No, I don't know

**Thank you for participation in the research!**



## Appendix 10B

### Questionnaire for Children (Norwegian version)

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#### Spørreskjema om egenkontroll til barn med diabetes

1. Liker du å spille og hvorfor, eller hvorfor ikke?  

---
2. Hvilke spill spiller du nå, eller hvilke har du spilt i det siste? På PC, mobiltelefon, spillkonsoll, osv.  

---
3. Spiller du som oftest for deg selv, eller spiller du sammen med andre (eller mot andre)? Evt. hvor mange?  

---
4. Hva synes du er morsomt i disse spillene og hvorfor fortsetter du å spille dem? Grafikk, lyd, historien, tjene poeng, eller noe annet? Eventuelt andre ting?  

---
5. Måler du selv blodsukkeret ditt eller gjør foreldrene dine det?
  - a. Jeg gjør det selv
  - b. Foreldrene gjør det for meg
6. Hvor ofte måler du (eller foreldrene dine) blodsukkeret?
  - a. 1-2 ganger per dag
  - b. 3-4 ganger per dag
  - c. 5-8 ganger per dag
  - d. 8-15 ganger per dag
  - e. >15 ganger per dag
7. Vet du hvordan insulindosen du skal sette skal beregnes?
  - a. Ja
  - b. Nei
8. Kjenner du når du har for lavt blodsukker?
  - a. Ja,
  - b. Nei
9. Vet du hva som må gjøres når du har for lavt blodsukker?
  - a. Ja, det vet jeg, og jeg har hatt for lavt blodsukker før
  - b. Ja, det vet jeg, men jeg har ikke hatt for lavt blodsukker før
  - c. Nei, det vet jeg ikke
10. Kjenner du når du har for høyt blodsukker?
  - a. Ja
  - b. Nei
11. Vet du hva som må gjøres når du har for høyt blodsukker?
  - a. Ja, det vet jeg, og jeg har hatt for høyt blodsukker før
  - b. Ja, det vet jeg, men jeg har ikke hatt for høyt blodsukker før
  - c. Nei, det vet jeg ikke

**Takk for deltakelse i forskningen!**



## Appendix 11A

### Interview Questions for Children (English version)

---

#### Children's questionnaire (interview) about the game

1. What do you think about the game? What is good and is bad?
2. How often do you think you would play it?
3. How much time per dag do you think you would play it?
4. How do you think about the game? Can you try to give a rating for these parts of the game:  
 = "I don't like",  = "It's quite good",  = "I like it very much"?
- a. Colors - what do you think of the colors we have chosen?   
- b. The background to the game   
- c. Sounds like game use   
- d. Player   
- e. Enemies, equipment and healthy food at every level and in store   
5. Did you like rewards you got?
6. Was it difficult to play the game?
  - a. It was difficult to move the player
  - b. It was hard to jump with player
  - c. It was hard to throw Coke
  - d. It was difficult to use insulin pens
  - e. It was difficult to use equipment and healthy food
7. Were the questions after each level difficult to answer?
8. Was it hard to understand how you could get points for what you did in the game?
  - a. Was it okay to understand how you could get points on every level?
  - b. Did you understand how you could get super points to buy anything in the game?
  - c. Did you understand how you could get gold points that can be used in real live?
  - d. Was it okay to understand how progress scale during the day work?
9. Do you find that you have better knowledge about diabetes from the game? Can you give some examples?
10. What did you like in the game and what did not?
11. What did you like most?
12. What was the most difficult for you in the game?
13. Was it fun to play game?
14. Would you like to play this game with your friends? Or against your friends?

15. Want to share your results with others in the game?
16. Do you have suggestions about what we can add to the game? Was there something you missed?
17. What do you think about the game uses the data (information) about your bloodglucose measurements from the Few Touch Application? Do you like it?
18. Do you have suggestions about what we can add to this connection?
19. Have you anything more to say?

**THANK YOU VERY MUCH FOR YOU'RE WILLING TO PARTICIPATE!!**

## Appendix 11B

### Interview Questions for Children (Norwegian version)

---

#### Spørreskjema (intervju) til barn om spillet

1. Hva synes du om spillet? Hva er bra og hva er dårlig?
2. Hvor ofte tror du at du ville spilt det?
3. Hvor lang tid om dagen tror du at du ville spilt det?
4. Hva synes du om spillet? Kan du forsøke å gi en karakter for disse delene av spillet:  
 = "det liker jeg ikke",  = "det er bra nok",  = "det liker jeg best"?
- a. Farger – hva synes du om de fargene vi har valgt?   
- b. Bakgrunnen til spillet   
- c. Lyder som spillet bruker   
- d. Spilleren   
- e. Fiender, utstyr og sunn mat på hvert nivå og i butikk   
5. Likte du premiene du fikk i spillet?
6. Var det vanskelig å spille dette spillet?
  - a. Det var vanskelig å flytte spilleren
  - b. Det var vanskelig å hoppe med spilleren
  - c. Det var vanskelig å kaste Cola
  - d. Det var vanskelig å bruke insulinpenn
  - e. Det var vanskelig å bruke utstyr og sunn mat
7. Var spørsmålene etter hvert nivå vanskelige å svare på?
8. Var det vanskelig å forstå hvordan du kunne få poeng for det du gjorde i spillet?
  - a. Var det greit å skjønne hvordan du kunne få poeng på hvert nivå?
  - b. Forstod du hvordan du kunne få superpoeng for å kjøpe noe i spillet?
  - c. Forstod du hvordan du kunne få gullpoeng som kan brukes i det virkelige liv?
  - d. Var det greit å skjønne hvordan fremgangsskala i løpet av dagen fungerer?
9. Synes du at du har fått bedre kunnskaper om diabetes fra spillet? Kan du gi noen eksempler?
10. Hva likte du med spillet og hva likte du ikke?
11. Hva likte du best?
12. Hva var det vanskeligste for deg i spillet?
13. Var det gøy å spille det?
14. Har du lyst til å spille dette spillet sammen med vennene dine? Eller mot vennene dine?
15. Vil du dele resultatene dine i spill med andre?

16. Har du forslag til hva vi kan legge til i spillet? Var det noe som du savnet?
17. Hva synes du om at spillet bruker opplysninger (informasjon) om dine blodsuktermålinger fra Diabetesdagboka? Liker du det?
18. Har du forslag til hva vi kan legge til av funksjoner?
19. Har du noe mer å si?

**TUSEN TAKK FOR AT DERE VILLE DELTA!!**

## Appendix 12A

### User Manual (English version)

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*The DiaSpill game is an educational game for 8-12-years-old children with type 1 diabetes. Its aim is to provide basic knowledge about diabetes in a comprehensible for children form, help children learn diabetes-related self-management skills, and motivate them to monitor their bloodglucose.*

*To play the game, you should have an Android-based smartphone with at least Android 4.0 “Ice Cream Sandwich”. The best graphics is reached on the 4.3” display with a 1280x720 resolution.*

When you have installed the DiaSpill game and the Few Touch Application (FTA), you can see the applications icons on your mobile phone desktop (Figure 1).



Figure 1. The Few Touch Application and DiaSpill installed on Android-based phone

If you have a glucometer with Bluetooth connection, all your bloodglucose measurements will be automatically registered in the Few Touch Application. If you do not have such a glucometer, bloodglucose level can be measured as ordinary and the values can be written manually into the FTA.

If you open the Few Touch Application, you see the following page (Figure 2).

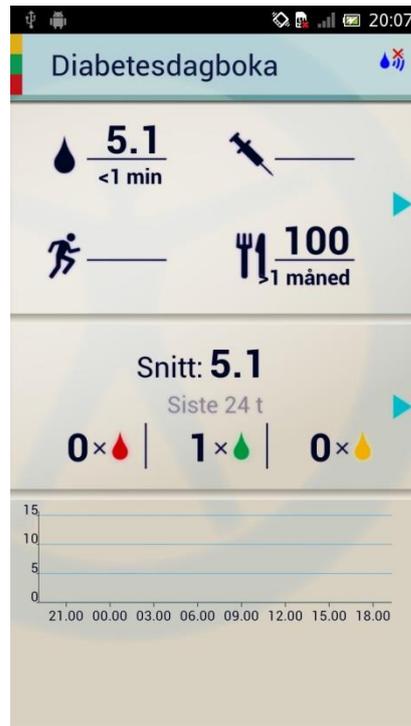


Figure 2. The first page of the Few Touch Application

If you click on the left top icon, you will be redirected to the next page where you can register your bloodglucose measurements (Figure 3).

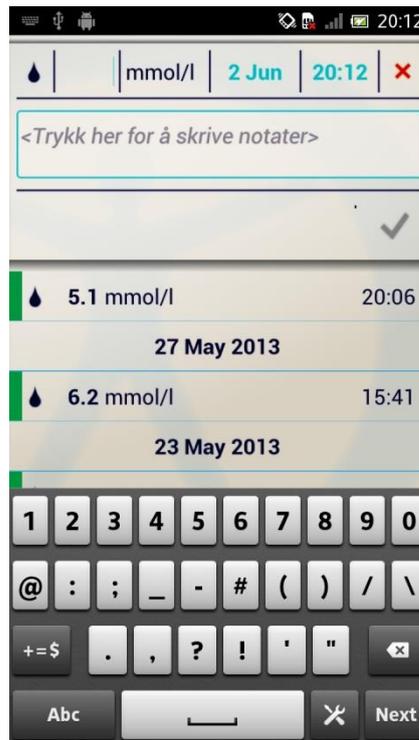


Figure 3. Registration of a new bloodglucose measurement in the FTA

Then, you can close the Few Touch Application. For this, use “Home” or “Back” buttons of your mobile phone.

If you click on the DiaSpill icon, you will see the page where you are offered to choose the language of the following game content (see Figure 4).

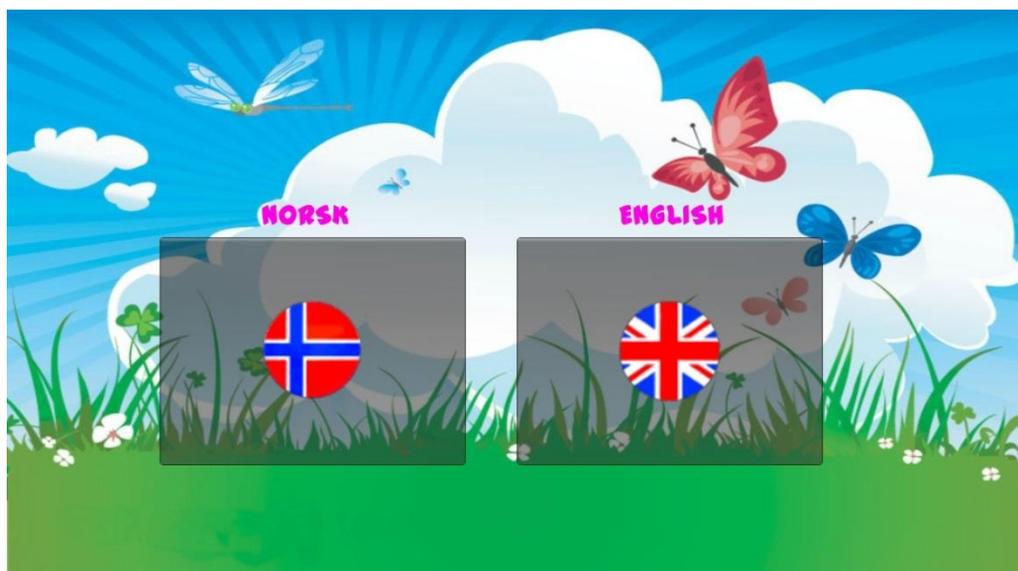


Figure 4. The language choice

When you have made a choice, a page where some information about you is needed to be filled in appears (Figure 5). It includes your gender, name, age and height which are going to be used further in the gameplay.

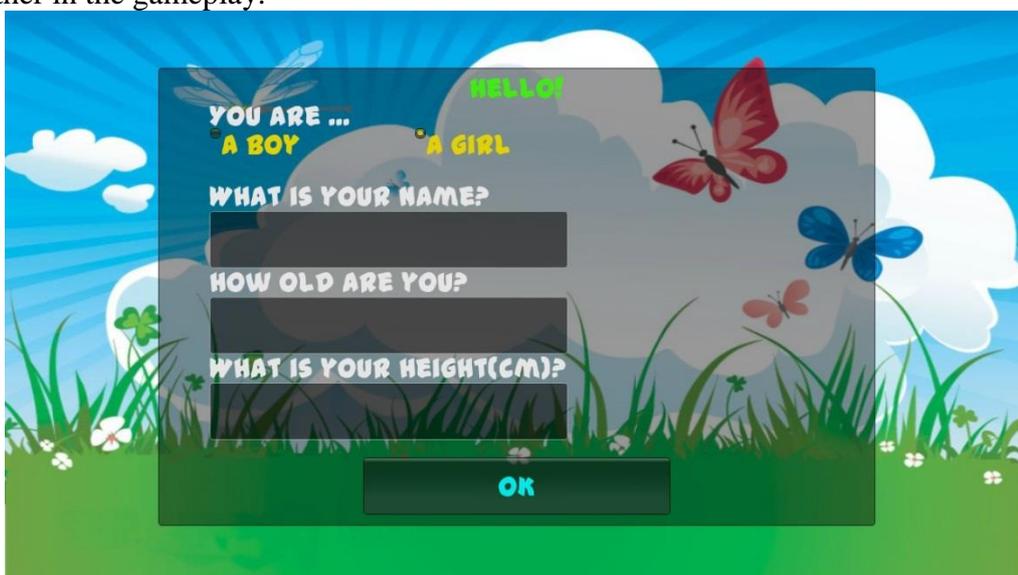


Figure 5. Information to be filled in to start a game

A virtual keyboard is available for data input (Figure 6).



Figure 6. Information input via a virtual keyboard

When all the required information is written, the page looks as follows (see Figure 7).

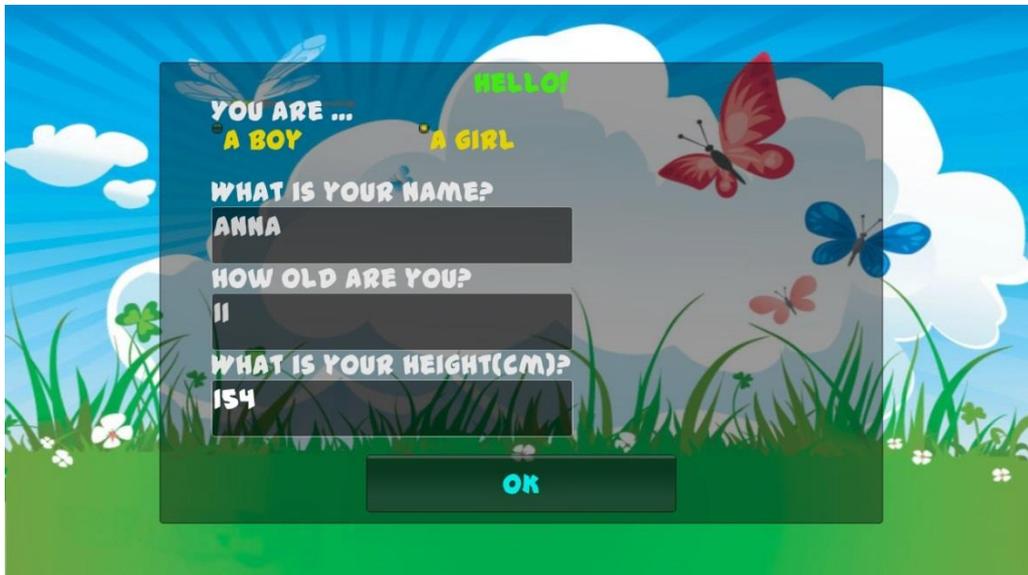


Figure 7. Filled-in user's information

Now, if you press the “OK” button, you can start playing.

Suddenly, a call-for-help message is received (Figure 8). The Evil Cake tribe with their leader, Super Boss, has attacked our planet. They would like to make all people fat. They even have stolen your friends. Therefore, your help is required. All people hope you can help get rid of the Evil Cakes. You have to fight against the tribe to free your friends and the rest of the world.

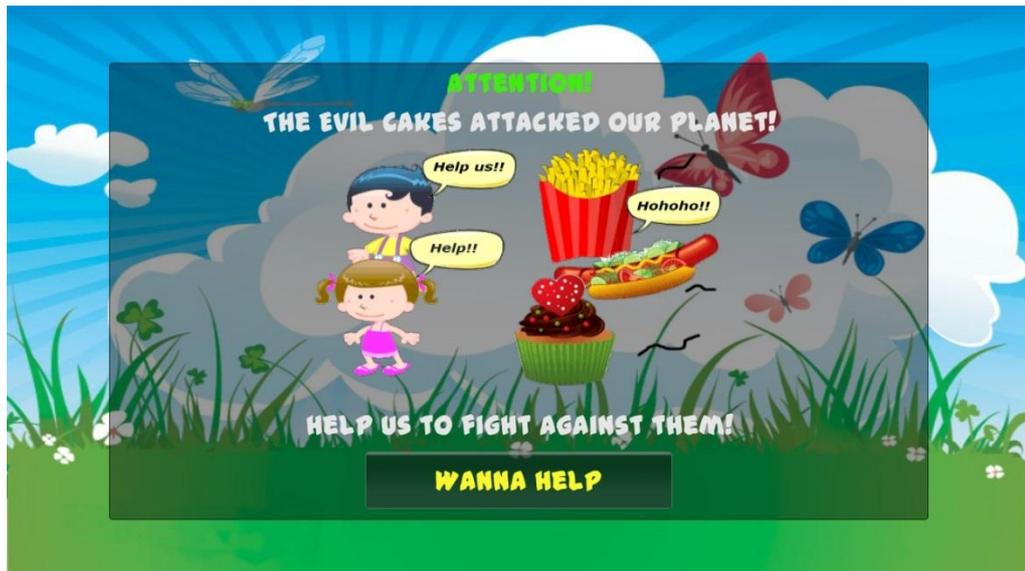


Figure 8. A call-for-help message

If you are willing to help, just click the “OK” button and choose a character you want to play. You can choose between 10 boys (Figure 9) or girls (Figure 10): it depends on your gender. A character has type 1 diabetes.

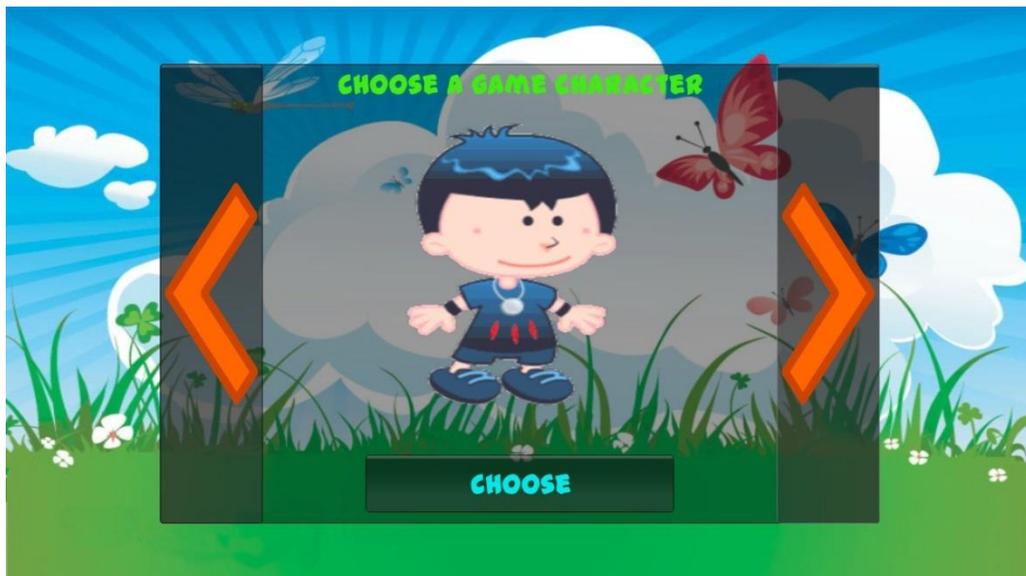


Figure 9. A character choice (boys)

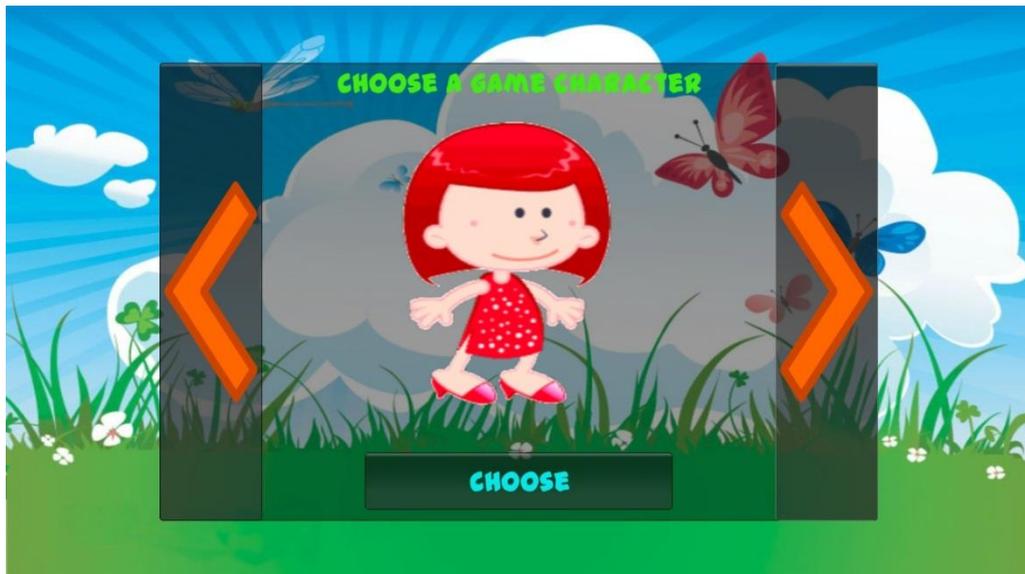


Figure 10. A character choice (girls)

Now you are ready to fight!

NB! If you open the DiaSpill game not for the first time, you can see the following page (Figure 11). On the top, there is a disclaimer where we warn you not to do the same things as with a game character in the real life. On the page, you see your name and two buttons “Play!” and “Quit!” for further actions. In addition, here you can change the game language.

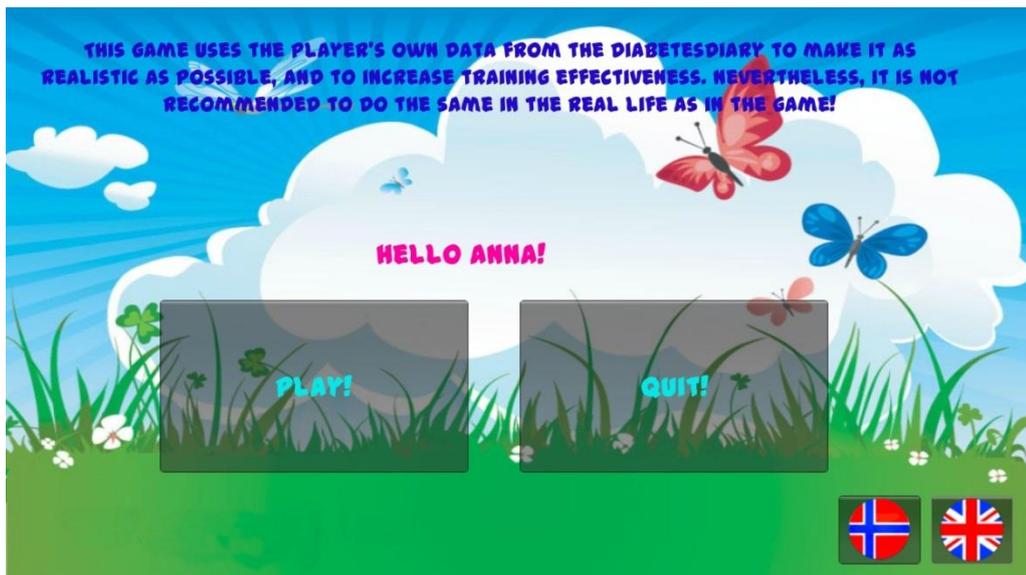


Figure 11. The first page of the game

Let's look at the main menu page of the game (Figure 12). You can get there if you press the “Play!” button, or in the case of the first game use, you will be automatically redirected there.

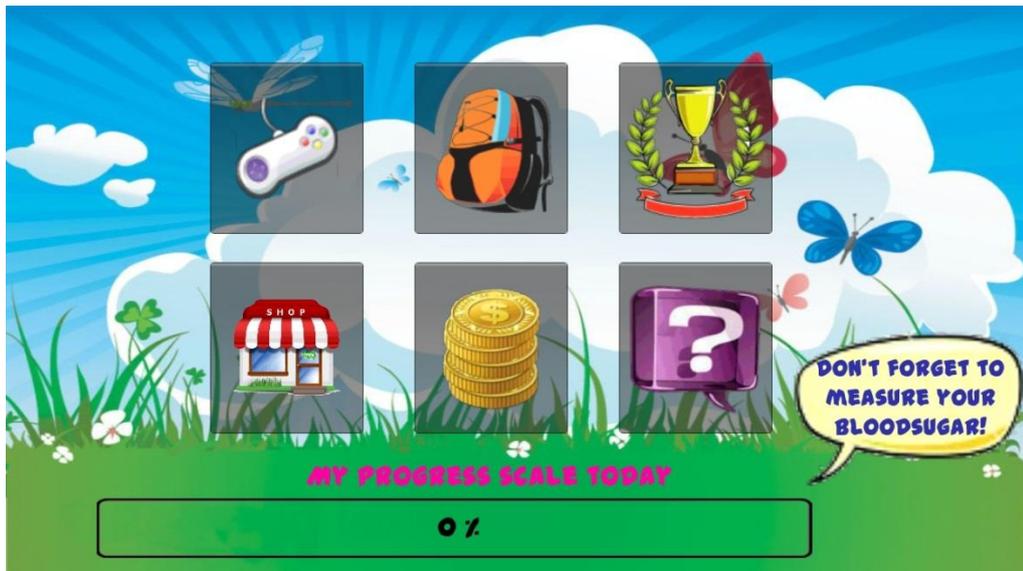


Figure 12. The main menu page

As you see, there is a lot of information on this page. First of all, let us look through the game rules (Figure 13).

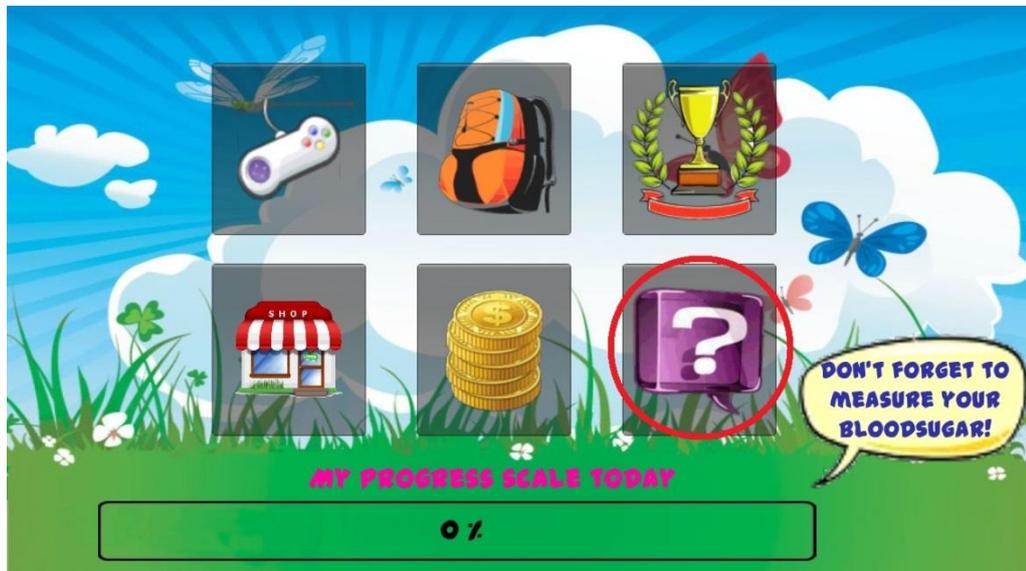


Figure 13. The game rules button on the main menu page

Here you can find some tips on how to move a character in the game (Figure 14), how to get ahead of progress in bloodglucose monitoring (Figure 15), how one can earn Superpoints (Figure 16), and how Goldpoints are charged (Figure 17).



Figure 14. Game rules: how to move the character

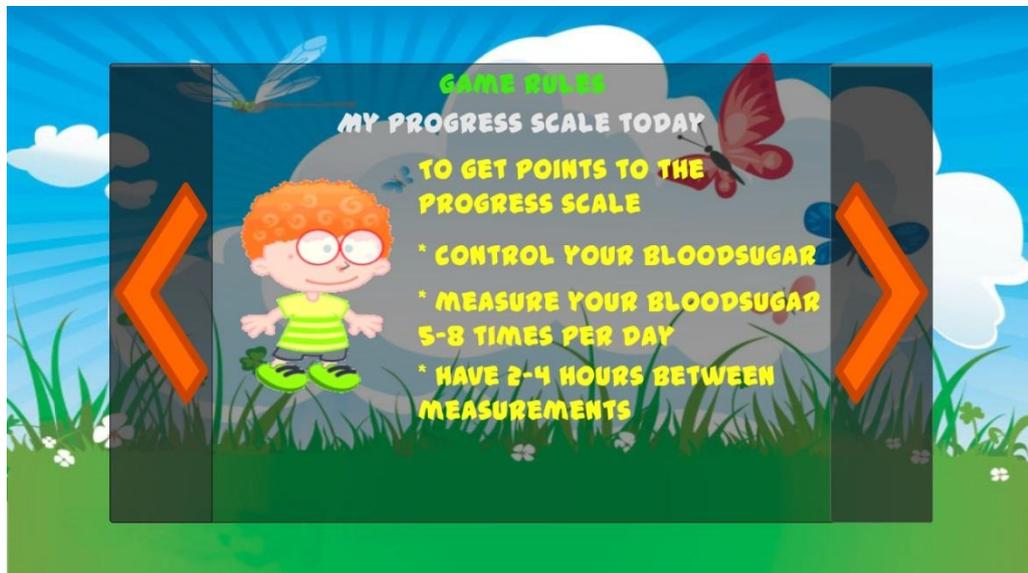


Figure 15. Game rules: how to get higher percentage on the progress scale



Figure 16. Game rules: how to earn Superpoints



Figure 17. Game rules: how to get Goldpoints

Now, let's say some words about the progress scale on the bottom of the main menu page (Figure 18). It works as follows. To get higher percentage here, you need to control your bloodglucose. This includes a certain number of measurements during a day, an interval between measurements, and measurements regularity. It is best if you measure your bloodglucose 5-8 times per day, with about 2-4 hours between measurements, and do it in the same time as yesterday. Depending on these parameters, you are awarded with one, two or three stars for the progress during a day: 51-75% give you one star (Figure 19), 76-90% are counted for two stars (Figure 20), and for 91% and more, you get three stars (Figure 21). In addition, you get different comments about the progress.

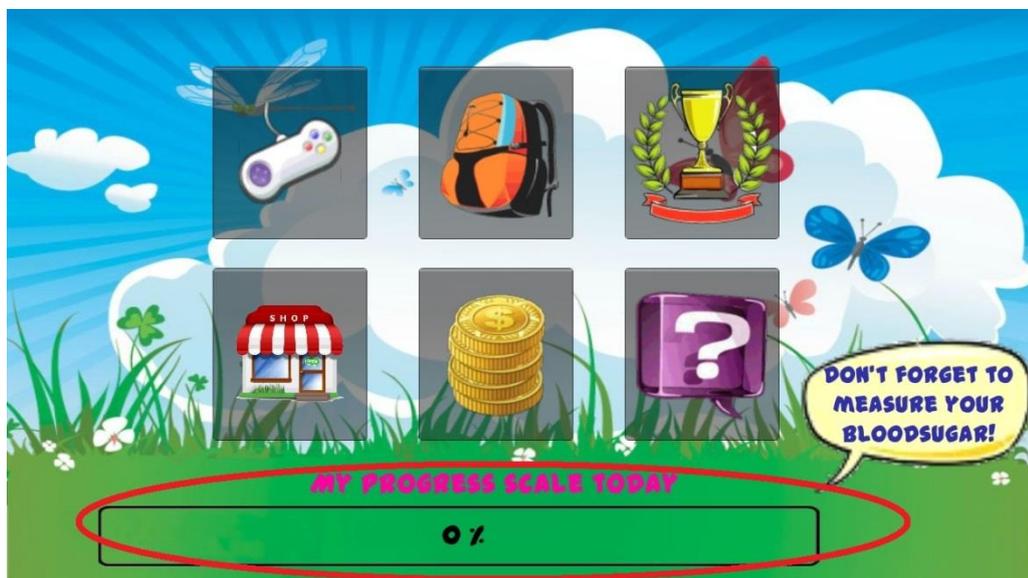


Figure 18. The progress scale on the main menu page



Figure 19. One awarded star for progress during a day



Figure 20. Two awarded stars for progress during a day

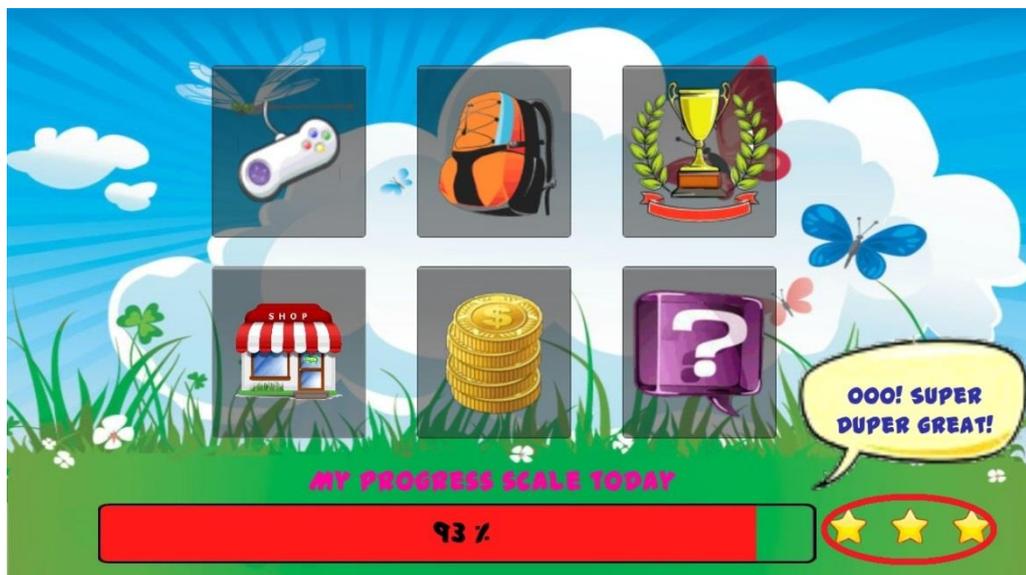


Figure 21. Three awarded stars for progress during a day

If you press the button with gold coins (Figure 22), you are in the Goldpoints menu (Figure 23). At the end of each day you get Goldpoints if you have managed to have enough points in the progress scale today. In addition, you get Goldpoints at the end of each month if your bloodglucose level in average is within the recommended range (4-7 mmol / l). You can use your Goldpoints to get prizes in real life, for example, movie tickets, gift certificates for sports equipment, etc. Prizes can be selected in regard to Goldpoints you have got.

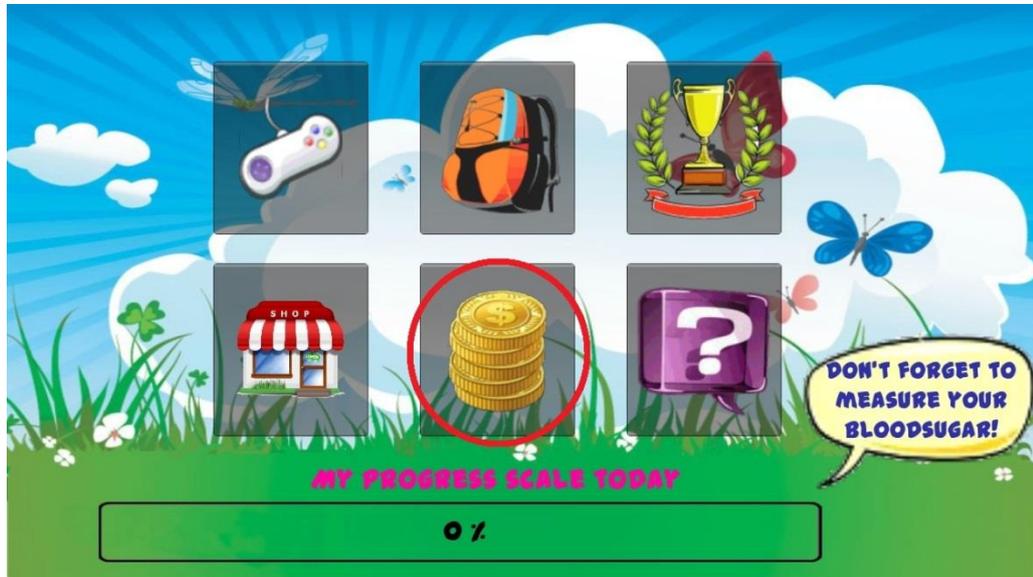


Figure 22. Goldpoints menu button on the main menu page

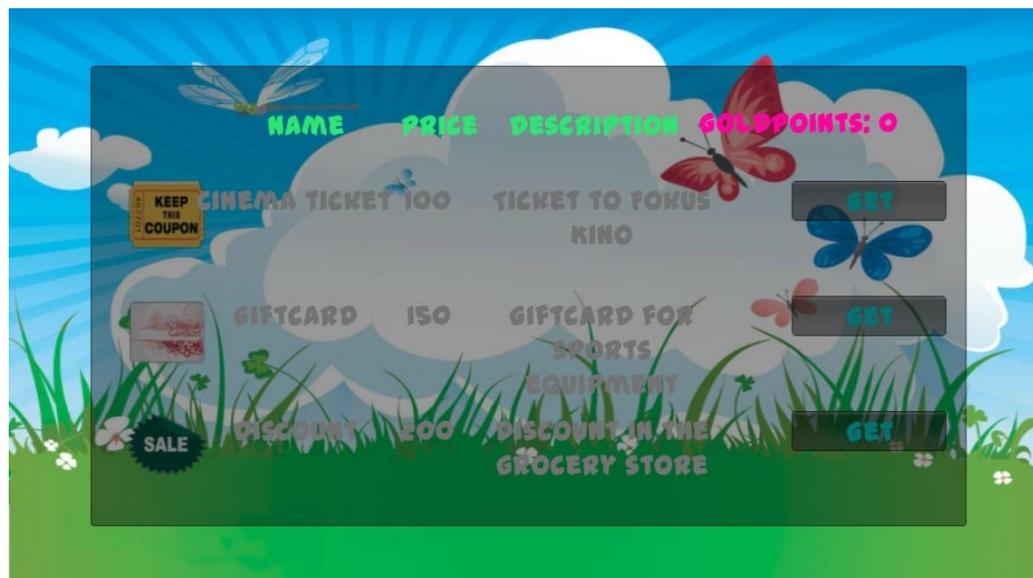


Figure 23. Goldpoints menu

Each time you measure your bloodglucose, you get 20 Superpoints. These points can be used to buy different healthy food and sports equipment items to regulate the game character's bloodglucose level. This can be done in the game Shop (Figure 24). Some information, such as an amount of calories and carbohydrates per portion, is provided for each shop item (Figure 25).

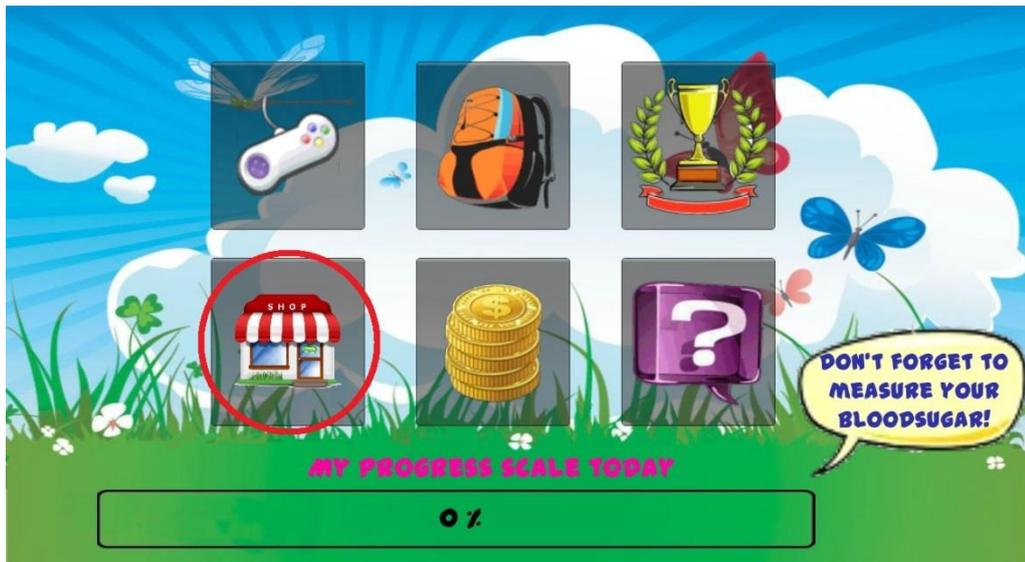


Figure 24. The Shop menu button on the main menu page



Figure 25. Shop menu

When you have bought something in the Shop, it can be viewed in the Backpack menu (see Figure 26 and Figure 27).

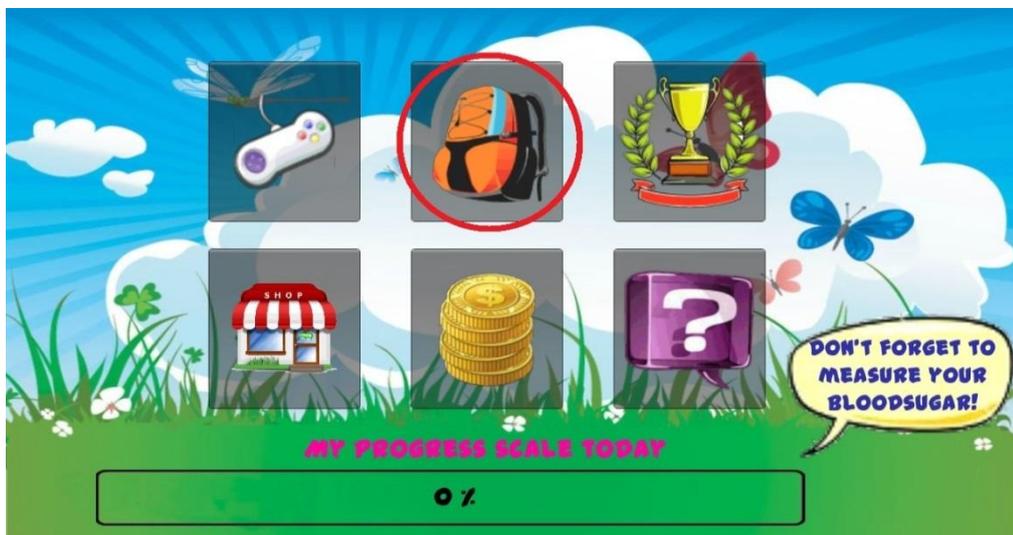


Figure 26. The Backpack menu button on the main menu page

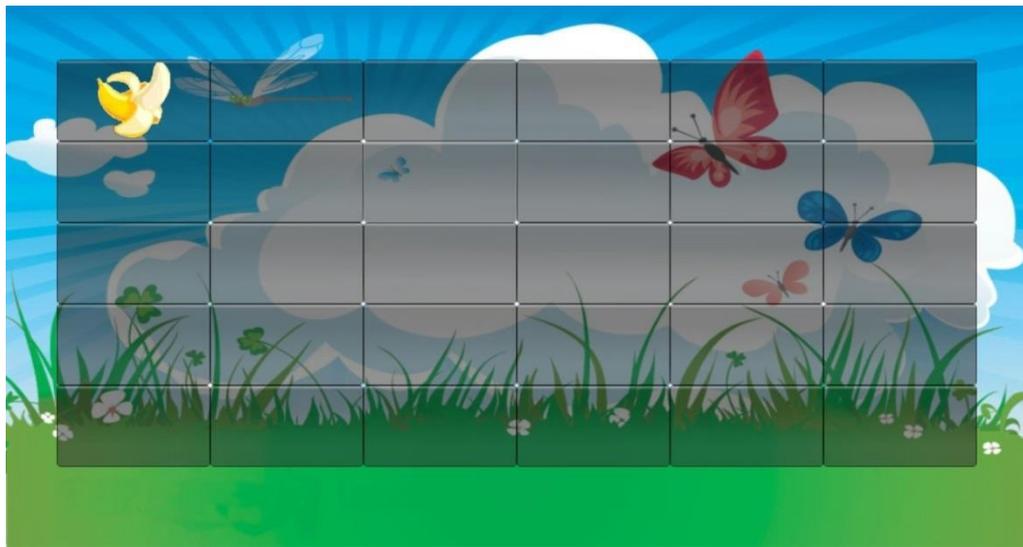


Figure 27. Backpack menu

Now, finally, you can start playing the game. Go to the Levels menu (Figure 28).

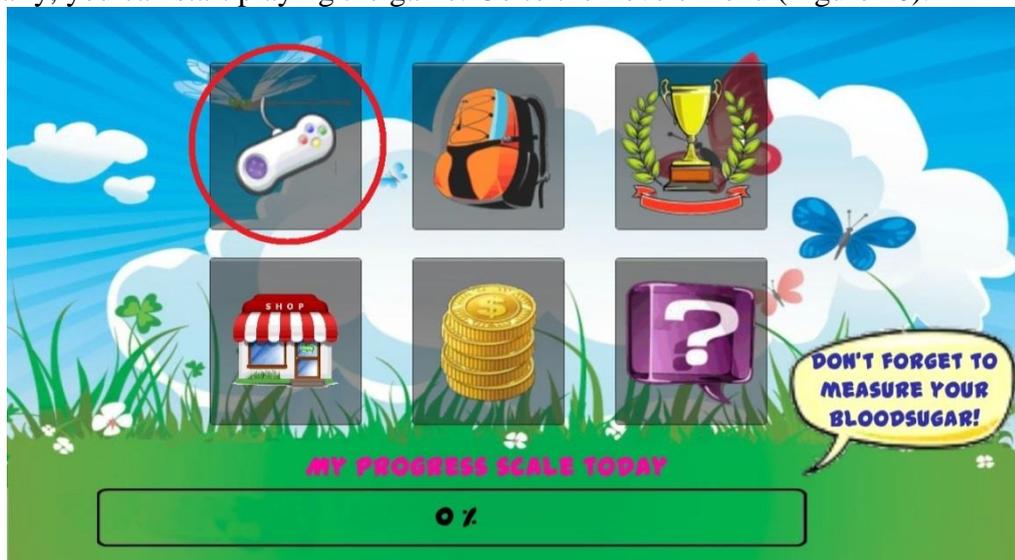


Figure 28. The Levels menu button on the main menu page

Here you see available (unlocked) levels (Figure 29).

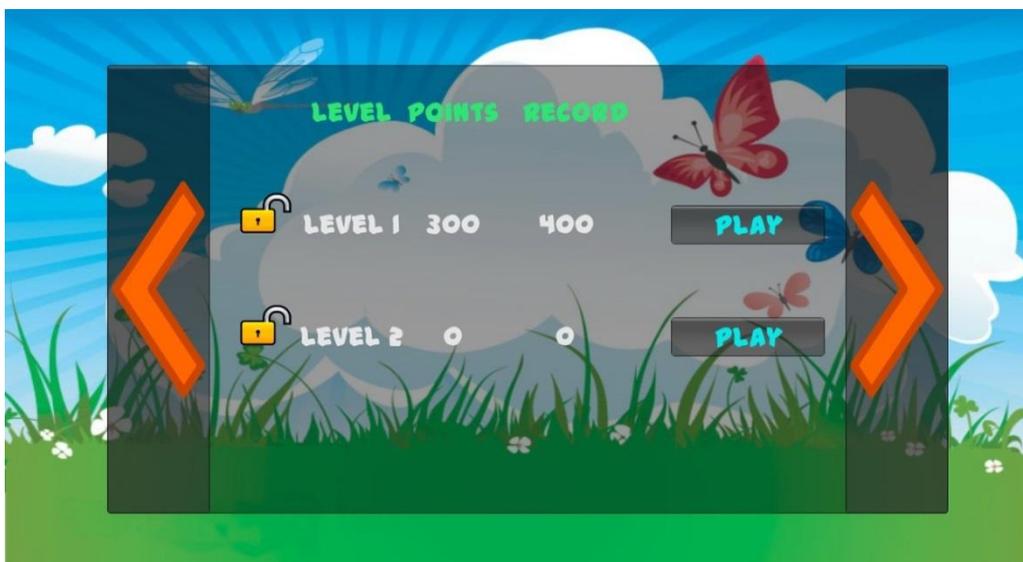


Figure 29. Levels menu

To play a level, just click on the “Play” button opposite this level name (Figure 30).

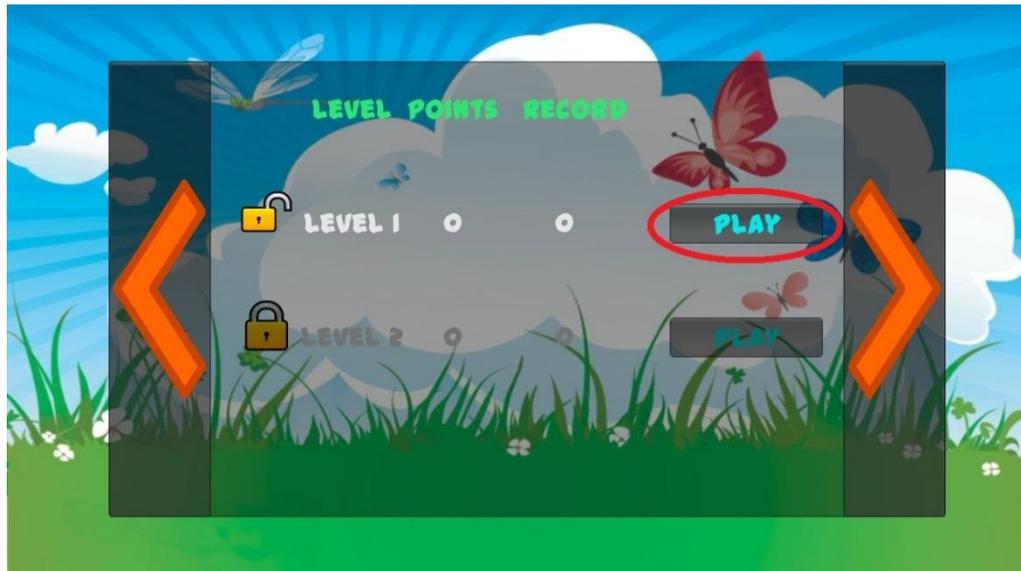


Figure 30. A “Play” button to play a level

Then a particular level is started (see Figure 31). During the level you run, overcome numerous blocks, resist various enemies, and collect insulin pens and orange juice boxes. To get ahead in the game, you run (just drag on the screen), jump over blocks (drag up on the screen), and throw Coke bottles into the enemies (by clicking on a character) (see Figure 14). You can recognize how much each enemy contains carbohydrates and how much it gives to a character’s bloodglucose level via the information in their bubbles.

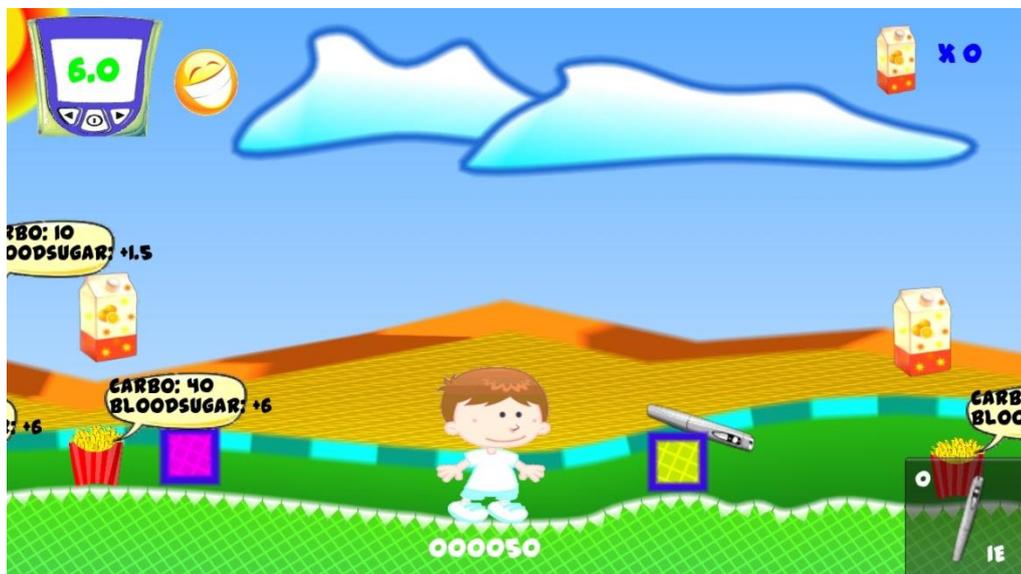


Figure 31. Level gameplay

As you have understood, a character has type 1 diabetes.

On the left top corner of the screen, you have a glucometer with your last bloodglucose level value at the beginning of each level (Figure 32). Values there are changed if you have been attacked by enemies or have used insulin pens or equipment that you have purchased in the Shop.

Also on the screen, you have a number of collected orange juice boxes in the right top corner, a number of gathered insulin pens in the right corner on the bottom, and equipment items icons on the bottom on the left (Figure 32).

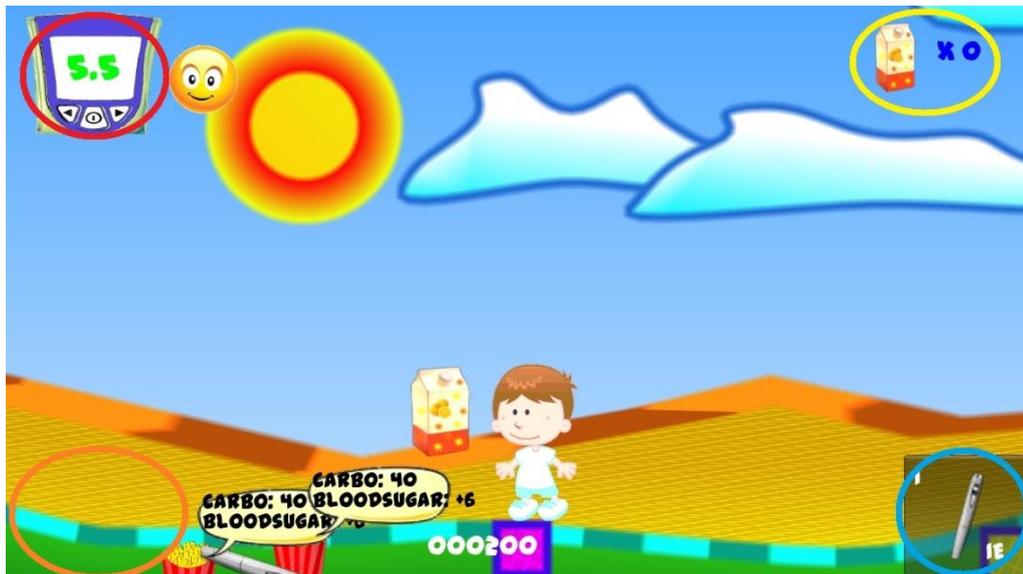


Figure 32. Level gameplay details

You gather insulin pens to control your character's bloodglucose level while orange juice boxes are collected to be used as missiles in the final mission when you are going to fight against SuperBoss. He is very strong and is not afraid of Coke bottles (as ordinary cakes are).

Insulin pens are collected on each level. They must be used each time your character is met by the enemies or if his/ her bloodglucose is too high (just click on the insulin pen icon). When insulin is required to be injected, the insulin pen icon is flashing.

Equipment items icons are also flashing when something is needed to be used. Equipment should be used to hold a character's bloodglucose level in the recommended range (between 4 and 7 mmol/l). If character's bloodglucose is lower than 2 mmol/l or higher than 18 mmol/l, you must play this level again. A bloodglucose level lower than 4 mmol/l is too low and labeled red on the glucometer. And if a character's bloodglucose level increases to 10 mmol/l and higher, it is too much and there are yellow numbers on the glucometer (Figure 33).

If your character gets too low bloodglucose levels 5 times or high bloodglucose 8 times, you must play a level previous to the level you have just completed.

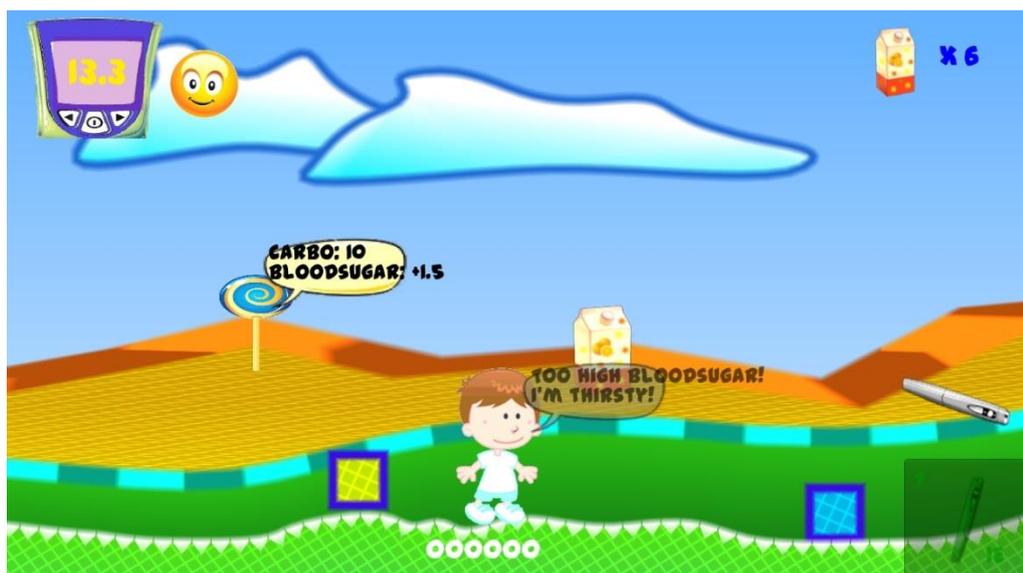


Figure 33. Too high bloodglucose level

In the end of each level, you see a finish sign (Figure 34).

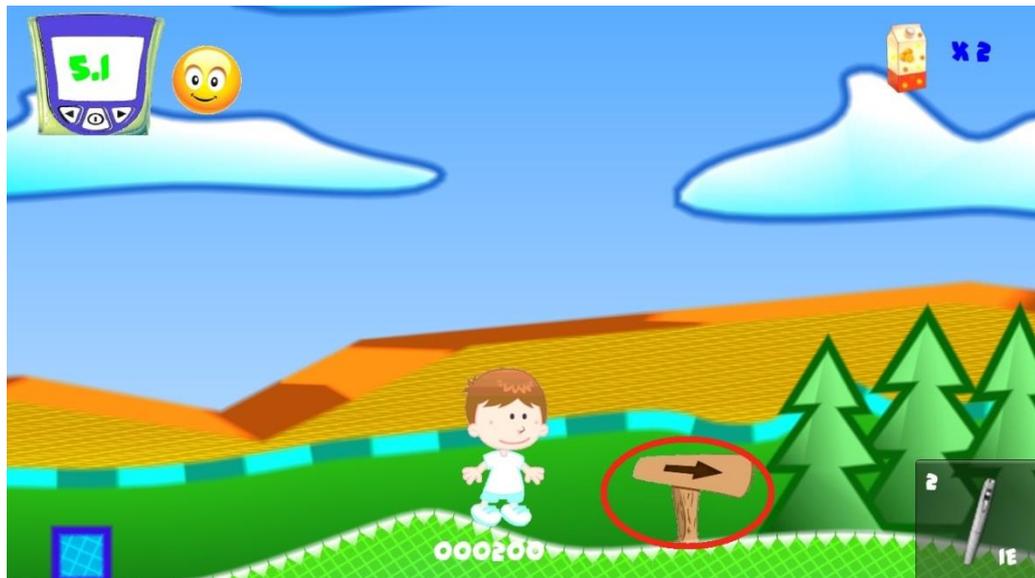


Figure 34. A finish sign

After you have gone through it, you get a question about diabetes stuff (Figure 35). If your answer is correct, you additionally get 200 points to your score after the level.



Figure 35. A question after finished level

All the results are described in details in the next window (Figure 36). The results include how many enemies have hit you, what equipment you have used against them, your score, a number of collected insulin pens and orange juice boxes, and whether your character has had too low and/ or too high bloodglucose level.



Figure 36. The results window

Then, you are awarded with cups and medals in regard to your score and collected missiles (orange juice boxes) (see Figure 37).

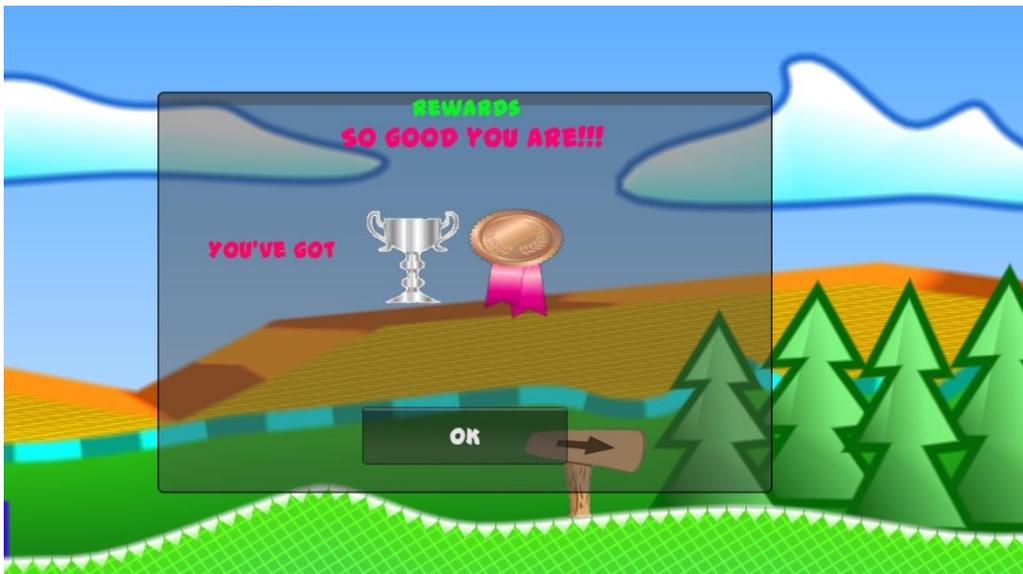


Figure 37. Rewards after each level

Your rewards for each level and for the whole game are available in the Rewards menu (see Figures 38-40).

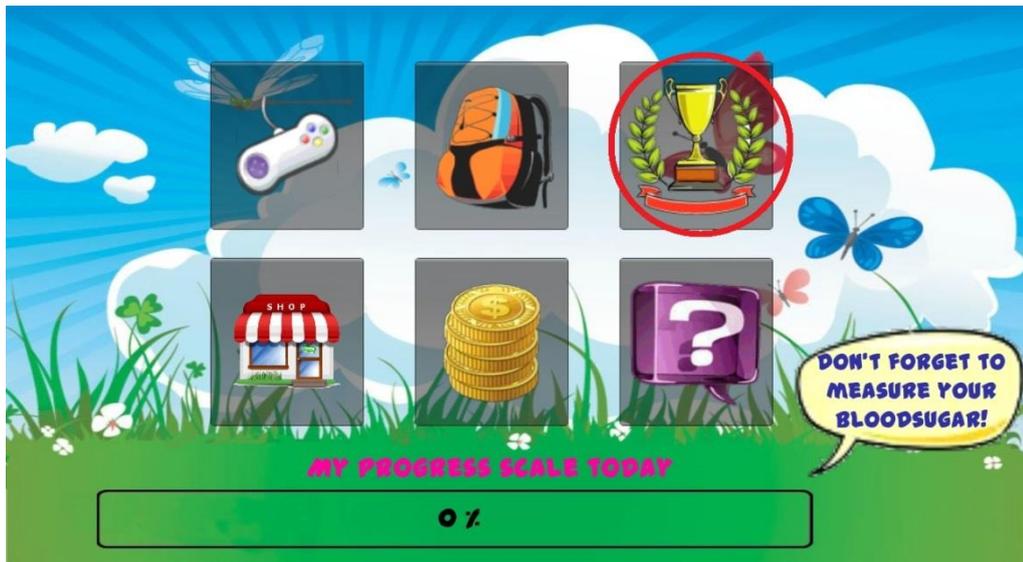


Figure 38. The Rewards menu button on the main menu page

On this page, you can also find information about the highest level you have played and how many insulin pens and orange juice packages you have gathered (Figure 39).

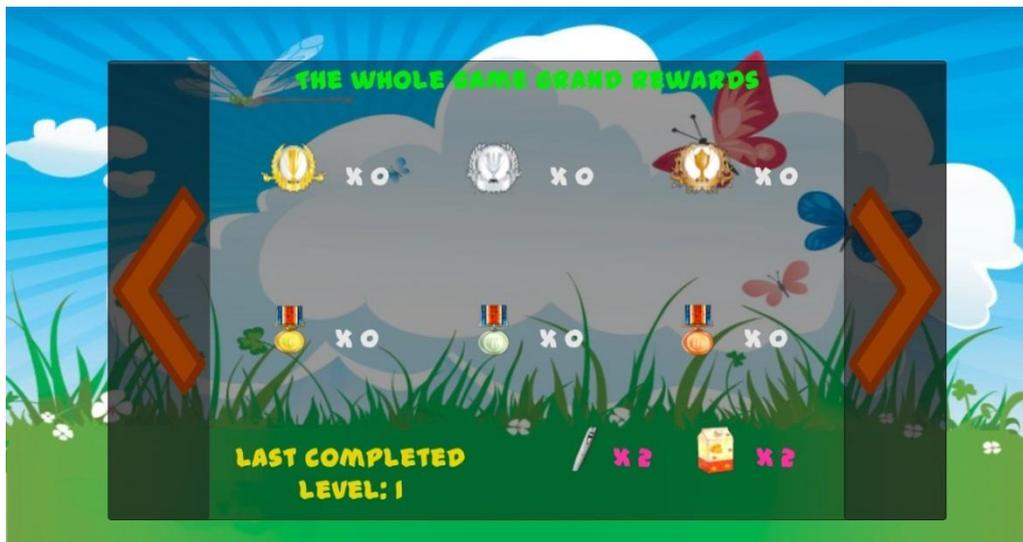


Figure 39. The whole game rewards

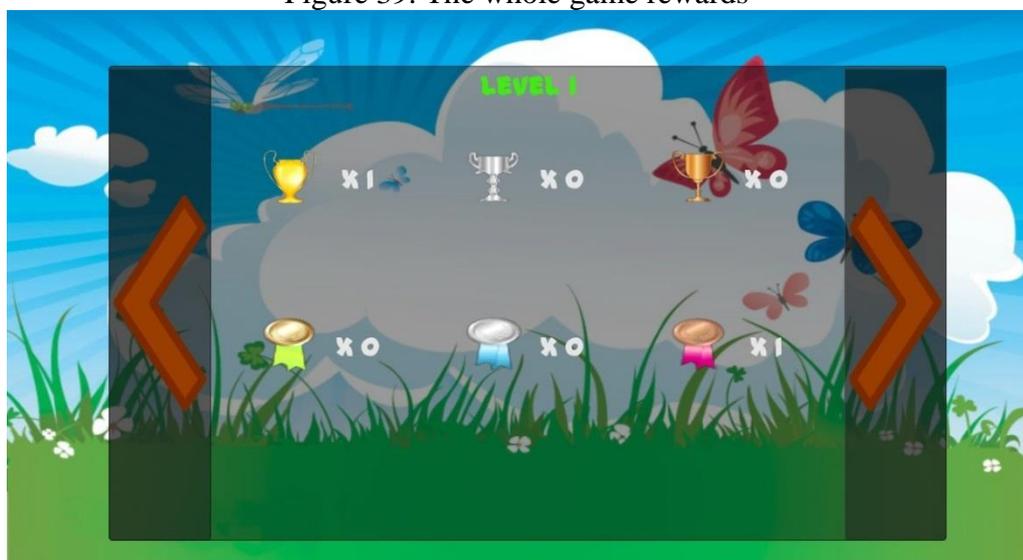


Figure 40. Rewards for a particular level

When you have won SuperBoss on the final level, the whole Evil Cakes tribe is destroyed. You get the victory message that all the enemies are scared and running away (Figure 41). All people are free. Good job!

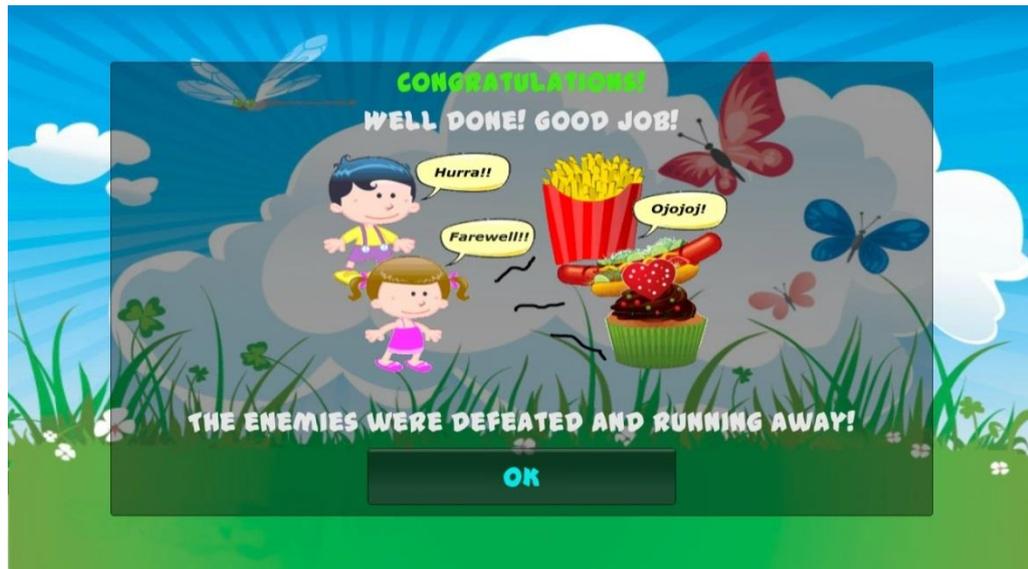


Figure 41. The victory message

Now you can play the game one more time, or play the levels you like most of all.



## Appendix 12B

### User Manual (Norwegian version)

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*DiaSpill spillet er et opplærende spill til 8-12 års gamle barn med type 1 diabetes. Spilletets mål er å gi grunnleggende kunnskap om diabetes i en forståelig for barn form, hjelpe barn å lære diabetes-relaterte egenkontroll ferdigheter, og motivere dem til å kontrollere deres blodsukker.*

*For å spille spillet bør du ha en Android-basert smarttelefon med minst Android 4.0 "Ice Cream Sandwich". Den beste grafikken er nådd på 4.3"-skjermen med en oppløsning på 1280x720.*

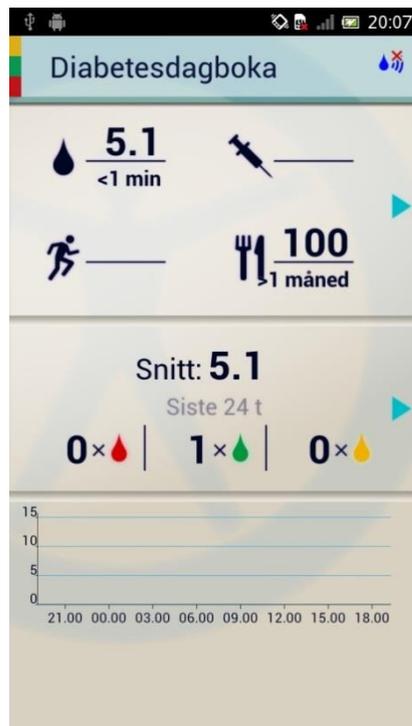
Når du har installert DiaSpill spillet og DiabetesDagboka, kan du se appene ikoner på mobiltelefon desktopen (Figur 1).



Figur 1. DiabetesDagboka og DiaSpill installerte på Android-basert telefon

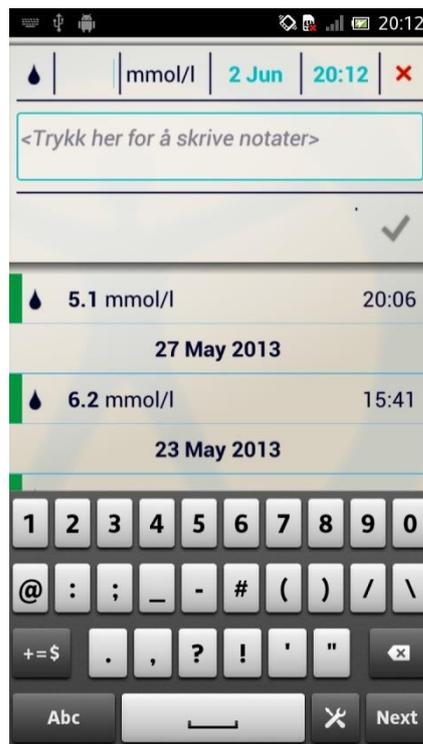
Hvis du har en glukosemåler med Bluetooth-tilkobling, blir alle dine blodsukkermålinger automatisk registrert i DiabetesDagboka. Hvis du ikke har en slik glukosemåler, kan blodsukker nivået måles som vanlig og verdiene kan skrives inn manuelt i DiabetesDagboka.

Hvis du åpner DiabetesDagboka, vises følgende side (Figur 2).



Figur 2. Den første siden i DiabetesDagboka

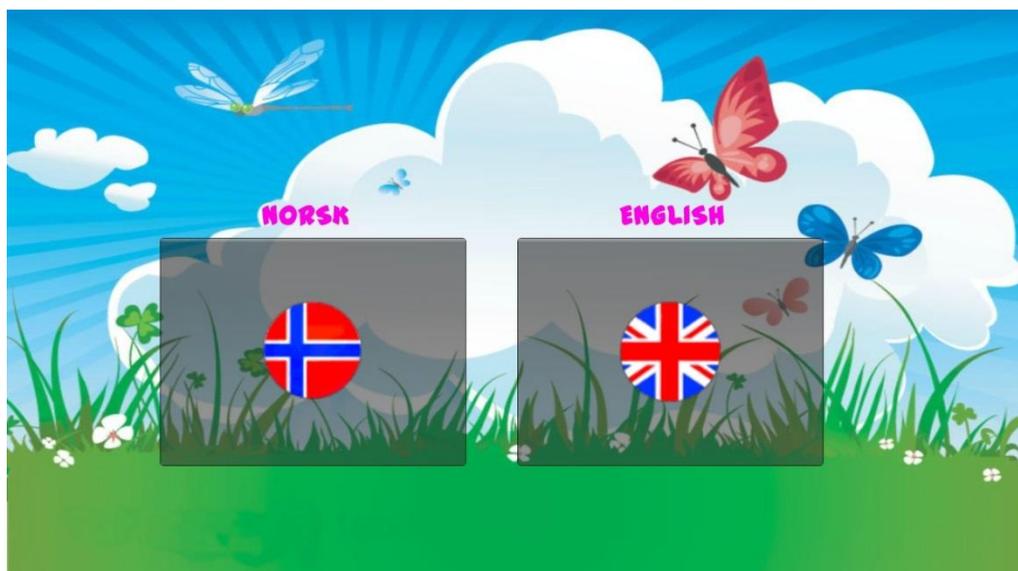
Hvis du trykker på venstre øverste ikon, vil du bli omdirigert til neste side hvor du kan registrere dine blodsuktermålinger (Figur 3).



Figur 3. Registrering av en ny blodsuktermåling i DiabetesDagboka

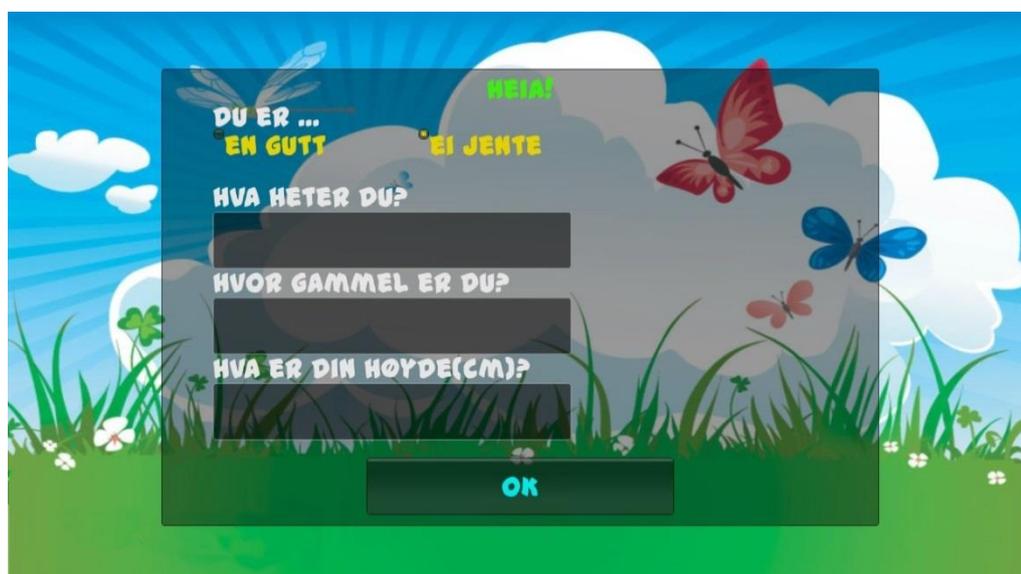
Deretter kan du lukke DiabetesDagboka. Til dette bruker “Home” eller “Tilbake” knappene på mobiltelefonen.

Hvis du klikker på DiaSpill ikonet, vil du se en side hvor du blir tilbudt å velge språk for følgende spillflyt (se Figur 4).



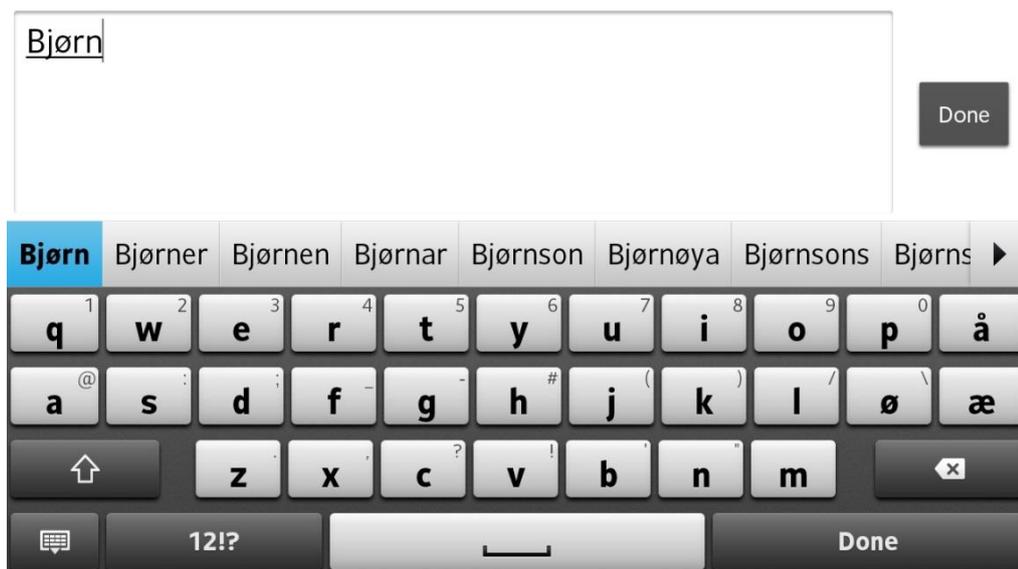
Figur 4. Språket valg

Når du har gjort et valg, en side hvor litt informasjon om deg er nødvendig for å fylles opp (Figur 5). Det inkluderer ditt kjønn, navn, alder og høyde som skal brukes videre i spillet.



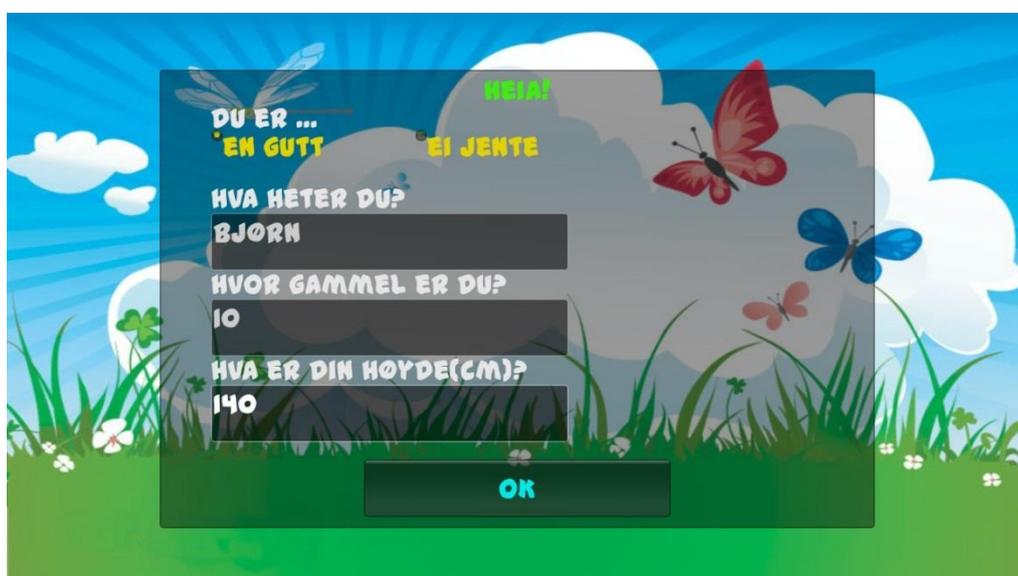
Figur 5. Informasjon som skal fylles ut for å starte et spill

Et virtuelt tastatur er tilgjengelig for opplysningsinnføring (Figur 6).



Figur 6. Opplysningsinnføring via et virtuelt tastatur

Når all nødvendig informasjon er skrevet, ser siden som følger (se Figur 7).



Figur 7. Utfylt brukerens opplysning

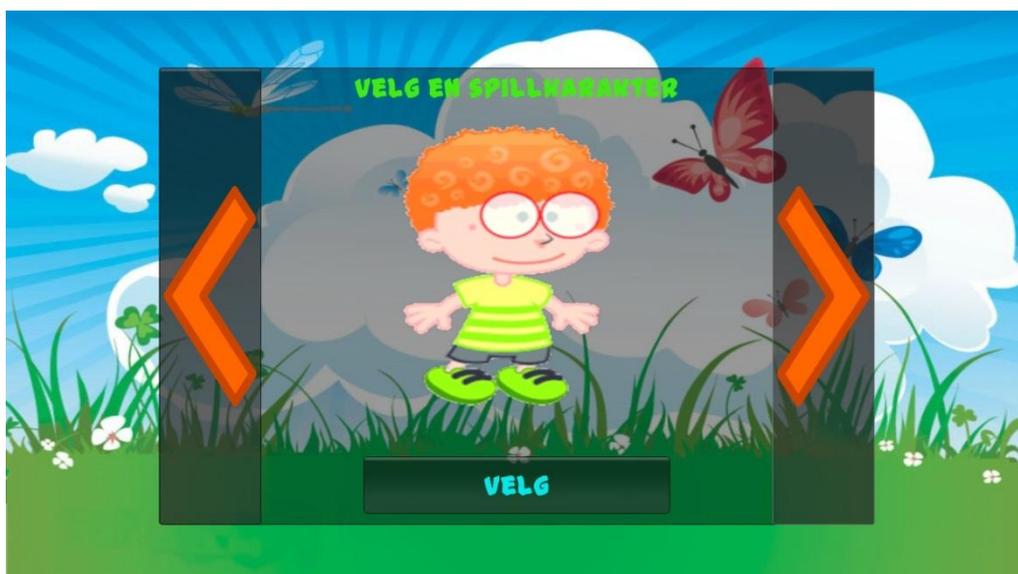
Hvis du nå trykker på “OK” knappen, kan du begynne å spille.

Plutselig er en tilkalle-hjelp melding fått (Figur 8). Den Onde Kakene stammen med deres leder, SuperBoss, har angrepet vår planet. De vil gjøre alle mennesker fete. De har stjålet vennene dine. Alle mennesker håper du kan hjelpe til med å bli kvitt de Onde Kakene. Du må kjempe mot stammen for å frigjøre vennene og resten av verden.

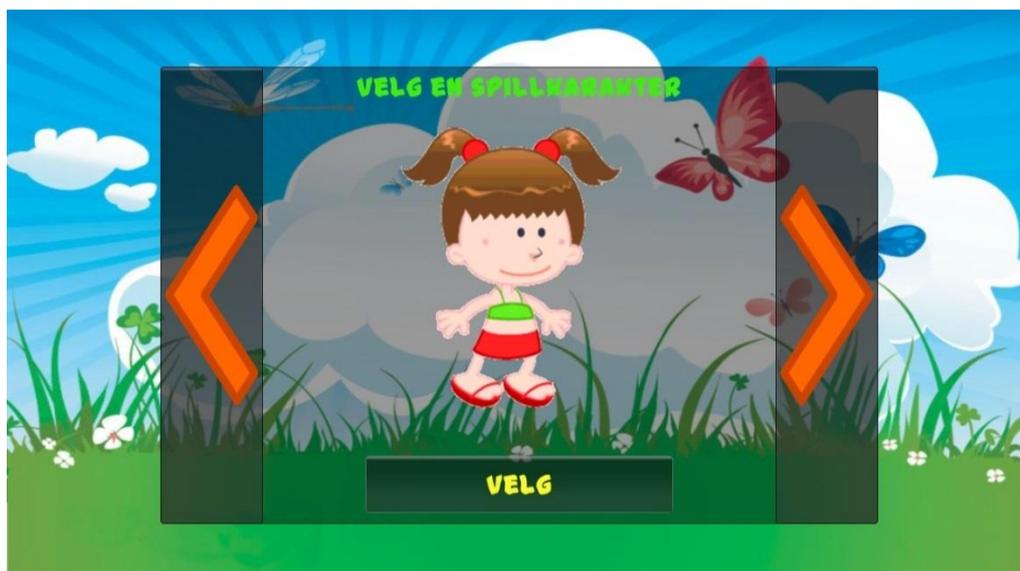


Figur 8. En tilkalle-hjelp melding

Hvis du er villig til å hjelpe, klikker du bare på “OK” knappen og velg en spillkarakter du ønsker å spille. Du kan velge mellom 10 gutter (Figur 9) eller jenter (Figur 10): dette er avhengig av ditt kjønn. En spillkarakter har type 1 diabetes.



Figur 9. Et spillkarakterens valg (gutter)



Figur 10. Et spillkarakterens valg (jenter)

Nå er du klar til å kjempe!

NB! Hvis det ikke er for første gang når du åpner DiaSpill, kan du se en følgende side (Figur 11). På toppen er det en ansvarsfraskrivelse hvor vi advarer deg mot å gjøre de samme tingene som for en spillkarakter i spillet i det virkelige liv. På siden ser du navnet ditt og to knapper "Spill!" og "Ut!" for ytterligere tiltak. I tillegg kan du endre spillets språk her.



Figur 11. Den første siden til spillet

La oss se på hovedmenyen til spillet (Figur 12). Du kan få dit hvis du trykker på "Spill!" knappen, eller i tilfelle av det første spillets bruk vil du automatisk bli omdirigert dit.



Figur 12. Hovedmenyen side

Som du kan se er den mye informasjon på denne siden. Først og fremst la oss se på spilleregler (Figur 13).



Figur 13. Spilleregler-menyen knappen på hovedmenyen siden

Her finner du noen tips om hvordan du flytter en karakter i spillet (Figur 14), hvordan du kan komme videre på fremgang ved blodsuktermåling (Figur 15), hvordan man kan tjene Superpoeng (Figur 16), og hvordan Gullpoeng belastes (Figur 17).



Figur 14. Spilleregler: hvordan spillkarakter kan beveges



Figur 15. Spilleregler: hvordan å få høyere prosent på fremgangsskalaen

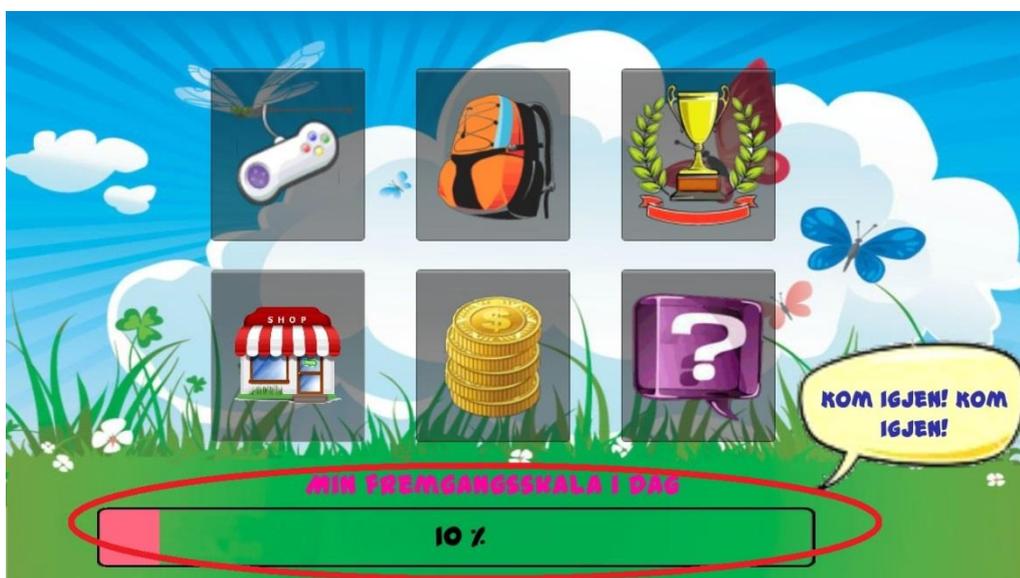


Figur 16. Spilleregler: hvordan å tjene Superpoeng



Figur 17. Spilleregler: hvordan å få Gullpoeng

Nå la oss si noen ord om fremgangsskalaen som er nederst på hovedmenyen side (Figur 18). Det fungerer som følger. For å få høyere prosent her, må du kontrollere ditt blodsukker. Dette omfatter et visst antall målinger i løpet av dagen, et intervall mellom målingene, og målinger regularitet. Det er best om du måler ditt blodsukker 5-8 ganger per dag, med omtrent 2-4 timer mellom målingene, og gjør det i de samme tidspunkt som i går. Avhengig av disse parameterne, får du en, to eller tre stjerner for din fremgang i løpet av dagen: 51-75% gir deg en stjerne (Figur 19), er 76-90% regnet for to stjerner (Figur 20), og for 91% og mer, får du tre stjerner (Figur 21). I tillegg får du forskjellige kommentarer om fremgangen din.



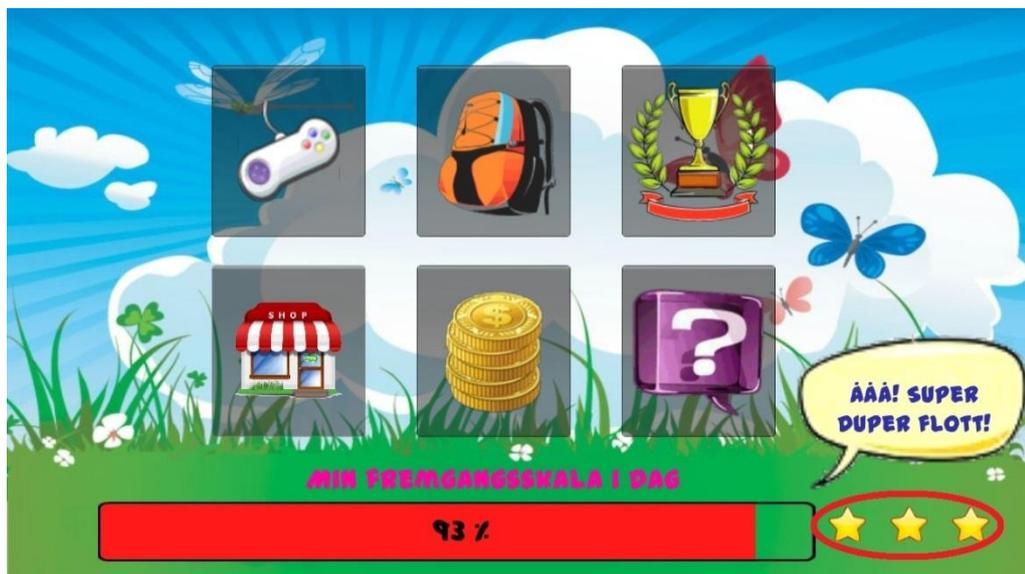
Figur 18. Fremgangsskalaen på hovedmenyen siden



Figur 19. En tildelt stjerne for din fremgang i løpet av dagen



Figur 20. To tildelte stjerner for din fremgang i løpet av dagen

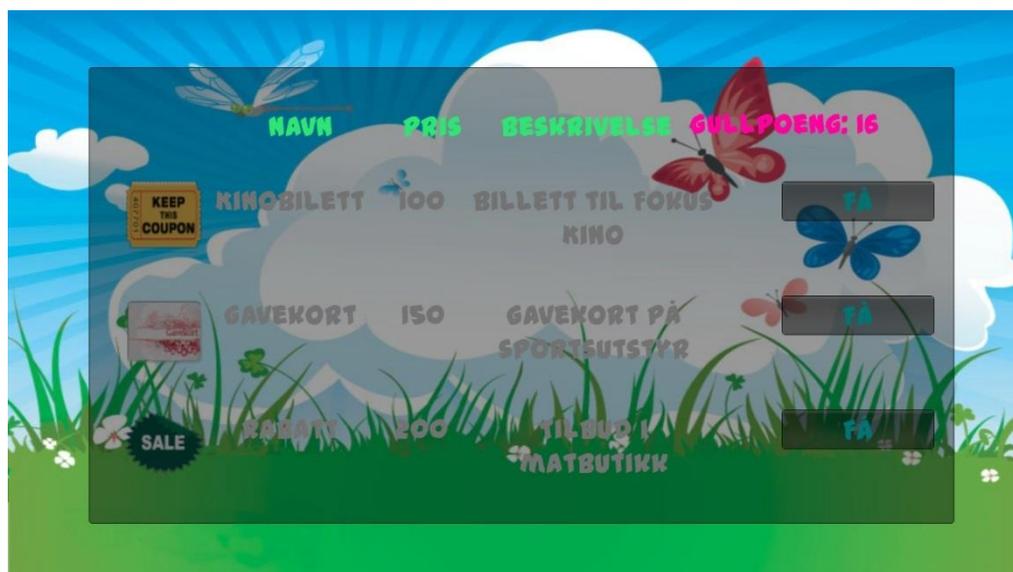


Figur 21. Tre tildelte stjerner for din fremgang i løpet av dagen

Hvis du trykker på knappen med gullmynter (Figur 22), er du i Gullpoeng menyen (Figur 23). På slutten av hver dag får du Gullpoeng hvis du har klart å få nok prosent på fremgangsskalaen i dag. I tillegg får du Gullpoeng på slutten av hver måned hvis ditt gjennomsnitt blodsukkernivå er i anbefalt området (4-7 mmol/ l). Du kan bruke Gullpoeng for å få premier i det virkelige liv, for eksempel, kinobilletter, gavekort til sportsutstyr, osv. Premier velges i forhold til Gullpoeng du har fått.



Figur 22. Gullpoeng-menyen knappen på hovedmenyen siden

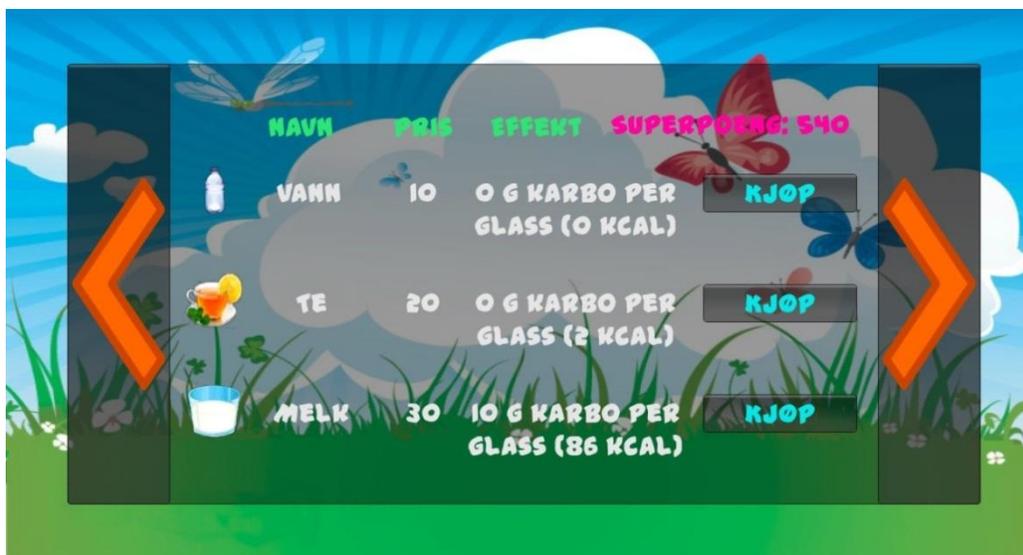


Figur 23. Gullpoeng menyen

Hver gang du måler ditt blodsukker får du 20 Superpoeng. Disse poengene kan brukes til å kjøpe ulike sunn mat og sportsutstyr elementer for å regulere spillkarakterens blodsukkernivå. Dette kan gjøres i Butikken (Figur 24). Noe informasjon, for eksempel en mengde av kalorier og karbohydrater per porsjon, er gitt for hver butikk element (Figur 25).



Figur 24. Butikk-menyen knappen på hovedmenyen siden

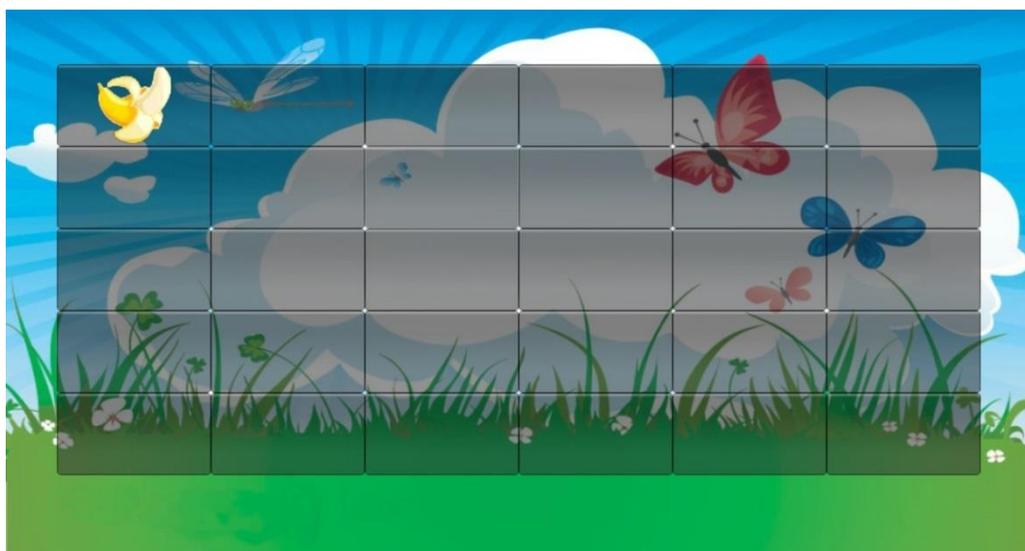


Figur 25. Butikk menyen

Når du har kjøpt noe i butikken, kan det sees i Ryggsekk menyen (se Figur 26 og Figur 27).



Figur 26. Ryggsekk-menyen knappen på hovedmenyen siden



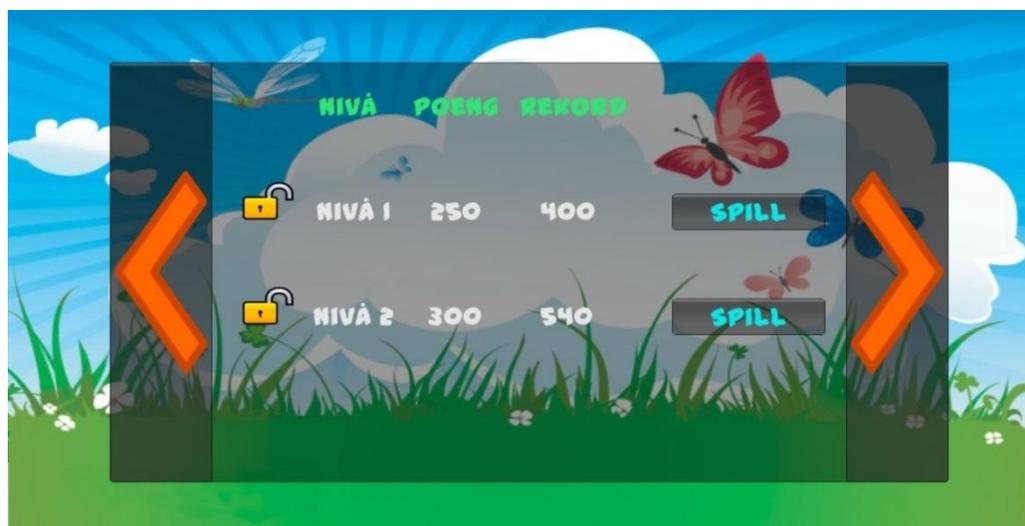
Figur 27. Ryggsekk menyen

Nå endelig kan du begynne å spille spillet. Gå til Nivåene menyen (Figur 28).



Figur 28. Nivåene-menyen knappen på hovedmenyen siden

Her ser du tilgjengelige (ulåste) nivåer (Figur 29).



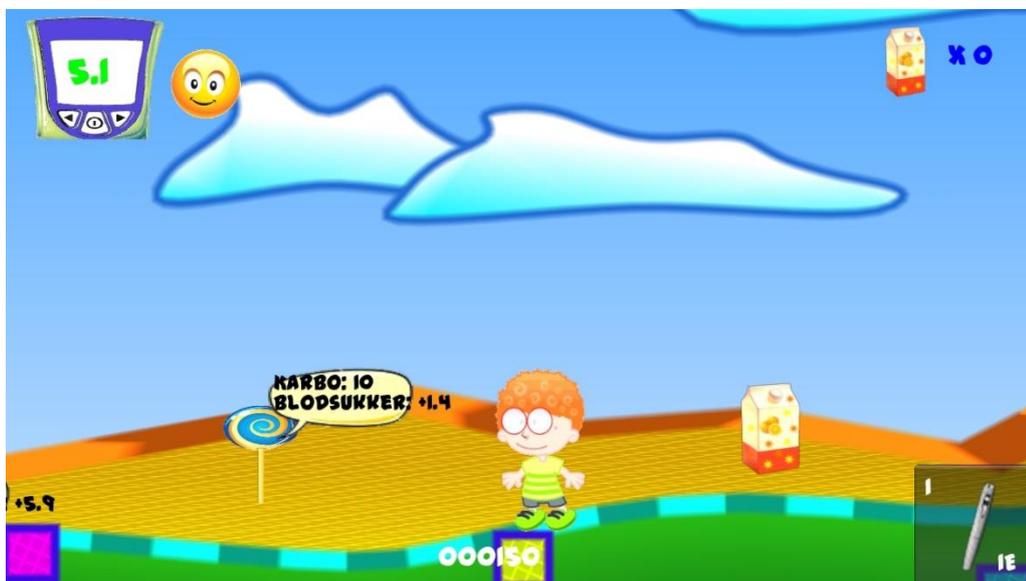
Figur 29. Nivåene menyen

For å spille et nivå, trykker du bare på “Spill” knappen midt imot dette nivået navn (Figur 30).



Figur 30. En “Spill” knappen for å spille et nivå

Da et bestemt nivå starter (se Figur 31). I løpet av nivået kjører du, overkommer mange klosser, motstår ulike fiender, og samler insulin penner og appelsinjuicepakker. For å komme videre i spillet, løper du (bare dra på skjermen), hopper over klosser (dra opp på skjermen), og kaster Cola flasker til fiender (ved å trykke på spillkarakteren) (se Figur 14). Du kan gjenkjenne hvor mye hver fiende inneholder karbohydrater og hvor mye det gir til et spillkarakterens blodsukkernivå ved informasjonen i sine bobler.

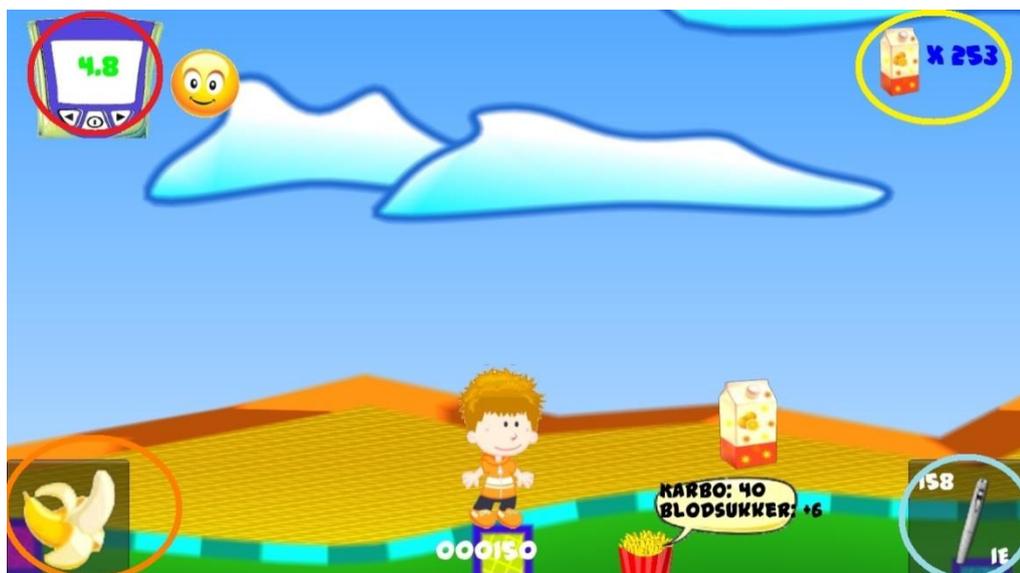


Figur 31. Nivå spillflyt

Som du har forstått, har en spillkarakter type 1 diabetes.

Øverst i venstre hjørnet av skjermen har du en blodsukkermåler med din siste blodsukkernivå verdi i begynnelsen av hvert nivå (Figur 32). Verdiene der endres hvis du har blitt truffet av fiender eller har brukt insulin penner eller utstyr som du har kjøpt i butikken.

Også på skjermen har du et antall av samlet appelsinjuicepakker i øverste høyre hjørnet, et antall av samlet insulin penner i høyre hjørnet på bunnen, og utstyr elementer ikonene nederst til venstre (Figur 32).



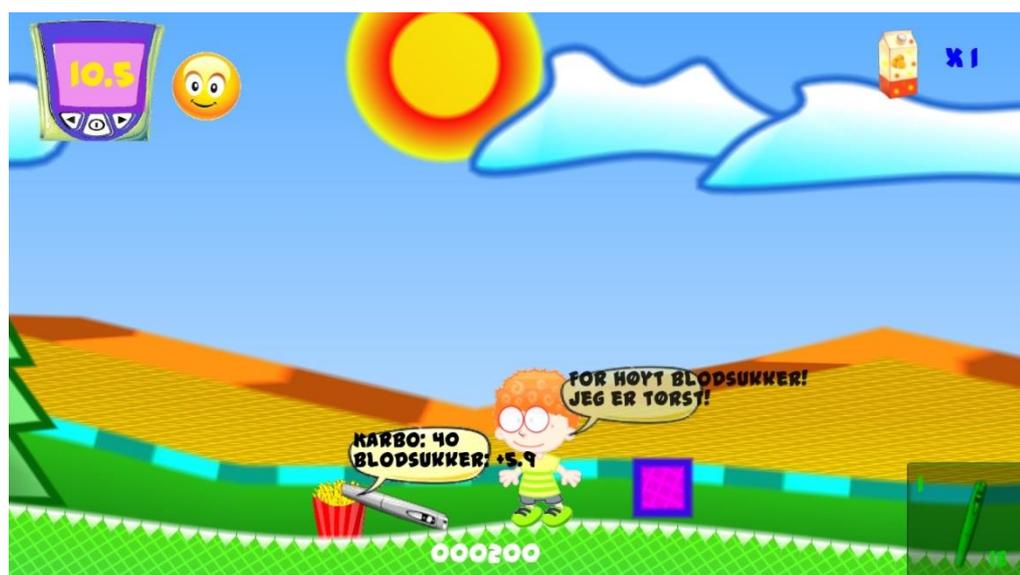
Figur 32. Nivå gameplay detaljer

Du samler insulin penner til å passe på spillkarakterens blodsukkernivå mens appelsinjuicepakker samles inn for å brukes som missiler i finalemisjon når du skal kjempe mot SuperBoss. Han er veldig sterk og er ikke redd for Cola flasker (som vanlige kaker er).

Insulin penner er samlet på hvert nivå. De må brukes hver gang din spillkarakter treffes av fiender eller om hans/ hennes blodsukker er for høyt (bare trykk på insulin penn ikonet). Når insulinsetting er nødvendig, blinker insulin penn ikonet.

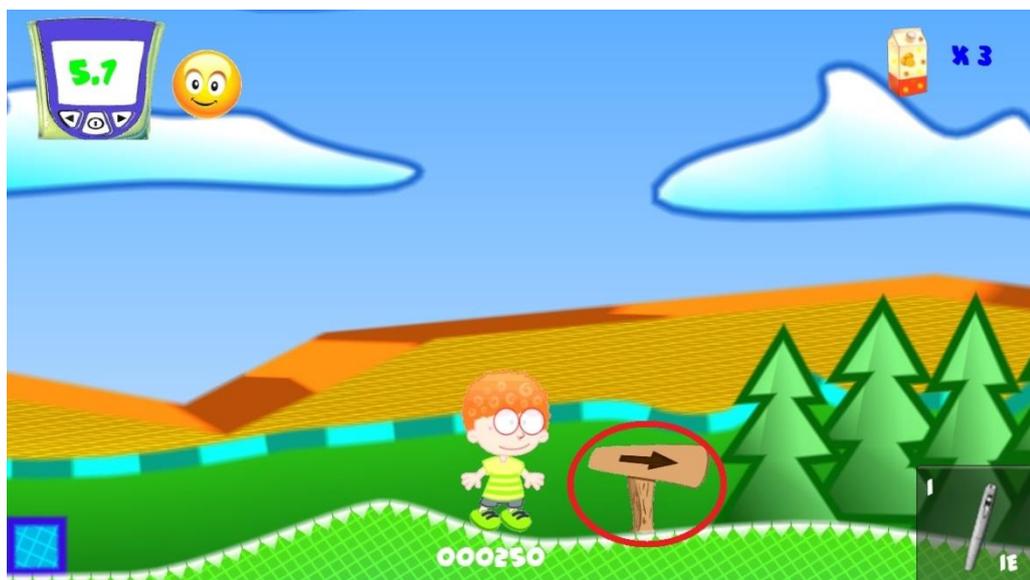
Utstyr elementer ikonene også blinker når noe trenges å bli brukt. Utstyret skal brukes til å holde et karakterens blodsukkernivå i det anbefalte området (mellom 4 og 7 mmol/l). Hvis spillkarakterens blodsukkernivå er lavere enn 2 mmol/l eller høyere enn 18 mmol/l, må du spille dette nivået igjen. Et blodsukkernivå som er lavere enn 4 mmol/l er for lavt og er merket rødt på blodsuktermåleren. Og når blodsukkernivå økes til 10 mmol/l og høyere, er det for mye og er det gule tall på blodsuktermåleren (Figur 33).

Hvis spillkarakteren din har fått fem ganger for lavt blodsukkernivå eller åtte ganger for høyt blodsukkernivå, må du spille et nivå tidligere til det nivået du har nettopp fullført.



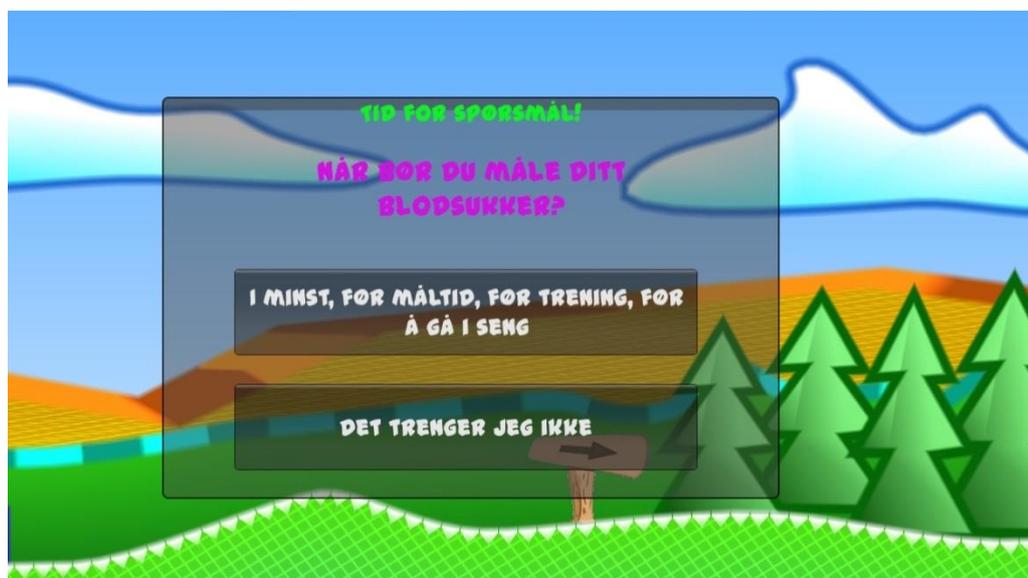
Figur 33. For høy blodsukkernivå

I slutten av hvert nivå ser du et avslutningsskilt (Figur 34).



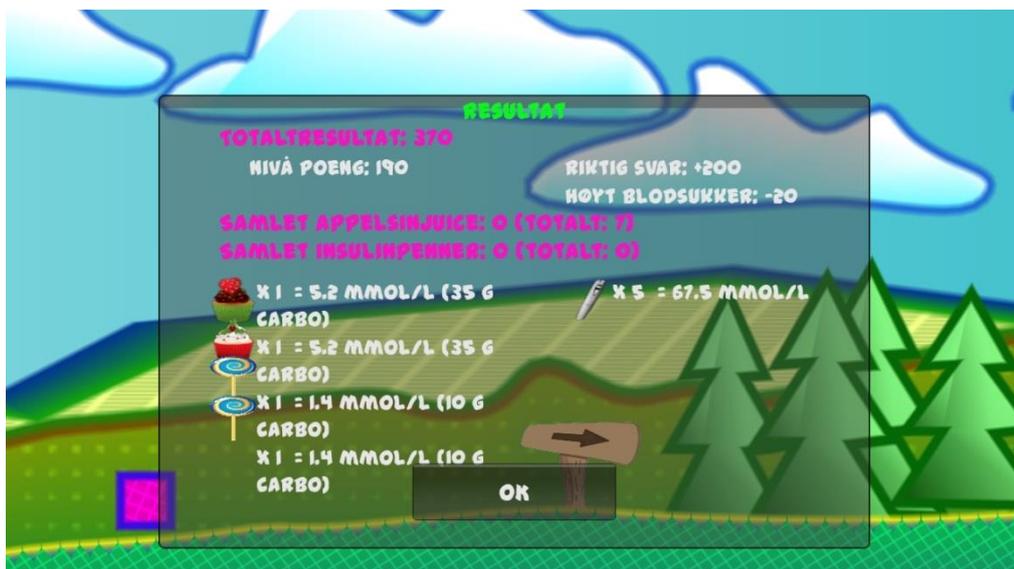
Figur 34. Et avslutningsskilt

Etter du har gått gjennom det skiltet, får du et spørsmål om diabetes greier (Figur 35). Hvis svaret ditt er riktig, får du i tillegg 200 poeng til poengsummen etter nivå.



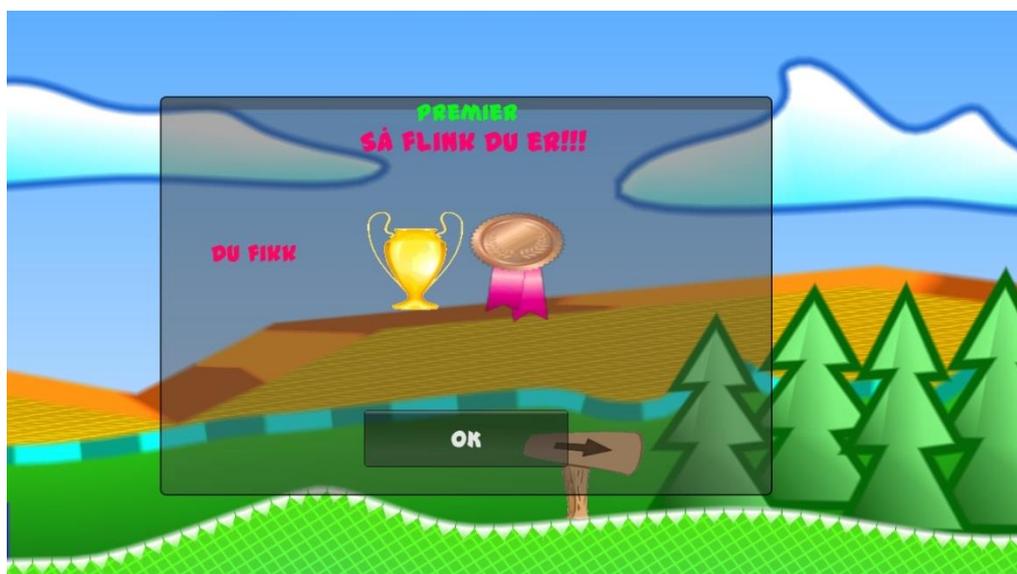
Figur 35. Et spørsmål etter fullført nivå

Alle resultatene er beskrevet i detaljer i det neste vindu (Figur 36). Resultatene inkluderer hvor mange fiender har truffet deg, hva slags utstyr du har brukt mot dem, poengsummen din, et antall av samlet insulin penner og appelsinjuicepakker, og om spillkarakteren din har fått for lavt og / eller for høyt blodsukkernivå.



Figur 36. Resultatene vinduet

Deretter blir du belønnet med pokaler og medaljer i forhold til poengsummen din og samlet missiler (appelsinjuicepakker) (se Figur 37).



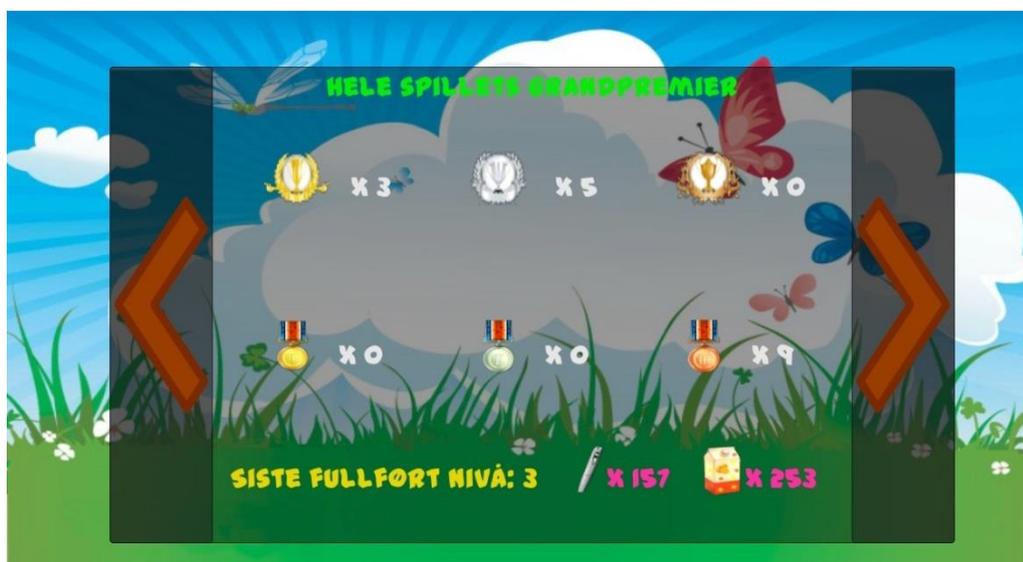
Figur 37. Premier etter hvert nivå

Dine premier for hvert nivå og for hele spillet er tilgjengelige i Premiene menyen (se Figurene 38-40).



Figur 38. Premiene-menyen knappen på hovedmenyen siden

På denne siden kan du også finne informasjon om det høyeste nivået du har spilt og hvor mange insulin penner og appelsinjuicepakker du har samlet (Figur 39).



Figur 39. Hele spilllets premier



Figur 40. Premier for et bestemt nivå

Når du har vunnet SuperBoss på det siste nivået, er hele Den Onde Kakene stammen ødelagt. Du får en seieren melding om at alle fiender er redde og løper bort (Figur 41). Alle mennesker er frie. God jobb!



Figur 41. Seieren melding

Nå kan du spille spillet en gang til, eller spille nivåene du liker best.





Photos by Eirik Årsand



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