Sapienza
Università di Roma

A new approach to management of diabetic children base on gamification

Department of Computer, Control, and Management Engineering (DIAG)
Corso di Laurea Magistrale in Engineering in Computer Science

Candidate
Soma Shekarchi
ID number 1746763

Thesis Advisor
Prof. Ioannis Chatzigiannakis

Academic Year 2019/2020

Thesis defended on 21 January 2020
in front of a Board of Examiners composed by:

Prof. Marco Schaerf (chairman)
Prof. Ioannis Chatzigiannakis
Prof. Daniele Cono D'Elia
Prof. Andrea Marrella
Prof. Massimo Mecella

A new approach to management of diabetic children base on gamification
Master's thesis. Sapienza – University of Rome

This thesis has been typeset by LaTeX and the Sapthesis class.

Version: January 14, 2020

Author's email: shekarchi.1746763@studenti.uniroma.it

Abstract

Changing the diet and lifestyle of today's society has led to many diseases. Diabetes mellitus is one of the most common and major increasing problems in the world.
This management ranges from control insulin-dependent diabetes through blood glucose control is to use fingerprint blood tests multiple times daily and adjust insulin doses based on these readings and associated information, to have the emotional and social support that they need to cope with the condition.
Diabetes is a disease characterized by high blood sugar levels as a consequence of the body's inability to produce and/or use insulin. In a healthy human, glucose homeostasis represents a closed-loop system which is able to regulate blood glucose levels. In this way, the pancreas presents beta cells which are sensitive to high glucose levels and produce insulin, a strong hormone able to reduce hyperglycemia in blood by allowing a "passage" for glucose to enter the cells. This regulation is not naturally possible in Type 1 Diabetes Mellitus (DM1). Patients with a certain evolution of DM1 do not produce any insulin and must inject this hormone or wear an insulin pump in order to reduce their glucose levels. Furthermore, diabetic people need to check their glucose level several times per day and, based on these data as well as other factors like meals, exercise, and many others, try to predict the evolution of their glycaemia. Then, they have to decide how much insulin is required to keep their blood glucose level within a normal range (avoiding both hyper- and hypoglycemia). So, the possibility of accurately forecasting future blood glucose levels is an important task in order to infer insulin dosages [106].
The global increase in the prevalence of diabetes along with the cost associated with complications is challenging traditional approaches to healthcare delivery.
Diabetic children must be injecting insulin in every morning, but this act have pain, they don't like their parent force to do plan every day, they cannot eat sweet and chocolate, usually they are almost shy, so they feel different of every kid in the world. children do not like static scheduled diet plan, because they think it is not a funny and it is static plan.
In the other hand most of parent have problem to manage and control our diabetic children, they try encouraging them with several ways, but it is very boring, when parents do not near to child, at most time parents try to care her child by calling to them and check own child so parents always are worry about her/his healthy, in conclusion manage the diabetic children is difficult and take more time.
So, we want a new model of interaction and encourage children to do his/her diabetic plan.
For a dynamic, nonlinear, and complex condition such as diabetes, this can be far from satisfactory. Factors such as insulin type and dose, diet, stress, exercise, illness, or insufficient sleep all have significant influences on the BGLs.
Application tools could help patients to track and record their tests and use alarming pattern in their daily diet.
While the pervasiveness of mobile phones has resulted in a consumer-driven market for diabetes-focused mobile health applications, most of these apps are not evidence-based or rigorously evaluated [55].
The main objectives of this research were to design, develop and evaluate, a consumer-

focused, behavioral app for the self-management of diabetes.
The app was developed following user-centered design principles, where iterative feedback was obtained from patients throughout the process.
The term gamification refers to a designed behaviour shift through playful experiences and became popular in the past years. In order to effectively motivate users to adopt desired behaviours, the games should provide information so that the user themselves will be able to evaluate their behaviour and increase their awareness on the negative consequences that it may have [92][13].
One of its main features is the use of game designs and techniques to reinforce positive behavior in managing diabetes. Game techniques are also used to increase users' interaction in the community and to encourage users to exchange experiences and knowledge and provide emotional support to each other.
Game-based approaches (gamification) can provide ideal strategies for health promotion, prevention, and self-management of chronic conditions [82].
Gamification elements are inseparable in such approaches: discovery and adventure are intemperate elements in childs play that leads them through knowledge. Gamification via the internet and social activity mechanisms, on the other hand, is multiplying the impact of the children engagement [124].
Gamifying disease management can help children, adolescents, and adults with diabetes to better cope with their lifelong condition [25].
In this perspective, this Graduation Project will aim at highlighting main children diabetes self-management issues, reviewing state-of-the-art Diabetes and user centered design methods and Empowerment through mHealth gamification, and proposing gamification in a mHealth/e-health context.

Acknowledgments

I would firstly like to express my deepest appreciation to my supervisor Prof.Ioannis Chatzigiannakis. He provided me with invaluable guidance and support.
Big thanks to my teammate Mr. Mostafa Ramezani. I am lucky to have worked alongside your brilliant minds. Thank you for sharing your experiences, giving great advice, and for providing the type of support only teammate can provide.
I would like to express my gratitude for the immeasurable support I have received from my family while pursuing this work.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

One of the most common chronic illnesses today is diabetes mellitus. It is rapidly spreading among both the young and old and is considered by many to be the disease of the 21st century [45].
Many factors contribute to this widespread emergence of diabetes. These include population growth, urbanization, socioeconomic developments and the changes in lifestyle [134].
However, with the discovery of insulin (extraction and purification) in 1920 by Dr. Frederick Banting and Charles Best, T1DM has become a manageable chronic disease. Patients worked with their diabetes care team to develop a self-management plan that works best for their individual needs [86]. Diabetes affects the glucose level in the blood. Patients could suffer from hyperglycemia or/and hypoglycemia [77].
According to the latest IDF [95] there are currently 425 million people living with diabetes and the total is expected to rise to 629 million by 2045. Some 75% of people with diabetes live in low- and middle-income countries and half of people living with diabetes are undiagnosed [132].
Diabetes is a chronic condition that places the burden of long term self-management on the individual affected. In addition to the medical challenges associated with diabetes, there are several challenges with self-care, including deficits in knowledge, sustained motivation, and psychosocial factors [118][76].
These numbers are alarming and represent a major public health concern. Furthermore, if diabetes is left untreated or is not properly managed, it can lead to devastating complications. These include cardiovascular disease, kidney failure, blindness and amputations [17].
Diabetes does not only affect the body parts of patients, but it also could lead to clinical depression. It has been proven that patients with diabetes are more prone to depression than others [43].
Although self-management training has long been acknowledged as a key component of the clinical treatment of diabetes, patients still lack diabetes knowledge and ability to manage their condition on a daily basis [91].
Therefore, the purpose of this research is to design and develop a mobile application that can help Child T1DM patients better manage their disease [86].
In the software industry there is problem and it has been widely reported recently

that more than 26% of all mobile applications are used just once. One of the most common reasons is the so-called “lack of user engagement”.
Most of the applications are not designed and architected with the end user in mind. Subsequently a lot of those applications do not meet user’s needs, which leads to very low usage and eventual failure [80].
A user-centered design process was followed, with an emphasis on features involving data visualization, social communities, and game-based design (gamification) [86]. Gamification tries to distinguish what elements of games make them so powerful and engaging, distills and examines those elements and then apply them to non-gaming concepts [80].
Heart disease and stroke are becoming the leading causes of death worldwide. Electrocardiography monitoring devices (ECG) are the only tool that helps physicians diagnose cardiac abnormalities. Although the design of ECGs has followed closely the electronics miniaturization evolution over the years, existing wearable ECGs have limited accuracy and rely on external resources to analyze the signals and evaluate heart activity [8].
The only tool available to physicians and cardiologists to evaluate irregular heart rate, heart rhythm, and diagnose cardiac abnormalities are Electrocardiography monitoring devices (ECG). Such high-accuracy devices that are capable of recording the heart’s patterns are available only in hospitals and are bulky for usage in outside place, e.g., in home environments. As many heart abnormalities take place at random intervals, assessments based on recordings at given the time of day are inadequate in spotting heart problems [7].
The design of advanced health-monitoring systems has always been a topic of active research. During the past decades, numerous portable devices have been introduced for the early detection and diagnosis of heart failure, since it is a common, costly, disabling, and deadly syndrome. Advanced heart-monitoring devices are capable of providing reliable, accurate heart monitoring and are able to detect sporadic events during periods of time when things would otherwise be unclear [108].
Wearable and remote monitoring devices enable monitoring of physiological and clinical parameters (heart rate, respiration rate, temperature, etc.) and analysis using cloud-centric machine-learning applications and decision-support systems to predict critical clinical states [108].
Type 1 Diabetes Mellitus (DM1) patients are used to checking their blood glucose levels several times per day through finger sticks and, by subjectively handling this information, to try to predict their future glycaemia in order to choose a proper strategy to keep their glucose levels under control, in terms of insulin dosages and other factors. However, recent Internet of Things (IoT) devices and novel biosensors have allowed the continuous collection of the value of the glucose level by means of Continuous Glucose Monitoring (CGM) so that, with the proper Machine Learning (ML) algorithms, glucose evolution can be modeled, thus permitting a forecast of this variable. On the other hand, glycaemia dynamics require that such a model be user-centric and should be recalculated continuously in order to reflect the exact status of the patient, i.e., an ‘on-the-fly’ approach [106].
Machine learning techniques combined with wearable electronics can deliver accurate short-term blood glucose level prediction models. These models can learn personalized glucose–insulin dynamics based on the sensor data collected by monitoring

several aspects of the physiological condition and daily activity of an individual [105].
The wearable device becomes capable of analyzing and interpreting sensor-data traces to provide actionable alerts without any dependence on cloud services. Therefore, we evolve the current paradigm for developing wearable solutions from a totally cloud-centric one to a more distributed one [108][9].
In summary, this design-oriented thesis used a user-centered design approach to design an application that would help children living with T1DM self-manage their disease.
We use wearable for measuring the beat-to-beat variation in heart rate is a promising device for the early detection of hypoglycemia, or low blood sugar, in type 1 diabetes. System sends immediate alerts to your smart device or receiver when your heartrate is trending too high or too low.

1.1 The Problem Definition

In 2013, about 382 million people had diabetes worldwide. Today, this number is estimated to be 415 million or, in other words, 1 in 11 adults, with equal rates in both women and men. According to the International Diabetes Federation (IDF) - the umbrella organization for 200 diabetes associations in more than 160 countries - the number of people with diabetes is even expected to rise to 592 million by 2035 [58] (Figure .1.1).

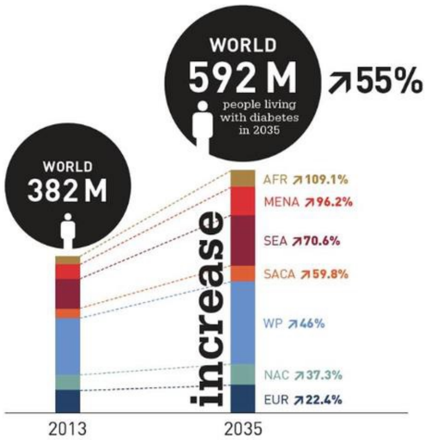

Figure 1.1. *IDF Diabetes projections [43]. Note that three quarters of people with diabetes live in low and middle income countries [91]. Legend: AFR; Africa. MENA: Middle East and North Africa. SEA: South-East Asia. SACA: South and Central America. WP: Western Pacific. NAC: North America and Caribbean. EUR: Europa.*

Type 1 diabetes is a chronic condition generally manifested in childhood or the early teenage years. While genetic and environmental factors are involved, the precipitating factors are unknown. Autoimmune destruction of the insulin-producing cells in the pancreas means that daily administration of insulin is necessary. A high degree of self-management and regular monitoring is required to achieve and sustain the level of glycemic control necessary, and to offset visual problems, nerve damage, renal impairment, and other long-term complications [36].
Uncontrolled diabetes could lead to serious complications and sometimes it could lead to death. Patients must keep track of their blood glucose levels and maintain a healthy diet [12].
From 2012 to 2015, diabetes is estimated to have resulted in 1.5 to 5.0 million deaths per year, which represents about 1 death every 6 seconds. Furthermore, the global economic cost of diabetes in 2015 is estimated to be 600 billion e, meaning that 12% of global health expenditure is spent on diabetes [2].
Children with type 1 diabetes have to monitor their blood glucose and diet, administer insulin, and participate in physical activity during school hours, which represent a large portion of a child's waking hours [50]. This situation can feel overwhelming and burdensome, if not stigmatizing, as the child tries to mingle with his or her peers who do not have diabetes [25].

There is, therefore, a pressing need to find innovative solutions at scale that encourage children and young people with diabetes to continually engage with glucose monitoring and therapy compliance during the transition phase to emerging adulthood. Solutions should assist decision support, be personalized, be responsive to individual needs, and demonstrate acceptability alongside measurable outcomes in increased self-management, quality of life, and crucially, maintenance of good glycemic control [25].
The majority of existing self-management tools are one-dimensional and focus on tracking diabetes-related measures, such as blood glucose readings [33]. They do not provide frequent, personalized, or actionable feedback on the impact of daily lifestyle behaviors on glycemic control or motivate positive behavior change [55].
Compared to traditional paper-based tools, mobile phones offer a unique opportunity to deliver highly personalized and dynamic behavioral interventions [64].
While the pervasiveness of mobile phones has resulted in a competitive and consumer-driven market for mobile health (mHealth) applications, the large majority of these apps are not evidence-based or rigorously evaluated [64][33]. and consequently are not highly impactful in improving the overall health of the individual living with diabetes [55].

Type 2 is the more common of the two by a long margin.In general, 90% of adult diabetics are Type 2 and only 10% are type 1 [97](Figure.1.2).

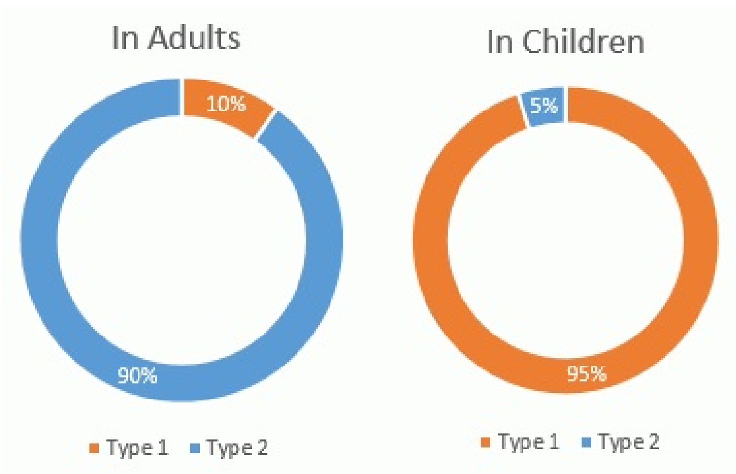

Figure 1.2. *Type 1 vs Type 2.*

However in young people below 19, the reverse is true - Type 1 diabetes accounts for about 95% of the diagnosed cases. Children with diabetes exhibit distinct lack of beta cells which makes the body incapable of producing insulin - a marked feature of Type 1. Within that age group Type 2 is very rare indeed [97].

1.2 Proposed Solution

The existing acute-care focused health care system does not meet the demands associated with the rapidly increasing prevalence of chronic disease [128].
The role of the individual affected by the chronic illness, previously understated, is central in the prevention, management, and maintenance of chronic disease [19].
Our idea's name is "DOC.HERO". the solution is usually parents do not know to how encourage her child to doing schedule, when be familiar with "DOC.HERO" they can satisfy own children.
In application, if child doing schedule plan and follow them then they can get candy, what is candy? Candy is virtual money, child pay candy to play game for finite time, so they do the effort to gain much candy to play more game(Figure.1.3).

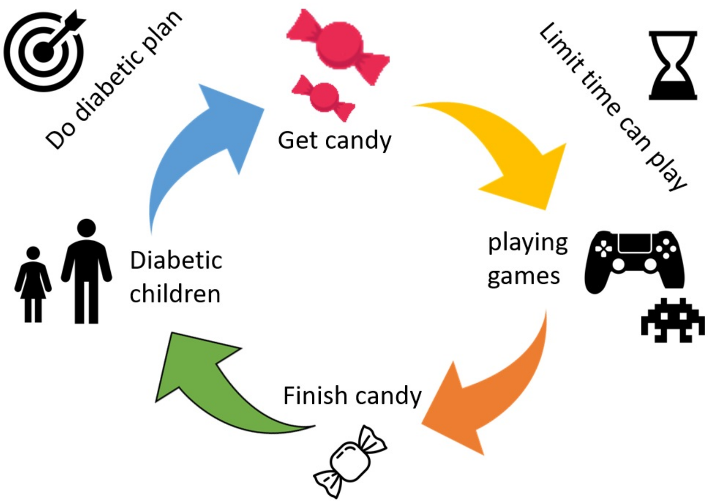

Figure 1.3. *Product overview and motivation.*

Parents after satisfying of following plan by child, take candy to child, when child do diet plan.
Child feel cool because child can play a lot go game after completing our schedule.
Parents happy and encourage their children to follow their task without need more care and attention.
Indeed, our solution can make eager diabetic children to do diet plan, without much care and control.
However, psychosocial factors, such as motivation, perceived susceptibility, readiness to change, and self-efficacy, can greatly influence the patient's ability or desire to participate in the self-management of their health [19].
optimizing quality of life through prevention of diabetes-related long-term complications, such as blindness, renal failure, amputations, and the high level of cardiovascular morbidity related to poor glycemic control, is essential to reduce direct and indirect health care costs associated with diabetes comorbidities [123][57].
Devices and apps that combine technology with entertainment and social interaction could prove a significant advance in the acquisition of skills to sustain self-reliance

for individuals with diabetes at varying stages of their condition and to benefit biomedical, psychosocial, and lifestyle measures [25].
Develop a consumer-focused self-management app for T2DM that is founded on evidence, user-centered design, and theoretical frameworks, and applies previously underexplored novel approaches to behavior change. Younger, and less experienced patients with type 1 diabetes (T1DM) struggle with the complex guidance involved, and ultimately fail to reach target A1c values [48].

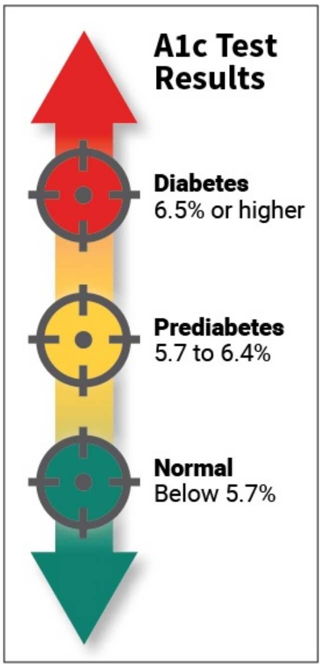

Figure 1.4. *The "gold standard" lab test for blood glucose control is called the Hemoglobin A1C. It's usually conducted in a clinic or hospital lab, although all that's really needed is one big drop of blood for an accurate test. It produces an average level of BG control over roughly the past three months, expressed as a percentage [84].*

In addition to monitoring glycemic variability, the psychological stress related to fear of hypoglycemia, future complications and impact on general wellbeing, results in a significant burden of care for both the patient and their family caregivers. The paper tools currently available to patients permit them to log blood glucose, carbohydrates and insulin doses, but remain suboptimal largely due to

(i) a high probability of erroneous manual data entry;
(ii) inability to capture enough data need for healthcare care provider clinical decision making;
(iii) lack of real-time feedback and behavior change motivation enabling patients to improve their ability to self-care [48].

One solution which is proposed is to incorporate behavioral insights with gaming techniques to provide an effective management tool for users. This is done through employing the principles of engagement, reward and motivation to certain tasks [75].

mHealth applications thus serve an important role in better facilitating self-care[85]. A burgeoning feature of mHealth applications very recently being leveraged to improve self-management behaviors is gamification[85].
Gamification is defined as the implementation of the most common and enjoyable mechanics of video games, in non-video game contexts [40][46].
Badges, leaderboards, points and levels, challenges and quests, as well as social engagement loops and onboarding are among the most commonly implemented mechanics of gamification [137].
Several frameworks have been proposed to better understand how particular game-design elements arouse emotions, moods, concerns, and needs in people. Since each person has her own personality and tastes, certain game elements that motivate her, may be irrelevant or non-engaging for other people. It is thus needed to consider different player types [21][1]., which suit each person according to how she interacts and reacts when playing a game [53].

In contrast, for a given domain, a well-designed gamification framework would require:

- Having as many player types and game-design mechanics as needed to meet the existing user personalities, tastes and needs, as well as the available activities and tasks.
- Validating the actual correspondence between each player type and each game design mechanic, and the implementation of the latter as certain domain-related action.[53]

It is suggested from a qualitative and design perspective, participatory design workshops with target audiences and stakeholders would be suitable to explore and identify suitable content, usability and accessibility issues, and to maintain the concept of audience inclusion from the start of a project.
Further, one-to-one interviews and focus groups would provide designers and researchers the opportunity to dig further into the perspectives of the users in relation to their engagement and experiences of the technology and the software. Additionally, to test health behavior components in the early design stages, pre-post surveys

assessing health behaviors or health status changes can be included to help bridge the gap of evidence required between small scale usability studies and randomized controlled trials to facilitate collaboration across stakeholders to aid in the design and iterative process of developing more high-fidelity prototypes for more effective mHealth apps [66].

1.2.1 The need for patient empowerment

Importance of lifestyle behavior
According to [96] and [98], there is an increasing recognition that lifestyle behaviors account for a substantial ($> 40\%$) portion of premature mortality and also play a determinant role in diabetes, in both types 1 and 2. Lifestyle and health-related behaviors include physical activity, nutrition, alcohol consumption, sleeping, socialization, and smoking. Unfortunately, poor health behaviors and habits appear to be easily acquired but difficult to eliminate. Perhaps even more challenging is the fact that once developed, good habits and behaviors are difficult to maintain long term. How can we keep patients engaged?[59]

Patient-centered approach
The serious and chronic nature of diabetes, the complexity of its management, and the multiple daily self-care decisions that diabetes requires mean that being adherent to a predetermined care program is generally not adequate over the course of a person's life with diabetes. This is particularly true when the self-management plan has been designed to fit patients' diabetes, but has not been tailored to fit their priorities, goals, resources, culture, and lifestyle.
Furthermore, there is considerable evidence that health interventions tailored to individuals are more effective that generic ones, and that timely feedback plays an important role in changing and sustaining behavior [96].

To manage diabetes successfully, patients must be able to set goals and make frequent daily decisions that are both effective and fit their values and lifestyles, while taking into account multiple physiological and personal psychosocial factors. That is the main issue patient empowerment, which aims to help patients discover and develop the inherent capacity to be responsible for one's own life (thus, closely related to "diabetes education"), should deal with [26][52].

Empowerment scale
Empowerment efficiency is not easy to measure. However, [15] provides a scale for that purpose. According to that study, empowerment can be sub-scaled into 3 mains aspects :

1. Managing the Psychosocial Aspects of Diabetes:
   this subscale assesses the patients' perceived ability to obtain social support, manage stress be self-motivating, and make diabetes-related decisions that are "right for me."
2. Assessing Dissatisfaction and Readiness to Change:

this scale assesses patients' perceived ability to identify aspects of caring for diabetes that they are dissatisfied with and their ability to determine when they are ready to change their diabetes self-management plan.

3. Setting and Achieving Diabetes Goals:
   this scale assesses patients' perceived ability to set realistic goals and reach them by overcoming the barriers to achieving their goals.

It has been shown that individuals with greater diabetes empowerment have greater knowledge about diabetes, have healthier diets, are more physically active, are more adherent to their medication treatment plans, and test their blood sugar more frequently compared to individuals with lower diabetes empowerment [67].

Empowerment through gamification
The best way to empower a diabetic patient is a personal face-to-face coaching [96], day after day, ideally in close collaboration with physicians, dietitians, nurses and other diabetes health care professionals. However, such solution is not an economically feasible method for helping people to improve and manage their health behaviors. [59]

This concept, which can be defined as the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals in non-game contexts [28], has become a trending topic in many fields. Amongst others, gamification attempts to improve user/customer engagement, organizational productivity, education, communication or physical exercise. A review of research on gamification shows that majority of studies on it have found positive and hopeful results [60].

However, the effectiveness of particular game-design elements and their correspondences with assigned player types are often ignored. In fact, in some cases, a limited number of motivations are taken into consideration [57]. Moreover, the player type assumed for a certain user may not be appropriate due to the actions that have to be performed in the domain of interest. [53]

Gamifying disease management can help children, adolescents, and adults with diabetes to better cope with their lifelong disease [85][20]. Gamification and social in-game components can be used to motivate players/patients and positively change their behavior and lifestyle, for example, help them develop the good habit of regular self-measurement of blood glucose [29][121]. Games would offer rewarding experiences in the form of "achievements" that can be shared with other players, progress points, and/or in-game virtual currency rewards—that can be spent to "buy" in-game power-ups—to help achieve all of this[25].
Games can also be used to educate and train health care professionals about various aspects of diabetes [41].

1.3 Project Goals: (Thesis Outline)

The project aims to create a mobile health (mHealth) applications. At the core of this project is the implementation of gamification, which is the use of game techniques and principles, to assist diabetic children patients in managing their condition and reinforce positive behavior. Furthermore, the system should provide the user with an electronic logbook for their tests. It should also allow users to visualize their progress by presenting these test results in a graph form. This will help them recognize patterns in their condition. [12]

The patient can receive customized feedback without having their caregiver continuously present, and by doing so learning to better manage their own condition. In this way, the independence of the patients is significantly increased. At the same time, continuous communication between patients and their caregivers/physicians is enabled in emergency situations or in cases when the patient requires their full support [7].
This thesis had three main objectives:

1) to understand the current landscape of diabetes self-management interventions and identify opportunities and challenges for consumer mobile health apps.
2) to understand User-Centered Design Method and Empowerment through mHealth gamification.
3) to follow a robust framework for the development of motivational system, design a user-centered, behavioral, self-management diabetes app.

Chapter 2

Literature Review and Background Research

2.1 Diabetes

Diabetes is a condition that occurs when the insulin–glucose–glucagon regulatory mechanism is affected [59].
Diabetes is a metabolic disorder that results from different conditions [138]. It is characterized by chronic hyperglycemia that is caused by a defect in the pancreas. Either it is not producing insulin, or the body is unable to use the insulin pumped out by the pancreas [17]. In normal individuals, high blood glucose levels (BGLs) induce the release of insulin,which enables its target cells to take up glucose. In low-glucose conditions, glucagon induces the breakdown of glycogen into glucose [59].
In opposition, in diabetic individuals, this synchronized mechanism is disrupted, which results in persistent too high blood glucose levels, known as hyperglycemia. Besides, in many cases - that will be further detailed - diabetic patients also strive to avoid too low BGLs or hypoglycemia [59].
Furthermore, hyperglycemia is characterized by a high concentration of glucose in the blood. On the other hand, hypoglycemia is the dramatic decrease in glucose in the blood [77].
Diabetes has two main types:

- insulin-dependent diabetes mellitus (IDDM), which is known as Type 1 diabetes [10].there is almost complete destruction of beta cells. More specifically, in individuals with a genetic predisposition, an unidentified trigger initiates an abnormal immune response and the development of autoantibodies directed against beta cells. The alpha cells are present in normal numbers but their function is impaired. T1D, being a complex genetic and autoimmune disorder, can not be prevented or cured, but it can be effectively treated with external supplies of insulin and managed through BGLs control [111][24].

- noninsulin-dependent diabetes mellitus (NIDDM), which is known as Type 2 diabetes [10]. the major islet pathology relates to amyloid deposition1. Beta-cell

> numbers are probably reduced by 25% to 30% and this reduction is progressive. Alpha-cell numbers may actually be increased and glucagon responses to hypoglycemia in type 2 diabetes are thought to remain intact [24][83].

Furthermore, it has been found that Type 1 diabetes is caused by autoimmune destruction of beta cells, causing an absolute deficiency in the production of insulin [136][17].
On the other hand, in Type 2 diabetes the deficient insulin action is caused by both an insufficient insulin production and the body's resistance to the insulin produced [17]. Even though both types have different causes, they have very similar symptoms such as polyuria, polydipsia, weight loss, and blurred vision [10].
Given the numbers of diabetic patients in the world and its high prevalence, it has been called an "epidemic" by some papers [22] [10].

One of the largest contributors to the total number of children with Type 1 diabetes. These children are estimated to account for almost a quarter of the region's total of 65200 children with type 1 diabetes. Therefore, it is essential to understand the magnitude of the problem and take the necessary steps to control it [12].

Nevertheless, diabetes is a very serious illness that requires time and effort to maintain a good and healthy life. If it is left untreated it could lead to death or at the very least cause damage to many organs in the body, especially eyes, kidney, nerves, heart and blood vessels [17]. Thus, monitoring diabetes is crucial to prevent these complications. However, it is not an easy task. Although in some situations patients can control their diabetes by exercising and adopting a healthier lifestyle, other patients require very close supervision and insulin to survive [17]. They also have to keep track of their blood glucose and watch their diet to maintain the average blood glucose level.

Note that T1D, the most severe kind, accounts for 5–10% of the total cases of diabetes worldwide. T1D has been historically, and continues to be, the most common type of diabetes in children (especially in Europe) and adolescents, although T2D is increasingly diagnosed in youth [78].

A general overview of the glucose homeostasis mechanism under normal and diabetic condition is illustrated in Figure .2.1

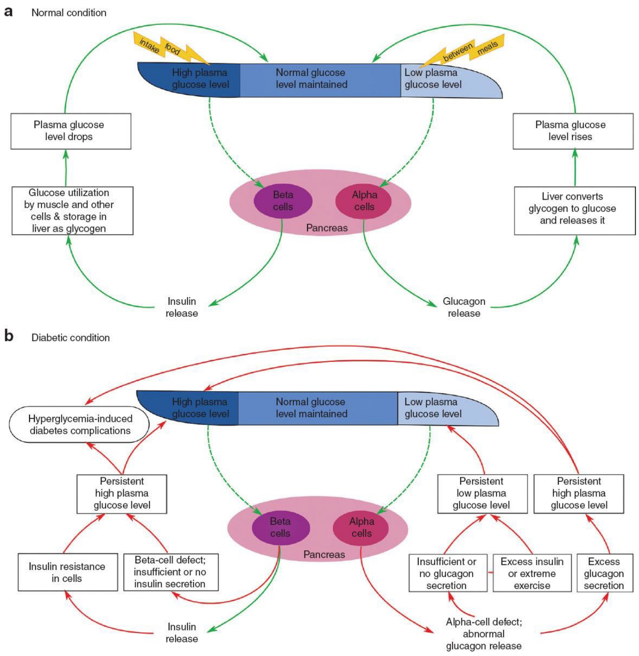

Figure 2.1. *General overview of the glucose homeostasis mechanism under normal and diabetic condition. Plasma glucose level is maintained within a narrow range through the combined antagonistic action of two pancreatic hormones: insulin and glucagon. (a) In normal individuals, high plasma glucose level induces the release of insulin from pancreatic β-cells, which enables the muscle and other cells to take up glucose for energy or to store it as glycogen in liver. On the other hand, at low plasma glucose level, glucagon secreted from α-cells counter regulates the glucose level by inducing the breakdown of glycogen into glucose. (b) In diabetic individuals, the synchronized mechanism between insulin and glucagon secretion is disrupted. Insufficient or lack of insulin production by β-cells, or insulin sensitivity in muscle and other cells, leads to persistent high plasma glucose level (hyperglycemia) [6].*

2.2 Diabetes Self-Management

The need for BG monitoring and prediction

The major concern associated with diabetes is its multietiological and systemic nature. Chronicity of hyperglycemia and/or hypoglycemia can result in multiple micro- and macrovascular damages, leading to several systemic complications [6].

Hyperglycemia, left untreated, can lead to several long-term complications. Amongst others, we can enumerate neuropathy (i.e. nerve damage, that can lead to diabetic foot disorders including severe infections, and may require amputation), nephropathy (kidney failure), retinopathy (i.e. bloods vessels of the retina are damaged and can lead to blindness), as well as cardiovascular diseases such as heart attacks and strokes [87].

Furthermore, if blood sugar rises high enough or for a Prolonged period of time, it can lead to two emergency conditions, i.e. diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar syndrome (HHS), which can both lead to life-threatening dehydration and a coma [39].

In the same manner, hypoglycemia - of which immediate symptoms are amongst others weakness, shaking, sweating, neurological disorders - can increase significantly the risk of cardiovascular diseases and lead to coma or death in the most severe

cases, if not treated in time [59].
Moreover, it should be noted that hypoglycemia affects all aspects of life for the person with type 1 diabetes, including employment, social interactions, driving, sport and leisure activities, and sleep [51].
Nocturnal hypoglycemic events, of which extra physical activity and alcohol consumption, or the improper take of long-effect medication are common causes, are particularly undesirable.
However, there is huge evidence that good BG control helps to delay or prevent these serious long-term complications [109]. Still, achieving and maintaining good BG control remains a difficult task, especially for T1D patients.
Ideally, one should maintain the blood glucose within the normal range (70 – 120 mg/dL). Lower glucose levels ($<$ 50mg/dL) is said to be Hypoglycemia, higher glucose levels ($>$ 200 mg/dL) is said to be Hyperglycemia.
There is therefore a real need for developing accurate blood glucose monitoring and prediction systems. Indeed, being able to accurately predict impending hyper or hypoglycemia would give patients time to intervene and prevent these BG excursions, improving overall health, safety, and quality of life [59].
The difficulty in BG prediction
The main reason is that diabetes is a nonlinear, multifactorial and dynamic condition, subject to huge intra- and inter-patient variability. Blood glucose prediction is therefore a very complex problem [59].

This difficulty can be illustrated based on personal experience of Adam Brown [27], type 1 diabetic patient since 13 years. Following conversations with experts, and scientific research, Adam enumerated a non-exhaustive list of 22 factors that can affect blood glucose, separated into five areas:

1. Food factors
   - **Carbohydrates** Of all the three sources of energy from food (carbohydrates, protein, and fat), carbohydrates affect blood glucose the most. Accurately counting carbs is very difficult, and getting the number wrong can dramatically affect blood glucose. The type of carbohydrate also matters – higher glycemic index carbs tend to spike blood glucose more rapidly.
   - **Fat** Fatty foods tend to make people with diabetes more insulin resistant, meaning more insulin is often needed to cover the same amount of food relative to a similar meal without the fat [135].
   - **Protein** Though protein typically has little effect on blood glucose, a protein-only meal, in the absence of insulin, can raise blood glucose [113][49].
   - **Cafeine** Many studies have suggested that caffeine increases insulin resistance and stimulates the release of adrenaline [74].
   - **Alcohol** Normally, the liver releases glucose to maintain blood sugar levels. But when alcohol is consumed, the liver is busy breaking the alcohol down, and it reduces its output of glucose into the bloodstream. This can lead to a increase of insulin sensitivity and a drop in blood sugar levels if the alcohol was consumed on an empty stomach. However, alcoholic drinks with carbohydraterich mixers (e.g., orange juice) can also raise blood sugar [69].

2. Medication factors
   - **Medication dose** The dose of medication (pills or insulin injections) directly impacts blood glucose – in most cases (but not always), taking a higher dose of a diabetes medication means a greater blood glucose-lowering effect.
   - **Medication timing** In addition to dose, medication timing can also be critical.For instance, taking rapid-acting insulin (Humalog, Novolog, Apidra) 20 minutes before a meal is ideal for Adam Brown - it leads to a lower spike in glucose vs.taking it at the start of the meal or after the meal has concluded. The timing of many type 2 diabetes medications matters a lot – some can consistently be taken at any time of day (e.g., Januvia, Victoza), while others are most optimally taken at meals (e.g., metformin).
   - **Medication interactions** Non-diabetes medications can interfere with your diabetes medications and blood glucose. Diabetic patients need to consult the information included in both diabetes and non-diabetes medications.

3. Activity factors
   - **High intensity and moderate exercise** Exercise is often positioned as something that always lowers blood glucose; however, high-intensity exercise, such as sprinting or weight lifting, can sometimes raise blood glucose. This stems from the adrenaline response, which tells the body to release stored glucose [3].

4. Biological factors
   - **Dawn phenomenon** The "dawn phenomenon" occurs in people with and without diabetes. The term refers to the body's daily production of hormones around 4:00-5:00 AM. During this time, the body makes less insulin and produces more glucagon, which raises blood glucose [107].
   - **Infusion set issues** Infusion sets are not as well understood as we would like,and a huge number of factors can lead to higher glucose levels: air bubbles in the tubing, an occluded cannula, an infected site, or even the location of the set.Adam Brown finds that his glucose always tends to run higher on the third day of wearing an infusion set [62].
   - **Insufficient sleep** Many studies have found that not getting enough sleep leads to worse diabetes control, insulin resistance, weight gain, and increased food intake [117][120][100]. In Adam's experience, he needs nearly 25% more insulin on days following less than seven hours of sleep. In addition, he observed his glucose was 21% more variable.
   - **Stress and illness** Stress and illness can cause the body to release epinephrine (adrenaline), glucagon, growth hormone, and cortisol. As a result, more glucose is released from the liver (glucagon, adrenaline) and the body can become less sensitive to insulin (growth hormone, cortisol). In some cases, people are much more insulin sensitive right before getting sick and can tend to run low blood sugars [18][16].
   - **A higher glucose level** Hyperglycemia can lead to a state known as "glucotoxicity," which can actually increase insulin resistance [71][127].
   - **Smoking** Some studies suggest that smoking can increase insulin resistance, and people with diabetes who smoke are more likely than nonsmokers to have

trouble with insulin dosing and managing their diabetes. Smokers also have higher risks for serious complications [31].

5. Environmental factors
   - **Insulin that has gone bad** According to the product labels from all three U.S. insulin manufacturers, it is recommended that insulin be stored in a refrigerator at approximately 4°C to 14°C. Exposing insulin to direct sunlight or leaving it in the car on a hot day can definitively alter insulin efficiency. In addition,accuracy may be limited due to strip manufacturing variances, strip storage, and aging [54].

   - **Errors in measurement** They may also be due to patient factors such as improper coding, incorrect hand washing, altered hematocrit, or naturally occurring interfering substances. As an example, for a meter that needs a tiny 0.3 microliter blood sample, a speck of glucose on the finger with the weight of a dust particle can increase the reading by 300 [mg/dl]! Wash properly his hands before using finger-prick device is crucial [54].

Self-management training has been acknowledged as a key component of the clinical treatment of diabetes since the 1930's [91]. Although many interventions have been developed and evaluated, there still exists a significant deficit of diabetes knowledge and skills amongst patients [91].
Self-management of diabetes is crucial. Patients are recommended to document their blood glucose results and physical activities and share them with their health providers [65].
Furthermore, it has been proven that the share of self-monitoring blood glucose data and receiving feedback from health care providers can help in achieving glycaemic goals, such as a reduction in the glaciated hemoglobin [103]. Indeed, with the use of electronic management services, this is made easier. Furthermore, today there is a wealth of apps that can aid people with diabetes in keeping a record of their daily activities. The features of these apps such as the ability to record, analyze, share and obtain feedback, might have a positive impact on patients[103].
these tools can also help users to notice any alarming behavior and view their progress easily.
With the emergence of various mobile technology platforms and the need to make diabetes logs more accessible, several forms of diabetes self-management applications have been developed. These range from a straight translation of conventional paper logs into an electronic form, to unique designs that strive to achieve positive health behavior changes in patients [29].

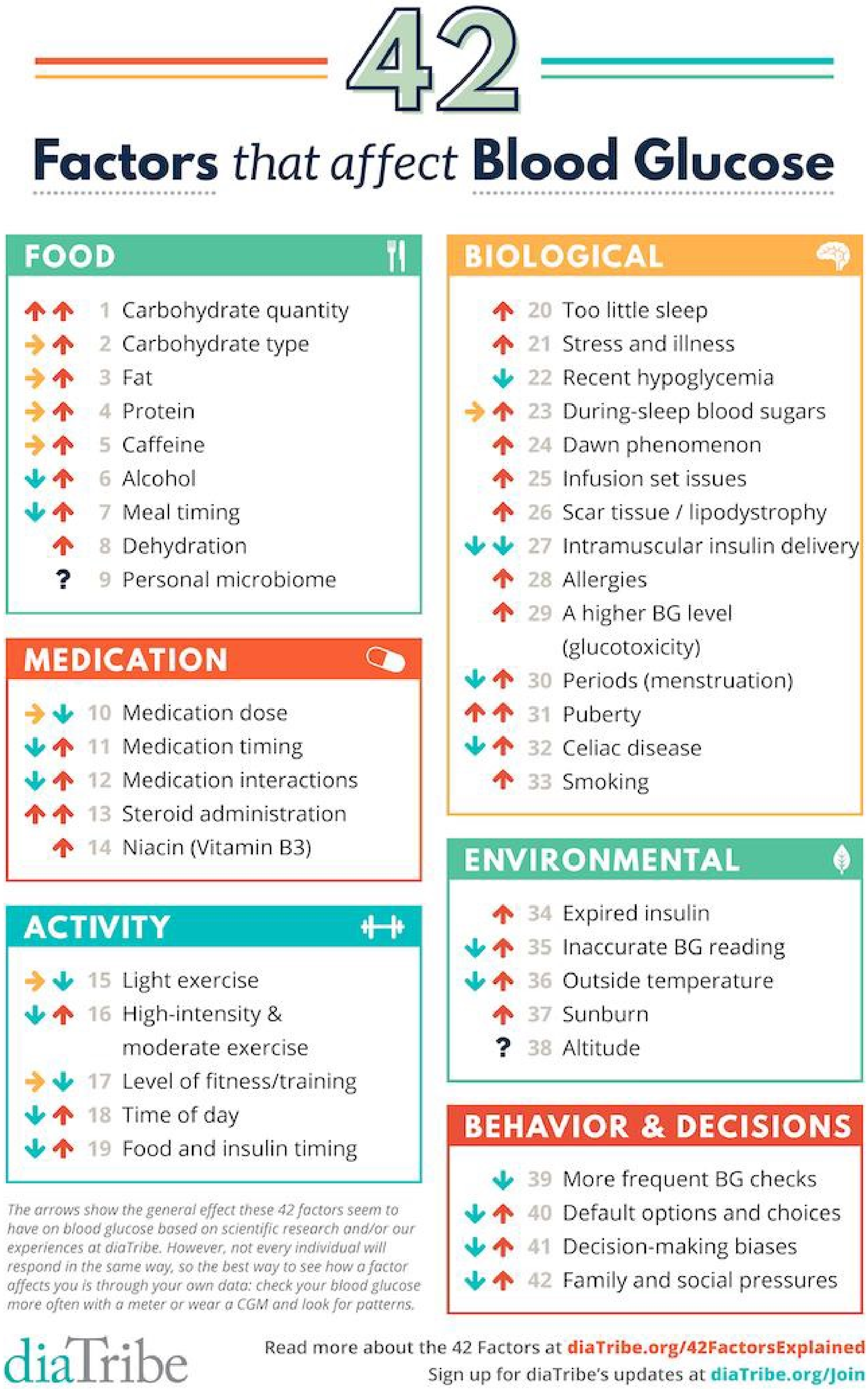

Figure 2.2. *42 Factors That Affect Blood Glucose [27].*

Chapter 3

Empowerment through mHealth gamification

3.1 mHealth Interventions

Mobile health applications or apps allow users to interact through software applications on their mobile devices for health-related or medical purposes [61]. The use of mobile health apps for physical activity, nutrition and health monitoring and information has increased in recent years [82]. Mobiles phones are inherently personal communications devices with powerful computing and touch based user interfaces. They can be used to deliver self-management tools that are embedded into the daily routine of individuals and facilitate habitual self-monitoring [63][101]. However, in order to elicit behavior change, the design of mobile applications requires a thoughtful, patient-centered, and evidence-based approach [93].
If patients are regularly collecting health data they can, in consultation with their physician/nurse practitioner, use that information to modify their behavior and better manage their condition. As such, healthcare apps have the potential to bring efficiencies into healthcare systems by reducing the frequency and cost of direct interventions by healthcare professionals with patients. Monitoring of vitals can be done remotely, and communication with healthcare professionals – including pharmacists, physicians and nurse practitioners – can be done without the patient having to physically meet with them [5]
Chronic diseases (e.g., heart disease, cancer, and stroke) account for nearly half of all deaths in America and the UK (ONS, 2013) with many of these conditions are preventable [73]. Furthermore, individuals living with chronic conditions often experience restrictions in activities of daily living (e.g., eating, bathing) resulting from disabilities due to chronic diseases [14]. Therefore, apps designed to aid in the prevention or self-management of chronic conditions show great potential to aid in improving the quality of life of individuals [82].
T1DM patients are encouraged to collect a significant amount of data from the day they are diagnosed. This information has typically been recorded in a paper logbook or kept stored in a glucose meter only to be reviewed when prompted either by a loved one or a member of their care team. With the increasing popularity of mobile devices, it seemed the next logical step would be to develop mobile applications

that can help support patients in their data collecting endeavors and also utilize computing technology to provide useful feedback [86].
mHealth technology and products show great potential as tools to improve access and quality of healthcare, reduce medical errors, and decrease healthcare costs [61].

3.2 Gamification in Healthcare

Gamification can be used in health care applications and websites to encourage behavioral change. Professor Kevin Werbach, the author of 'For the Win: How Game Thinking Can Revolutionize Your Business', argues that a gamification is fundamentally a motivational tool [42], increasing users commitment to certain health behaviors, or encouraging users to exercise more and take medication regularly [12].
Referring back to Skinner's work, the reinforcement explained in his experiment could be seen as either positive or negative [112].
For instance, rewarding systems could be used to encourage healthier choices.
In the context of T1DM self-management in adolescents, gamified design has been used to encourage patients to adhere to their care regime.
What guidelines currently exist for gamification in health design, and how have fields other than healthcare implemented gamified design?[86]
In a paper that discussed games for health, a couple of T1DM related educational video games were analyzed to identify concepts that health games should aim to achieve [89]. These have been listed below:

- Enhance the players' self-awareness through the use of avatars
- Improve self efficacy
- Increase knowledge
- Include communication and social support.

However, the concept of gamification, if used correctly, can motivate people to make better decisions concerning their health.

Thus, in designing mobile health applications, research is needed to determine what kinds of motivational tools (e.g., badges, levels, points, rewards, etc.) should be used to achieve the desired behaviors in various contexts.

3.3 Motivational system

In [38], the author, editorial member of JMIR Serious Games - a journal devoted to research and opinion around gamification - provides a behavioral science view on gamification and health behavior change. Based on a review of popular gamification taxonomies [37],[137],[99], the author identified 6 gamification persuasive strategies that can be enumerated as follows:

1) Clear goals and challenges setting.
2) Constant feedback on performance.
3) Reinforcement through rewards (not punishments).

4) Progress monitoring and comparison with self and others.
5) Social connectivity.
6) Fun and playfulness.

According to [38], these core ingredients are complementary and in dissociable. If we take away some of them, we lose the persuasive capacity of gamification. These strategies, which are the broad principles that make gamification addictive, can be implemented with several tactics, as detailed in the next subsection [59].

3.4 Empowerment through mHealth gamification

In recent years, mobile applications have become a key driver of mobile Health (mHealth) deployment, especially as a complementary way for self-monitoring. It is foreseen that the market of mHealth app users will reach 2 billion by 2017 [88].
According to Research2Guidance's annual survey, 76 % of mobile health app publishers see diabetes as the therapeutic area with the highest business potential for mobile health. In 2013 only 1.2 % of people with diabetes who own a smartphone or tablet used apps to manage their condition, the latest report found. Research2Guidance is predicting that will increase to 7.8 % in 2018 [104]
Besides, as said earlier, there is evidence that gamifying disease management can help children, adolescents, and adults with diabetes to better cope with their lifelong condition. Gamification and social in-game components are means to keep motivate players/patients and positively change their behaviour and lifestyle [59].

3.5 Best Diabetes mHealth design practices

According to the Diabetes App Market Report 2014 by Research 2 Guidance, a mobile applications market analysis firm, there exists 7 best practice elements a diabetes app should take care of. By applying the following design principles, mobile apps would come closer to leverage the potential they have in better supporting diabetes management [104]:

1) **Personalization** : A successful diabetes app should allow the user to choose how data is displayed, how and what information is transmitted to third parties (such as friends, family, social networks, physicians),what metrics are being measured and what are the reference levels for these metrics,taking into account various lifestyle factors. In addidition, based on the data generated by users, diabetes apps should provide customized feedback and actions to improve behavior.
2) **Feedback** : Successful diabetes apps should include a social dimension and create a supportive network (family, friends, health care professionals) to provide coaching and real-time feedback on users progress, in order to sustain behavioral change.

3)**Feature coverage** : A good diabetes app should include all the tools and features that are needed for successfully keeping diabetes under control. Amongst others, it should include tools for tracking insulin, carbohydrate, weight, activity and trend charts.
4)**Integration and interoperability** : Diabetes apps should be designed in a way that allows users to input and access their data through multiple devices from various sources. Ideally, diabetes apps should be integrated with external devices, sensors, databases and other apps, which help users achieve better control of critical health parameters in the management of diabetes(such as BGL, blood pressure, cholesterol), support the necessary lifestyle changes (weight, exercise, nutrition) and provide new ways for connecting patients with their physicians (electronic health records).
5)**Motivational system** : A good diabetes app should include a well-designed motivational system, which engages users, provides incentives for constant use and ultimately leads to behavior change. Best practice apps make full use of gamification elements.
6)**Ease of data input** : The usage should be effortless. Diabetes apps should fit seamlessly into users' lives and routines, making the input of data as easy as possible without requiring too much effort from the users. Solutions should automatically transmit their glucose readings, for instance, from the blood glucose monitor to the mobile device.
7)**Design and user experience** : The aesthetic dimension plays a very important part in keeping users engaged and motivated and, at the same time,it can constitute a powerful differentiation element. Just like with any other app, the design and initial visual impression determines the entire user experience and can definitely determine whether a diabetes app is successful or not. In addition, accessibility should be taken into account for people experiencing disabilities.

3.6 Data Visualization

Since T1DM is a lifelong disease, data collected for an individual patient can be massive and difficult to interpret [14]. However, it is important for patients and their health care providers to regularly survey this data to maintain a good understanding of how the disease is being managed. The paper logbook, although helpful with tracking data, does not provide the patient with useful information at a glance when filled out. Electronic tools can provide a means for turning this data into rich visualizations [86].
For example, insulin pumps collect data over extended periods of time on behalf of a patient.When uploaded into a computer, a series of reports are displayed to the patient; these reports tend to be complex and difficult to understand [86].
Kerr [70] argues that regardless of whether a patient uses a pump or multiple daily injections (MDI), patients need to be adept at handling numbers in order for them to be able to properly understand the nuances of glucose monitoring.
Several researchers have attempted to address this issue. Frost and Smith [114] con-

ducted a preliminary study looking at how associating photographs to visualizations of blood glucose over time would impact patients and their understanding.
The blood glucose visualization was essentially a chart with each column representing a day and each row representing an hour; colored boxes were used to indicate whether a reading was low, high, or acceptable. Upon review with diabetics and medical professionals, it was confirmed that the visualization allowed them to easily inspect blood sugar trends. However, this type of visualization may be too detailed to view easily on a mobile device.
Providing visualizations of collected data to patients is valuable. However, an appropriate means to do this on a mobile device that is easy to understand has not yet been developed [86].

Chapter 4

User-Centered Design

People use diverse interfaces in their daily lives. It is likely that most people have experienced difficulties at some point while they used it. The problem is not about the users, but about the design of the product or service [32]. Don Norman, an academic in the field of cognitive science, design and usability engineering, has said that if users are having trouble using something, it is not their fault, but it is most likely poorly designed. If a product or interface design is not easy to use and makes users confused to use it, the design has not considered by the factors of user-centered design [90].

What is "User-Centered design?" According to Stone et al., in his book, User Interface Design and Evaluation, "User-centered design is an approach to user interface design and development that involves users throughout the design and development process." He continues, "User-centered design not only focuses on understanding the users of a computer system under development but also requires an understanding of the tasks that users will perform with the system [119]."

User-centered design also helps users have a high degree of usability. According to Stone et al., usability is defined as "the extent to which a product can be used by particular users to achieve specified goals with effectiveness, efficiency, and satisfaction in a particular context of use" [119].

What about user-centered design for a mobile application? The Smartphone has the characteristic of a small screen size, so the application needs to be designed to fit the smaller screen. The effective use of visual elements and concepts of usability need to be considered for making a user-centered mobile application. There are some things to consider for enhancing the user interface design for mobile applications [32].

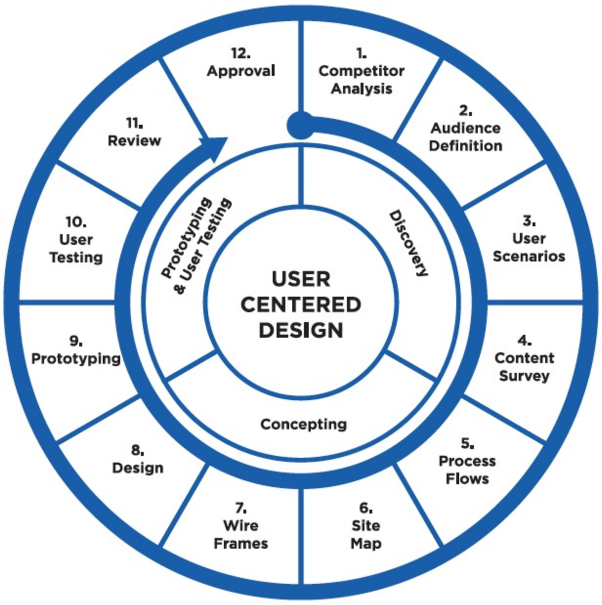

Figure 4.1. *user-centered design diagram [30].*

4.1 User-Centered Design for Mobile Applications

What is a problem with this? What made the user get stressed to the point where he cannot even start? There is probably a lack of user-centered design approaches for mobile applications. Poor interface design makes users confused and disengaged toward the application. User interfaces that are enhanced by a user-centered design approach consider an application's functionality and usability as well as give users the desire to use the interface and the feeling of positive emotions. Understanding the basic concept of user-centered design is important [32].

4.2 Design and Emotion

What is the relationship between design and emotion? Does a more attractive design make a stronger impact on users' emotions? What about the relationship between attractive things and usability? Is an attractive design more usable? Does aesthetics influence the usability of an object? To know the relationship between design and emotion and between aesthetics and usability is important because when designers understand these relationships, they can consider both aesthetics and the usability aspects to enhance a design's functionality and give a positive emotional feeling and satisfaction to users [32].
Don Norman, in his essay, Emotion & Design: Attractive things work better, states that attractive things work better. His study on emotion and affect has an impact on the science of design. Affect has implications for the process of cognition. Therefore, it is important that human-centered design should be considered especially when

designing products for use under stress because stress makes people less able to be flexible to problem solving. Norman points out that “Products designed for more relaxed, pleasant occasions can enhance their usability through pleasant, aesthetic design. Aesthetics matter: attractive things work better [90].” He insists that aesthetics inspires users’ emotions and affections, and affect influences the cognition process, therefore, aesthetics have an effect on users’ perceptions on usability [32]. According to the article, “What is beautiful is useful”, Tractinsky [122] studied the relationship between users’ perceptions of a computerized system’s beauty and usability. They conducted an experiment using a computerized application as a surrogate for an Automated Teller Machine (ATM). Participants were asked to express their perceptions before and after they used the system. Not only pre-experimental measures but also post experimental measures indicated strong correlations between the system’s perceived aesthetics and usability. They concluded that the degree of the systems’ aesthetics affected the post-use perceptions of both aesthetics and usability. This study concluded that the role of aesthetics in human-centered design is an important factor on how users experience their interaction with computerized systems.

Chapter 5

Analysis and Requirements

Qualitative research was carried out in order to develop a deeper understanding of children T1DM patients. The main goal was to understand their culture and to generate a theory about what their needs would be for a mobile self-management support application since the focus of this stage was to understand the T1DM population.
For the requirements analysis we use UCD with respect to understanding the user, their tasks, and their environment.

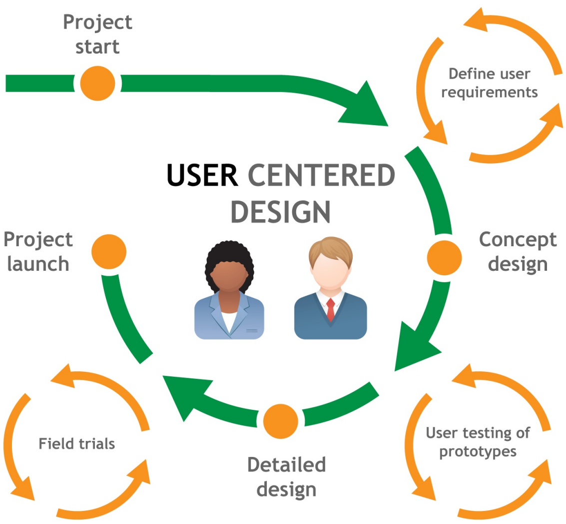

Figure 5.1. *The User-Centered Design (UCD) process outlines the phases throughout a design and development life-cycle all while focusing on gaining a deep understanding of who will be using the product. [56].*

5.1 Observation

Patient age range is 8 to 14 and at we choose some clinic base on be match of the target population for this research, observing the interaction between patient and physician at a routine visit still proved to be valuable in understanding the disease and the impact it has on an individual.
A total of 18 patient visits were observed. Prior to observing any appointments, patients and their parents/guardian were first asked for permission by their healthcare provider.
Visits often take longer than anticipated due to scheduling of blood work, physicals, and other clinic related activities such as pump information sessions etc. These visits are routinely scheduled every three months. Patients were asked to provide their blood glucose (BG) monitor or pump, from which all of their readings taken over the last 30 days were imported into the clinic computer and printed out for review. The only data a typical BG monitor provides is the BG measurement, date, and time of day the reading was taken. Pumps will also include insulin bolus/basal rates. For additional information, the clinician would often request to review a handwritten logbook. These logs would typically include additional information such as carbohydrate counts, level of activity, and the amount of insulin taken.
This data was then used to cross reference readings in order to better understand out of range BG measurements and identify the root cause of trends. The physician would then work with the patient to recommend appropriate changes to help regulate BG levels. Changes would either be made to insulin basal or bolus dosage, diet, and activity levels.
It was important to take note of this, as the majority of T1DM patients either use a paper log on a regular basis or have been encouraged to use a log book at some point from someone within their circle of care [86].
Figure 5.2 below depicts what the standard logbook layout looks like.

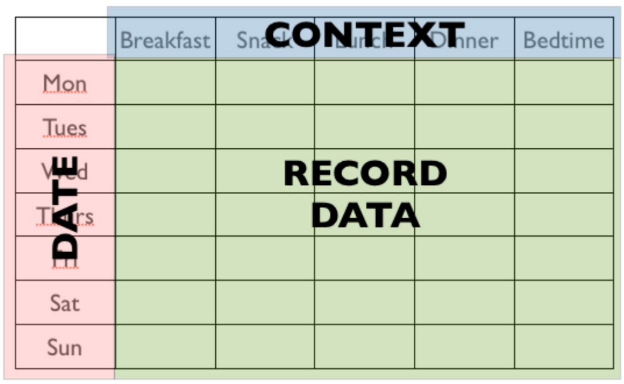

Figure 5.2. *Columns are organized by context (blue box); users are encouraged to log their blood glucose according to the context of each reading. These are typically defined as meals: breakfast, snack, lunch, and dinner. Each row (pink box) represents a day of the week. The format for recording data (green box) varies but users are encouraged to record their blood glucose before and after a meal, as well as track the number of carbs consumed and units of insulin taken [86].*

Overall, the main point of discussion for all appointments was blood glucose and how best to regulate and keep it within target range. In addition, a lot of emphasis was placed on the HbA1C measurement, a measure of average plasma blood glucose over extended periods of time.
In order to develop a deeper understanding of what self-management involves for adult T1DM patients, I attended a carbohydrate counting.
There were two additional activities built into the session:

1) **Self-Assessment:** A quiz that tests how knowledgeable the patient is on carb counting tools, sources of carbohydrates, and glycemic index.
2) **Bolus Insulin Worksheet:** This form consists of three scenarios where the patient was asked to determine how much insulin to take based on the information provided.

Each food item was provided on a 'Carb Counting Worksheet' and the goal was to determine the portion size and grams of carbs for each portion.
That patient's face when estimating their carbohydrate intake.
Dining out and trying unfamiliar foods were identified as the most difficult situations for everyone who participated in the session.
As the design of the mobile application will be focused on how to effectively present data to users, this session highlights the need to allow users to record their carb counts in relation to their blood glucose measurements.

5.2 Brainstorming

Brainstorming session to review the data collected and determine what design changes need to be made in order to address the issues with the application uncovered from the pilot.
Although brainstorming is not typically considered a means for collecting and defining user requirements, it is an effective tool to develop and collect many design ideas in a group setting [94].
Although this feature discussion was specific to the children version of the app, it provided a good starting point for beginning to map out and visualize the child version. This also helped guide the questions for the semi-structured interviews regarding whether specific design features would be appropriate for a more mature user.

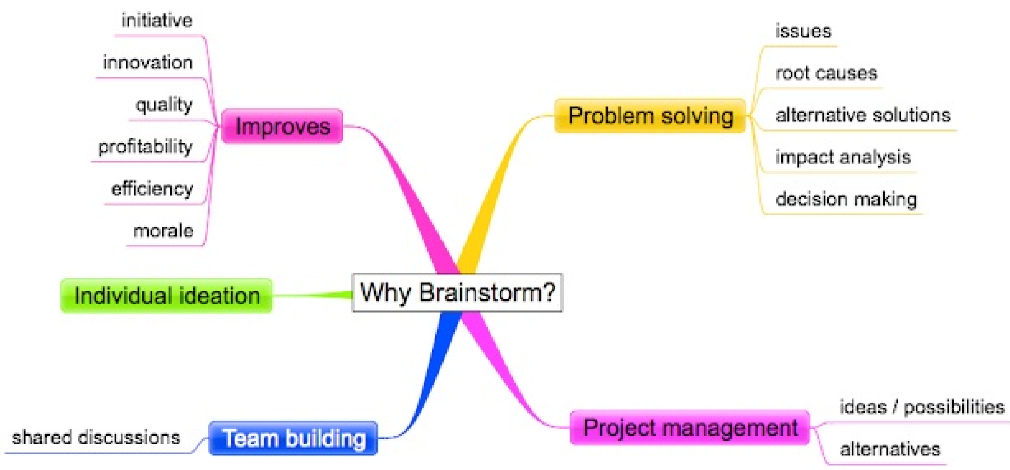

Figure 5.3. *Why Brainstorm? [102].*

5.3 Semi-Structured Interviews

Definition Interviewing is a technique that involves structured or unstructured discussion between requirement engineers and potential users of the application or system. users, stakeholders and domain experts are questioned to collect information about their needs or requirements in relation to the new system to be developed [81].
Structured interviews can be conducted if the requirements engineer already has a fairly good knowledge about the user's requirements. Interviews are usually semi-structured based on a series of fixed questions with scope for the user to expand on their responses [81].
Advantages

- The questions can vary to adapt to the context.
- the evaluator is free to start a discussion with the user to investigate interesting issues as they arise.

Results of Interviews
The next stage of requirements gathering involved conducting interviews with children T1DM patients and their parent.
The recruitment inclusion criteria were any Persian-speaking children (8 and older) who had been diagnosed with T1DM for a minimum of a year, and who was willing to provide consent to participate in the study. A total of 20 participants were recruited from the Iran Hospital Diabetes clinic; some of them were pump users and used multiple daily injections (MDI) of insulin. Interviews were conducted at the clinic and were approximately one-hour each in duration. Data collected through the literature review, observational research, and brainstorming session helped guide the development of the semi-structured interview questions. Particular areas of interest include effective data tracking and visualization, social community interaction, and motivational design techniques (i.e. reward mechanisms). The list of questions used to guide the interviews are outlined in Table 1 below.

Table 5.1. *Interviews table.*

Type of Question	Questions
Problem Validation	Does parent have problem in their children to follow diabetic diet schedule? Do you use drugs and insulin by yourself or with your parent?
Solution Validation	Does your child spend a few hours each day on Video games? How do you Motivate and encourage your children to follow their nutrition and medication plan? What keeps you motivated to stay on track with your self-management practices? Do you ever set goals relating to your self-management practices or overall health? If so, how do you set out to achieve them? Do you currently play any mobile games? If so, what keeps you interested in the app?
Planning and Scheduling	Who do you typically share your blood glucose information with? When? How frequently? How do you currently track, and record information related to your diabetes management? What information do you record and why? How often? When you do make changes to your routine, what do you base your decisions on and why?
Data Visualization	How and when do you review and interpret your blood glucose results? What tools do you employ? what works well in your current information capture and review practices? What would you like to change?

In addition to being asked questions, participants were shown and encouraged to provide feedback on rough paper sketches and high-fidelity screenshots of preliminary design ideas.

The purpose of this activity was to validate problem and solution and collect preliminary design feedback and to determine which design features, if any, would be appropriate for children use as well. The following section outlines the analysis performed on the data collected from these patient interviews.
Here we can add three steps: problem validation, solution validation and UI.

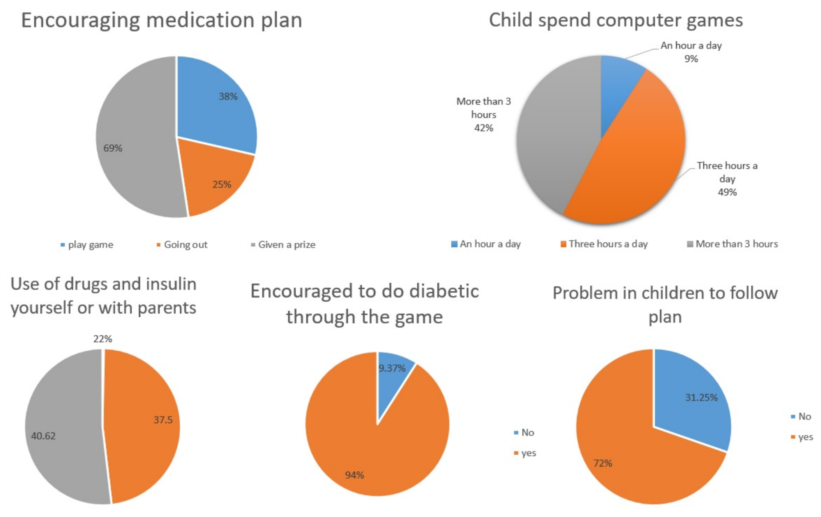

Figure 5.4. *Problem and Solution validation result.*

5.4 Interviews with Doctor

Interviews were conducted at Hospital and were approximately Two-hour each in duration.
Result of Interviews:

Table 5.2. *Interviews with Doctor.*

Type of Question	Result
Problem Validation	Children with diabetes mellitus (sweet) and their families suffer from various types of psychiatric disorders such as: stress, anxiety and depression. After a while, they suffer from fatigue from everyday problems: insulin injections, blood glucose check and diet. So can cause problems for the patient
Solution Validation	The use of software as a game for diabetic children: • to train and treat them. • communicate with their virtual physician and their parents. • Follow diet plane step by step into computer games.
Final comment	• A very interesting. • new and wonderful idea. • Will be successful among children and teenager with diabetes. • Children loves computer games. • Finally this idea is pleasure and attractive.

5.5 Qualitative Data Analysis

Analyze the data collected from the interviews.
Due to the large number of statements, the feedback was classified by interview

category: information sharing, data visualization, design elements (comments on preliminary sketches), and rewards/motivation.
Also, collecting data is a task that is required for the majority of persons with diabetes and as a result, people had lots of opinions on how to present and visualize that information.
There was a total of 6 sub-categories identified:

- Reflection Period: How far back patients look through data collected.
- Data Loads (Frequency): The frequency with which BG readings and other information are recorded or loaded.
- Data Tracked: The information that is actually tracked.
- Tools Used: A summary of the various tools used to assist with data tracking.
- Making Decisions: Insights into how decisions related to diabetes selfmanagement are made.
- Making Changes (Frequency): How often changes are made to self-management
- routines.

When participants were shown the sketches and preliminary screen shots, the interviews shifted from a question/answer format to an open discussion around thoughts and opinions on the drawings.
Five sub-categories were identified and are described briefly below:

- Historical Data: How far back participants looked through data.
- Important Statistics: The numbers and figures that participants found most interesting and helpful.
- Desired Features: Features that participants look for in a mobile application.
- Data Organization: The preferred way to view data.
- Colour Meaning: Colours associated with high and low BG readings.

Figure 5.5. *Paper Mock-ups.*

Paper prototyping is a widely used method in user-centered design because it is fast, cost effective, and encourages creativity [115].
In addition, when a user interacts with a high-fidelity prototype, they are more

likely to become frustrated if the testing device is slow or certain links or buttons don't function as expected. Using a paper prototype frees the participant from these expectations and also allows for more open discussion as the facilitator works through each paper screenshot [86].

5.6 Storyboard

A storyboard is a graphic organizer that consists of illustrations or images displayed in sequence for the purpose of pre-visualizing a motion picture, animation, motion graphic or interactive media sequence. The storyboarding process, in the form it is known today, was developed at Walt Disney Productions during the early 1930s, after several years of similar processes being in use at Walt Disney and other animation studios [133].

Storyboarding is used in software development as part of identifying the specifications for a particular set of software. During the specification phase, screens that the software will display are drawn, either on paper or using other specialized software, to illustrate the important steps of the user experience. The storyboard is then modified by the engineers and the client while they decide on their specific needs.

The reason why storyboarding is useful during software engineering is that it helps the user understand exactly how the software will work, much better than an abstract description. It is also cheaper to make changes to a storyboard than an implemented piece of software [133].

General Concepts [72]

- Screens
  o You are not designing the detailed interface yet
  o Include general layout, navigation elements, core concepts
  o Capture relevant information, remove extraneous information
- Scenes
  o Personas in their physical context
  o Cultural/Interpersonal relationships or handoffs
- Show sequencing of main ideas
- Although these can be quite visually attractive, they are not works of art:
  o Black & white, pencil
  o Quick
  o No renderings!

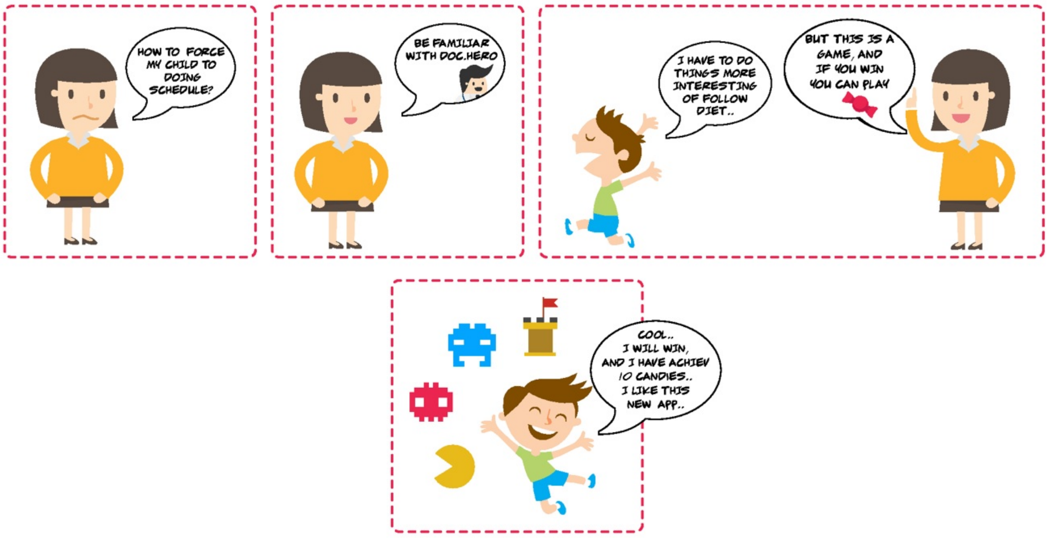

Figure 5.6. *Storyboard.*

5.7 User Requirements

With the data from the interviews organized into category and sub-category, the next stage of the process was to translate the groupings into user requirements.
Requirement statements for the system were formulated after a careful study of existing solutions and defining the goals and objectives for the recommended solution. Writing and verifying a complete set of requirements is key to the production of a successful system [11].
In this section, both functional and nonfunctional requirements are presented.
The functional requirements are the basic functions expected of the system. On the other hand, nonfunctional requirements are about performance, security and reliability [12].

5.8 Functional Requirements

The functional requirements describe the desired functionality of the system. It consists of high-level statements that outline the behavior of the system. Each requirement listed in Table5.3 is arranged in a scale from low to high where "high" indicates its importance to the system. It also includes a rationale to explain each requirement.

Table 5.3. *Functional Requirements.*

Number	Requirement/Rationale	Priority
F.R.1	The system shall provide profile accounts for each user.	HIGH
Rationale	Each user must have his/her own account to be able to keep a log of his/her glucose levels, share progress, and communicate with other users.	

F.R.2	The app should allow users to record and track their blood glucose, carbohydrate intake, insulin, and activities.	HIGH
Rationale	Each user should be able to keep a logbook of his/her blood glucose levels and related information to help manage their diabetes and recognize any patterns. Patients most frequently track and record the following information: carbohydrates, blood glucose, insulin, and activities.	
F.R.3	The system shall reward users based on several aspects such as committing to logging test values.	HIGH
Rationale	Users who log their test readings continuously should be rewarded for that. As their points accumulate, they will receive advantages over those who did not log continuously. This will encourage users to keep logging.	
F.R.4	The system shall provide the user with a graph of his/her blood glucose information for each month.	HIGH
Rationale	Users need to view their progress every month. A graph is an easy way to allow them to do so.	
F.R.5	The app should provide users with a means to occasionally (1/month) share information related to their diabetes with close family and friends.	MODE RATE
Rationale	Patients share diabetes related information with close family members and significant others on a monthly basis and are not interested in sharing with an online community. Sharing information	
	helps patients to better understand T1DM and their bodies.	
F.R.6	The act of recording data into the app should be fast, easy, and straightforward.	HIGH
Rationale	Recording information is time consuming. Patients reported recording regularly only in anticipation of a clinic visit.	
F.R.7	The color green should be used to indicate in range readings and red to indicate out of range readings regardless of whether the values are high or low (as red is commonly known to represent ‘danger’).	HIGH
Rationale	Patients associate the color green with being in range. However, there is no consensus on a color code for low and high readings (blue vs red).	
F.R.8	The app should highlight or emphasize the use of good health and feeling well to motivate the user to stay on track.	HIGH
Rationale	Fear of future T1DM related complications motivate patients to stay on track. General good health and feeling well motivates patients to stay on track with self-management practices.	
F.R.9	The app should provide Food Database.	MODE RATE
Rationale	Food database would make it easier for the patient to estimate their carbohydrate intake.	

5.9 Nonfunctional requirements

Nonfunctional requirements can be defined as statements that describe the behavior of the system instead of what it does [34]. These include performance requirements, external interface requirements, design constraints and quality attributes. Furthermore, nonfunctional requirements describe the qualities that the system must have to be a successful product. They place restrictions on the system and process and specify external constraints that the product must meet. As with the functional requirements above, Table 5.3 lists the nonfunctional requirements and specifies their priority from low to high, where high means it is fundamental to the success of the system and must be fulfilled.

Table 5.4. *Nonfunctional Requirements.*

Number	Requirement/Rationale	Priority
N.F.R.1	The system shall be simple to use and user friendly.	HIGH
Rationale	Users should be able to use the system without any complications.	
N.F.R.2	The system shall adopt a credible diabetes control chart.	HIGH
Rationale	It is very important to build the system using the right information about diabetes control, such as acceptable glucose levels.	
N.F.R.3	The system shall secure passwords and data.	HIGH
Rationale	Users' data should be secure and protected against any misuse.	
N.F.R.4	The system shall have a simple backup facility.	HIGH
Rationale	Backup facility should be used to prevent the loss of data and ensure its restoration if its problems occur.	

5.10 Persona and Scenarios

Definition

Scenarios are used to provide detailed examples on how users may carry out their tasks in a real-world context. They can help to identify user characteristics that may impact the design and the tasks that the system needs to support. They can help to identify user characteristics that may impact the design and the tasks that the system needs to support. They help to identifypotential design issuesatan earlystage [81].

Scenarios can also be used to:

- communicate with others (e.g. designers, clients, users)validate other models, a detailed scenario can be 're-played' against other models, e.g., task and dialog models.
- reproduce system dynamics, while screenshots and pictures primarily give an idea of system appearance, a scenario can give an idea of system behavior.

Parent Customer:

- User Profile:
  - oAge: 25 – 50
  - oGender: 30 % Male – 70 % Female
  - oJob title: Any
  - oLocation: Any
  - oTechnology: Android App User
  - oPassions: Reading, golfing, going to movies, traveling, going Party,Exercising & Eating Healthily

- **Persona:**
  - oCatty is 40 years old, she lives in Rome ,her job is architected ,five days of week works in private company ,she loves her job but he due to most of time go to place job by metro and bus ,in the holiday days must making other plans so does not enough time for rest, although she has 2 daughter ,rose 8 and anna 12 years old , anna has diabetes child. Most of the time she uses 4G mobile Internet for browsing via her phone or to install applications.

- **Scenario:**
  - oAt weekend Catty want go to party with friends but Catty have many problem with anna, because anna doesn't execute medicine ,anna should inject insulin , this act has pain ,at the other hand anna like sweetness but eat that is harmful for her, catty at most time try to check her child by calling anna.
  - oCatty should encourage anna and she says "if you inject insulin , I will buy new toy for you" , or she said "we will go to funfair at end days of week" or "we will go to cinema at the holidays".

Children Customer:

- **User Profile:**
  - o Age: 8-14
  - o Gender: 50 % Male – 50 % Female
  - o Job title: Student
  - o Location: Any
  - o Technology: Android App User
  - o Passions: Play Game, Dance

- **Persona:**
  - o Anna has 12 years old, she has cutely girl, she likes sweetness very much, when she come back from school usually she loves to go to sweetness shop and buy there, but she has diabetes.

- **Scenario:**
  o At weekend Anna does it her homework,she want play video game but Anna must be inject insulin in every morning, this act has pain so she doesn't like that, also she can eat little chocolate, she likes play games, she has tablet and enjoy playing video game very much. her mam is employer and if she is doing schedule so can go to cinema or funfair with her mam at the end days of week.

5.11 Feasibility Study

A Feasibility study is carried out in order to examine the likelihood of the project success before the actual start of a project. It shows the advantages and disadvantages of the project. Furthermore, it helps in deciding whether the project is the best solution for the problem or not. The acronym TELOS [131] is used to assess the different dimensions of feasibility.

5.12 SWOT

All projects have risk factors associated with them. However, it is necessary to carry out a risk analysis in the early days of the project to prevent or minimize negative events that could impact the success of the project [12]. As Scoy explained: '... we must learn to balance the possible negative consequences of risk against the potential benefits of its associated opportunity' [126].

SWOT Analysis is a strategic management tool that assists an enterprise in discerning their internal Strengths, and Weaknesses, and external Opportunities, and Threats, to determine its competitive position in the market [44].
The SWOT Analysis helps in ascertaining the factors that influences the efficiency and effectiveness of any product, project, or business entity [44].
These are explained as under [44]:

Strengths: The strengths of a company are the core competencies, in which the business has an edge over its competitors. It covers aspects such as:
- Strong financial condition
- A large customer base.
- Strong brand name or a unique product
- Latest technology or patents
- Influential advertising and promotion.
- Cost Advantage
- Quality in product and customer service.

Weaknesses: Weaknesses can be described as the areas of limitations of the business, that hinders the growth of the company and even leads to a strategic disadvantage.

These are the areas which need improvement to perform competitively. It encompasses:

- Obsolete facilities and outdated technology.
- The unit cost of a product is higher than the competitors.
- No or less internal control.
- Less quality in products and services offered.
- Weak brand image.
- Financial condition is not very sound.
- Underutilization of plant capacity.
- Lack of major skills or competencies, and intellectual capital.

Opportunities: Opportunities can be understood as the condition, which is favourable or beneficial to the organization in the business environment, that the business could exploit to gain an advantage. These are:

- Looking for areas of development, by utilizing skills and technology to enter new markets
- Adding new products to the existing product line to increase customer base.
- Forward and backward integration.
- Acquiring rivals businesses.
- Joint ventures, mergers and alliances to increase market coverage.

Threats: Threat implies an adverse condition which can lead the business enterprise to losses, and can also harm the overall position and reputation of the enterprise. It entails:

- A downtrend in market growth.
- A new entrant to the market.
- Substitute products that can decrease sales.
- Increasing the bargaining power of customers and suppliers.
- New regulatory requirements
- Changes in a demographic environment that will decrease demand for firm's product.

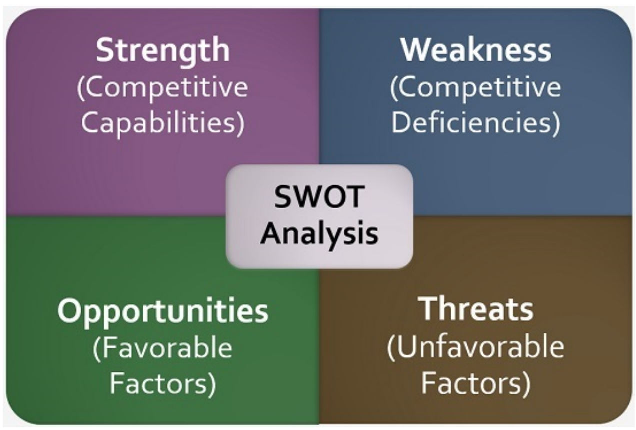

Figure 5.7. *SWOT Analysis [44].*

Importance of SWOT Analysis

- **Logical framework of analysis:** SWOT Analysis equips the management with an insightful framework for eliminating issues in a systematic manner, that can influence the condition of business, formulation of various strategies and their selection [44].
- **Presents a comparative report:** The analysis facilitates in presenting systematic information about the internal and external environment. This helps in making a comparison of external opportunities and threats with internal strengths and weaknesses, as well as reconciling the internal and external business environment, to help the managers in choosing the best strategy, by considering various patterns [44].
- **Strategy Identification:** Every organization has its strengths weakness, opportunities and threats. So, the SWOT Analysis acts as a guide to the strategist to reckon the exact position, i.e. where the business stands, so as to identify the primary objective of the strategy under consideration [44].

Figure 5.8. *Our SWOT.*

5.13 Market Research and Competitive Analysis

Market research helps you find customers for your business. Competitive analysis helps you make your business unique. Combine them to find a competitive advantage for your small business [4].

Market Research
Market research blends consumer behavior and economic trends to confirm and improve your business idea. It's crucial to understand your consumer base from the outset. Market research lets you reduce risks even while your business is still just a gleam in your eye [4].
Gather demographic information to better understand opportunities and limitations for gaining customers. This could include population data on age, wealth, family, interests, or anything else that's relevant for your business [4].
Then answer these questions to get a good sense of your market [4].

- **Demand:** Is there a desire for your product or service?
- **Market size:** How many people would be interested in your offering?
- **Economic indicators:** What is the income range and employment rate?
- **Location:** Where do your customers live and where can your business reach?
- **Market saturation:** How many similar options are already available to consumers?
- **Pricing:** What do potential customers pay for these alternatives?

You'll also want to keep up with the latest small business trends. It's important to gain a sense of the specific market share that will impact your profits. You can do market research using existing sources, or you can do the research yourself and go direct to consumers [4].

Our Market Research:
It is estimated that close to 50% of people are living with undiagnosed diabetes. Every 7 seconds a person dies from diabetes and the global health expenditure in 2014 to treat diabetes is estimated to be a whopping 612 billion dollars. In 2013 over 79,000 children were diagnosed with Type 1 diabetes [97].
The prevalence rate of Juvenile Type 1 diabetes is highest in Europe. The highest occurrence of diabetes is seen in the western pacific region (China, Japan, Australia, Vietnam and others) [97].

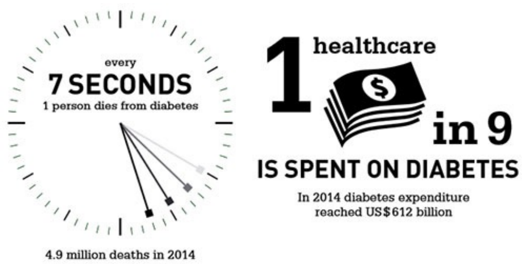

Figure 5.9. *Global health expenditure in 2014 to treat diabetes [97].*

Competitor Analysis

Competitive analysis helps you learn from businesses competing for your potential customers. This is key to defining a competitive edge that creates sustainable revenue [4].

Your competitive analysis should identify your competition by product line or service and market segment. Assess the following characteristics of the competitive landscape [107]:

- Market share
- Strengths and weaknesses
- Your window of opportunity to enter the market
- The importance of your target market to your competitors
- Any barriers that may hinder you as you enter the market
- Indirect or secondary competitors who may impact your success

Our Competitor Analysis:

For each apps, our analysis focused on the followings 7 criteria:

1. Communication
   - Possibility to easily share information with family ,health care providers, physician
2. Tracking
   - Blood glucose tracking
   - Diet tracking
   - Exercise tracking
   - Insulin dose estimator
   - Blood pressure, sleep, mood, heart rate tracking
   - Blood glucose levels prediction
3. Integration
   - Supported on multiple devices from various system (Android, iOS, ...)
   - Compatible with sensors, blood glucose measuring devices, insulin pumps and other related apps
4. Gamification
   - Feedback on performance
   - Goals and challenges
   - Progress monitoring (points, levels, leaderboards, badges)
   - Fun and playfulness (avatar, quests, ...)
   - Virtual vs tangible rewards
5. Data input
   - Automatic transmission of glucose readings from the glucose monitor to the mobile device
   - Food database
6. User Experience
   - Aesthetic dimension
   - Usability, ergonomics

Table 5.5. *Competitors.*

App Name	Comm-unication	Tracking	Integr-ation	Gamifi-cation	Data Input	UX	Specially for Children	Rate
BG Monitor Diabetes	No	Yes	Yes	No	Yes	Yes	No	4.6
BlueLoop	Yes	Yes	Yes	No	Yes	Yes	No	4.2
Diabetes in check	Yes	Yes	Yes	Yes	Yes	Yes	No	4
Glooko	No	Yes	Yes	No	Yes	Yes	No	4
Glucose Buddy	Yes	Yes	Yes	No	Yes	Yes	No	4
MySuger	No	Yes	Yes	Yes	Yes	Yes	No	4.6

According to our analysis most of the apps do not propose any Gamification.

5.14 Business Model generation

A business model is defined as:
A plan for the successful operation of a business, identifying sources of revenue, the target customer base, products, and details of financing.
Essentially it tells us how the key drivers of a business fit together [47].

For developing our business model, we use Canvas. That's where the Business Model Canvas comes in. It gives you a way to create a pretty clear business model using just a single sheet of paper. And what is great about it is it can be used to describe any company – from the largest company in the world to a startup with just one employee [47].
Business Model Canvas is a strategic management and lean startup template for developing new or documenting existing business models. It is a visual chart with elements describing a firm's or product's value proposition, infrastructure, customers, and finances. It assists firms in aligning their activities by illustrating potential trade-offs [130]. The Business Model Canvas was initially proposed by Alexander Osterwalder based on his earlier work on business model ontology. Since the release of Osterwalder's work around 2008, new canvases for specific niches have appeared [130].

Advantages of the Business Model Canvas [47]:

1. **Easy to understand:** Because the canvas on just a single page and is very visual it's very easy to understand.
2. **Focussed:** It removes any fluff that might have been present in a traditional business model. It's all killer no filler.
3. **Flexible:** It's quick and easy to make changes to your model and sketch out different ideas.

4. **Customer Focused:** the canvas forces you to think about the value you're providing to your customers, and only then what it takes to deliver that value.
5. **Shows Connections:** The single page graphical nature of the canvas shows how the different parts of the model interrelate to each other. This can be really difficult to ascertain from a traditional business plan.
6. **Easy to Communicate:** Because the canvas is so easy to understand you'll be able to share and explain it easily with your team, making it easier to get them on board with your vision.

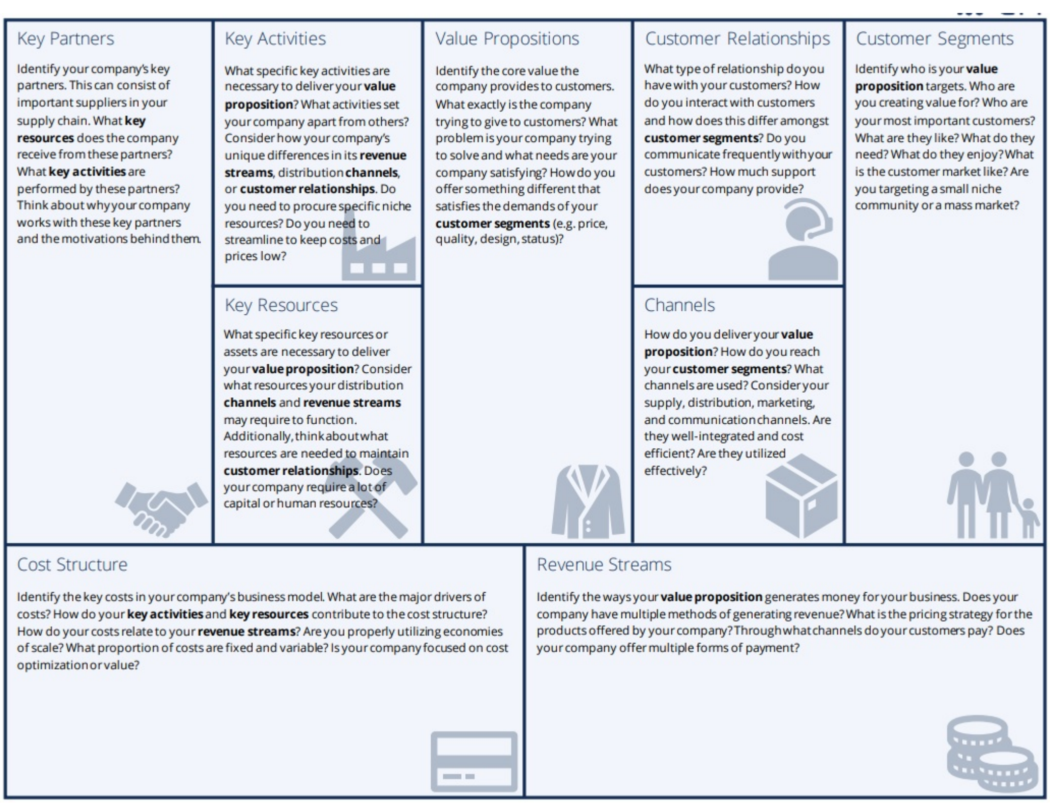

Figure 5.10. *Business Model Canvas [68].*

Using the Business Model Canvas

We'll look at each building block of the canvas in more detail shortly, but briefly, each segment tries to answer the following questions [47]:

1. **Customer Segments:** Who are your customers?
2. **Value Proposition:** Why do customers buy from you? What is the gain you provide or the need you satisfy?
3. **Channels:** How are your products and services delivered to the market?
4. **Customer Relationships:** How do you get, keep, and grow your customers?
5. **Revenue Streams:** How does your business earn money?
6. **Key Resources:** What unique strategic resources does your business have or need?
7. **Key Activities:** What unique strategic activities does your business perform

to deliver your value proposition?

8. **Key Partnerships:** What non-key activities can you outsource to enable you to focus more on your key activities.
9. **Cost Structures:** What are the major costs incurred by your business?

Figure 5.11. *Our Business Model Canvas.*

Chapter 6

Prototype Development

Designing from data requires taking a creative leap. There are no set rules that outline how to translate user requirements into specific design features. However, there are tools that can be used to help guide the process. In this section, the steps used to develop the prototype and the final design prepared for usability testing are described in detail [86].

Work Plan:
After collecting of the Requirements, and analyzing the data, we start with the design of the first prototype by HTA,STN then we implement it, then we apply the expert-based evaluation techniques on that prototype (including Cognitive Walk-through, Heuristics, and Review-based), and we come up with prototype 2 where we applied the User-based evaluation techniques (including Think aloud, Cooperative evaluation, . . .) to evaluate that prototype (we repeat that in an iterative way until we get our final product), and finally we have our final product [79].

6.1 Storyboards

Storyboarding is a technique that was derived from the film industry and has now been commonly applied to developing system designs. Bayer and Holtzblatt [23] describe storyboards as a means to demonstrate how specific tasks will be accomplished in the new world.
In this case, storyboarding was used to identify what tasks an children T1DM will attempt to complete using the mobile application and what the expected system response would be to accommodate the action [86].

This storyboard does not address all of the identified design principles, however the thinking process behind creating the above figure was useful in determining an initial user workflow. In other words, the act of thinking through how a user may approach the mobile application was helpful in determining what the user might expect to see and be able to do. The following section outlines the iterative approach taken to develop the prototype [86].

6.2 Hierarchical Task Analysis (HTA)

What Is Hierarchical Task Analysis?
A structured, objective approach to describing users' performance of tasks, hierarchical task analysis originated in human factors. In its most basic form, a hierarchical task analysis provides an understanding of the task's users need to perform to achieve certain goals. You can break down these tasks into multiple levels of subtasks. In user experience, you can use hierarchical task analysis to describe the interactions between a user and a software system. When designing a new system, hierarchical task analysis lets you explore various possible approaches to completing the same task. When analyzing an existing system, it can help you to optimize particular interactions [125].
Once you've created a hierarchical task analysis, it can serve as an effective form of system documentation, enabling developers to rapidly understand how users interact with a system. As software engineers are all too aware, the intimate familiarity you may have gained with why users do something in a certain way can quickly fade in just a few days or weeks. A hierarchical task analysis is an effective means of capturing this information [125].

Hierarchical Task Analysis (HTA) is a task description method and a variant of task analysis. Task description is a necessary precursor for other analysis techniques, HTA is used to produce an exhaustive description of tasks in a hierarchical structure of goals, sub-goals, operations and plans. In HTA, tasks are broken down into progressively smaller units [79].

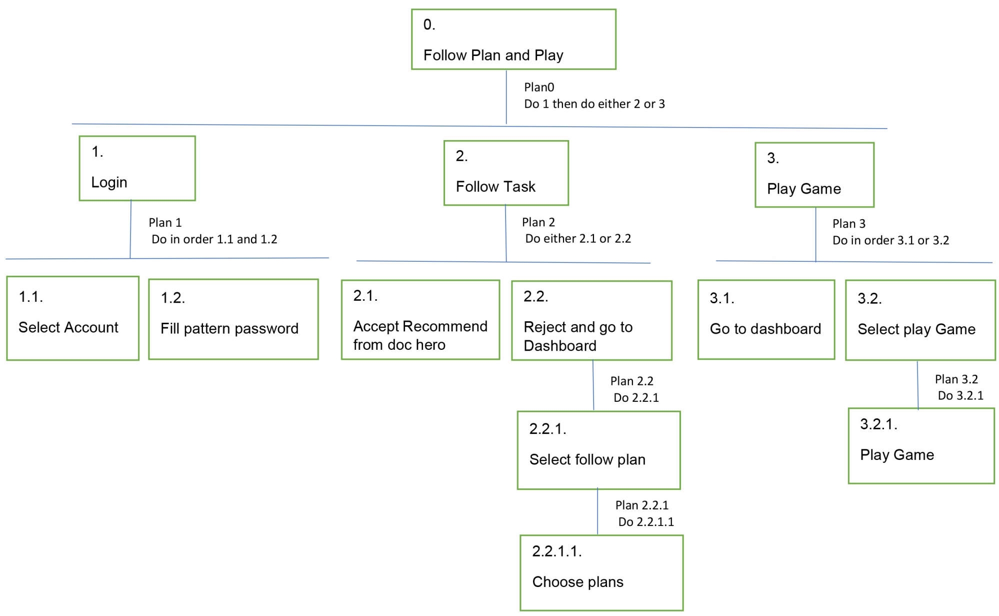

Figure 6.1. *Hierarchical Task Analysis for Children.*

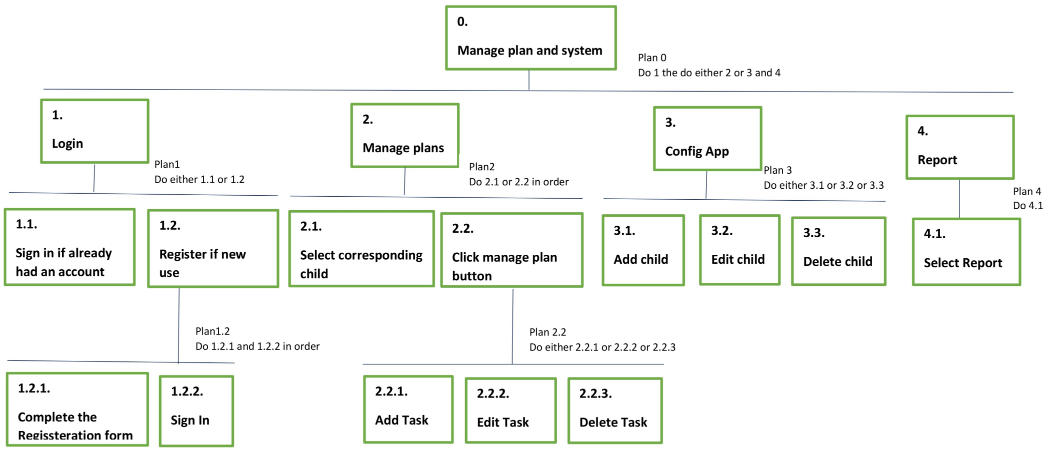

Figure 6.2. *Hierarchical Task Analysis for Parent.*

6.3 State Transition Network (STN)

The State Transition Diagram [95] was probably the first and the most frequently used formal method to model a dialog, as expanded in State Transition Networks (STN) [129].
User Software Engineering is a methodology for the specification and implementation of interactive information systems. An early step in the methodology is the creation of a formal executable description of the user interaction with the system, based on augmented state transition diagrams [129].
A state transition network is a diagram that is developed from a set of data and charts the flow of data from particular data points (called states or nodes) to the next in a probabilistic manner. State transition networks are used in both academic and industrial fields. State transition networks are a general construct, with more specific examples being augmented transition networks, recursive transition networks, and augmented recursive networks, among others [79].

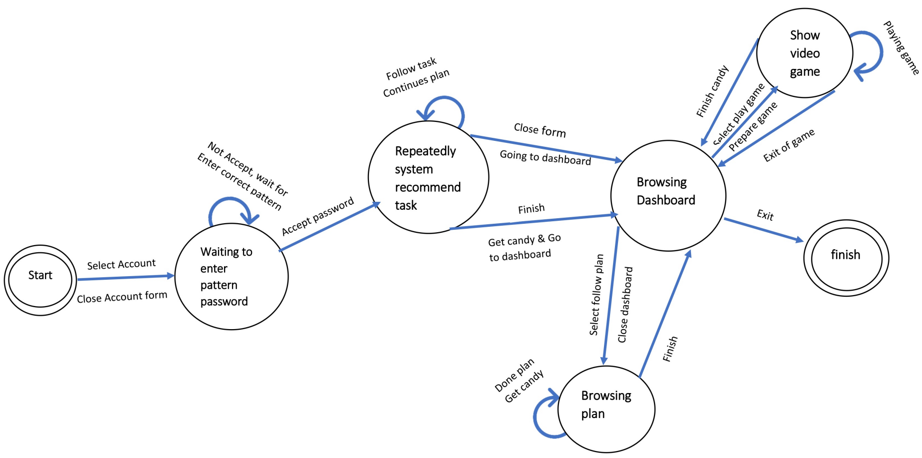

Figure 6.3. *State Transition Network for Children*

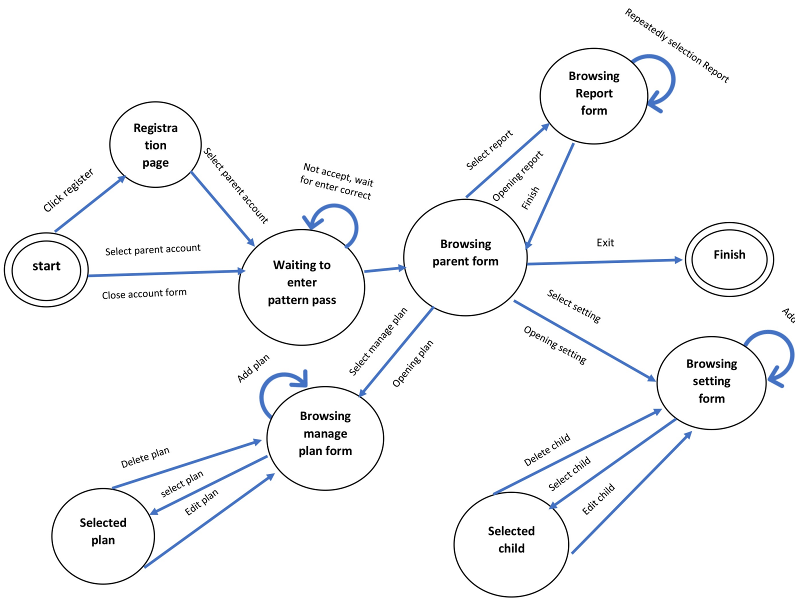

Figure 6.4. *State Transition Network for Parent.*

6.4 First Prototype

After we finish the design part with modelling the possible tasks, we implement our first prototype with mockup.

Figure 6.5. *Login for Children and Parent.*

Figure 6.6. *Welcome Page.*

Figure 6.7. *Follow of Auto Schedule/plan.*

Figure 6.8. *Give candy to Children.*

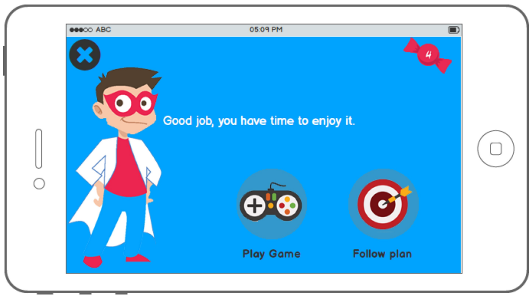

Figure 6.9. *Children Dashboard.*

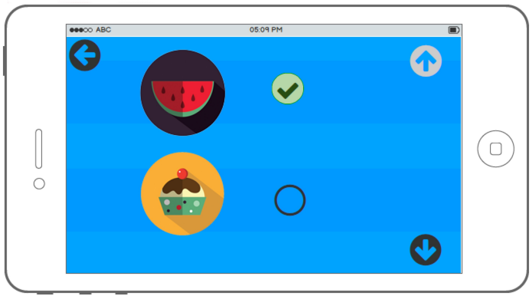

Figure 6.10. *Follow of Manual Plan.*

Figure 6.11. *Parent Dashboard.*

Chapter 7

7.1 Future Work and Conclusion

I realized the magnitude of the problem in diabetic children, Type 1 diabetes mellitus (T1DM) is the most common metabolic disorder during childhood. Type 1 diabetes mellitus (T1DM) is a complex disease that requires constant monitoring and active patient participation in the development and maintenance of their daily self-management routine.

Infants, toddlers, and preschool-age children ($\leq$ 5 years of age) are enrolled in the more than 330,000 childcare programs across the USA country. These children wholly depend on adults for most, if not all, aspects of their care. Pediatric health care providers, parents/guardians, and childcare staff must work together to ensure that young children with diabetes are provided with the safest possible childcare environment. This collaboration is essential to achieve a seamless transition in care from home to the childcare setting [110].

Managing type 1 diabetes in young children in childcare programs presents unique challenges due to the young child's developmental level. The limited communication and motor skills, cognitive abilities, and emotional maturity of young children can challenge even the most experienced childcare provider. For example, young children with hypo- or hyperglycemia may or may not exhibit abnormal behavior or irritability. As erratic behavior is typical in this age-group, the childcare provider may not recognize hypo- or hyperglycemic symptoms and may miss the fact that the behavior is caused by low or high blood glucose levels that may require treatment [110].

The diabetes regimen must be adapted quickly to the child's dynamic growth and development. As the child develops and desires greater autonomy, childcare providers and parents/guardians may face challenges with the toddler's refusal to cooperate with his or her diabetes care regimen (8).

Once the child enters the prekindergarten years, he or she may begin to be able to participate in his or her own care by indicating food preferences, checking blood glucose, and choosing a finger-prick or injection site. With further cognitive and physical development, he or she may verbalize symptoms and become more cooperative, but the child still needs constant supervision and blood glucose monitoring to detect hypo- or hyperglycemia. The age at which children are able to perform self-care tasks is variable and depends on the individual child's capabilities, but self-care is not expected from the young child and the parent/guardian or other caregiver must provide diabetes management and perform associated diabetes care tasks such as blood glucose monitoring and insulin administration [110].

Blood glucose prediction remains a very complex problem due tue the nonlinear, multifactorial, dynamic aspects of the condition, which, in addition, is subject to huge intra- and inter-patient variability [59].Patients with diabetes have low adherence to clinical recommendations for medication therapy and lifestyle changes, leading to suboptimal glycemic control and a low quality of life. Patients with controlled diabetes can reduce their lifetime risk of renal failure by 87%, blindness by 72%, symptomatic neuropathy by 68%, and lower-extremity amputation by 67% (166). This impact is significant, and it is thus necessary to adopt new methods of enabling patients to effectively self-manage their diabetes, leading to improve clinical outcomes [55].

To manage diabetes successfully, patients must be able to set goals and make frequent daily decisions that are both effective and fit their values and lifestyles, while taking into account multiple physiological and personal psychosocial factors. That are the main issues patient empowerment, whose ultimate goal is to help patients discover and develop their inherent capacity to be responsible for their own life, should deal with [26][52].

The best way to empower a diabetic patient is a personal face-to-face coaching, day after day, ideally in close collaboration with physicians, dietitians, nurses and other diabetes health care professionals. However, such a solution is not an economically feasible method. In view of the empowerment scale we described, another and hopeful way for keeping patients motivated appears suitable : the gamification, which can be defined as the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals in non-game contexts [59][26][28].

We explored and study existing diabetes mobile applications and their features to a better understanding of user requirements, translating those requirements into a paper prototype and collecting feedback from customers and finally we design and implement the final product. In addition, background research of similar tools and sciences was conducted. The system uses gamification to help children to manage diabetes and detect heart attack with machine learning approach. There is a positive motivation and support provided by the game to reinforce

positive behavior in diabetes management. These include recording daily test blood sugar and being aware of one's diet plan. Therefore, it allows the children to understand and make decisions based on each pattern.

Future research should include another iteration of design making changes using the feedback collected from usability testing, developing mobile app and heart rate monitoring.

Finally, I hope our thesis, with highlighting and working on the main children's diabetes management issues and underlining the importance of heart attack prediction and gamification approach, could encourage the children to follow their diet plan and self-management.

Bibliography

[1] "user types-andrzejs blog"gamified uk blog. .

[2] Internation diabetes federation, “diabetes atlas (7th edition).”. , 2019. Accessed: 2019-10-18.

[3] O Peter Adams. The impact of brief high-intensity exercise on blood glucose levels. *Diabetes, metabolic syndrome and obesity: targets and therapy*, 6:113, 2013.

[4] U.S. Small Business Administration. “market research and competitive analysis”. , 2019. Accessed: 2019-10-18.

[5] Murray Aitken and Carolyn Gauntlett. Patient apps for improved healthcare: from novelty to mainstream. *Parsippany, NJ: IMS Institute for Healthcare Informatics*, 2013.

[6] Ishan Ajmera, Maciej Swat, Camille Laibe, Nicolas Le Novere, and Vijayalakshmi Chelliah. The impact of mathematical modeling on the understanding of diabetes and related complications. *CPT: pharmacometrics & systems pharmacology*, 2(7):1–14, 2013.

[7] Orestis Akrivopoulos, Dimitrios Amaxilatis, Athanasios Antoniou, and Ioannis Chatzigiannakis. Design and evaluation of a person-centric heart monitoring system over fog computing infrastructure. In *Proceedings of the First International Workshop on Human-Centered Sensing, Networking, and Systems*, pages 25–30. ACM, 2017.

[8] Orestis Akrivopoulos, Dimitrios Amaxilatis, Irene Mavrommati, and Ioannis Chatzigiannakis. Utilising fog computing for developing a person-centric heart monitoring system. *Journal of Ambient Intelligence and Smart Environments*, 11(3):237–259, 2019.

[9] Orestis Akrivopoulos, Ioannis Chatzigiannakis, Christos Tselios, and Athanasios Antoniou. On the deployment of healthcare applications over fog computing infrastructure. In *2017 IEEE 41st Annual Computer Software and Applications Conference (COMPSAC)*, volume 2, pages 288–293. IEEE, 2017.

[10] Kurt George Matthew Mayer Alberti and Paul Z Zimmet. Definition, diagnosis and classification of diabetes mellitus and its complications. part 1: diagnosis and classification of diabetes mellitus. provisional report of a who consultation. *Diabetic medicine*, 15(7):539–553, 1998.

[11] Ian Alexander. 10 small steps to better requirements. *IEEE software*, 23(2):19–21, 2006.

[12] Alaa Almarshedi. *A gamified management tool and community for Arab diabetic patients*. PhD thesis, University of Southampton, 2013.

[13] Dimitrios Amaxilatis, Ioannis Chatzigiannakis, Irene Mavrommati, Evdoxia Vasileiou, and Andrea Vitaletti. Delivering elder-care environments utilizing tv-channel based mechanisms. *Journal of Ambient Intelligence and Smart Environments*, 9(6):783–798, 2017.

[14] G Anderson, R Herbert, T Zeffiro, and N Johnson. Chronic conditions: making the case for ongoing care. baltimore, md: John hopkins university, 2004.

[15] Robert M Anderson, Martha M Funnell, James T Fitzgerald, and David G Marrero. The diabetes empowerment scale: a measure of psychosocial self-efficacy. *Diabetes care*, 23(6):739–743, 2000.

[16] American Diabetes Association. "how stress affects diabetes.". , 2016. Accessed: 2016-08-19.

[17] American Diabetes Association et al. Diagnosis and classification of diabetes mellitus. *Diabetes care*, 36(Supplement 1):S67–S74, 2013.

[18] Diabetes Teaching Center at the University of California. "blood sugar and stress.". . Accessed: 2016-08-19.

[19] Albert Bandura. Health promotion by social cognitive means. *Health education & behavior*, 31(2):143–164, 2004.

[20] TV BARGEN, Christoph Zientz, and Reinhold Haux. Gamification for mhealth–a review of playful mobile healthcare. *Integrating Information Technology and Management for Quality of Care*, 202:225, 2014.

[21] Richard Bartle. Hearts, clubs, diamonds, spades: Players who suit muds. *Journal of MUD research*, 1(1):19, 1996.

[22] M.T BASSETT. *Diabetes is Epidemic. American Journal of Public Health*. PhD thesis, 2005.

[23] Hugh Beyer and Karen Holtzblatt. *Contextual design: defining customer-centered systems*, volume 1. Morgan kaufmann, 1998.

[24] R. Bilous. "role of alpha cells in diabetes.". , 2014. Accessed: 2016-08-18.

[25] Maged N Kamel Boulos, Shauna Gammon, Mavis C Dixon, Sandra M MacRury, Michael J Fergusson, Francisco Miranda Rodrigues, Telmo Mourinho Baptista, and Stephen P Yang. Digital games for type 1 and type 2 diabetes: underpinning theory with three illustrative examples. *JMIR Serious Games*, 3(1):e3, 2015.

[26] Paulina Bravo, Adrian Edwards, Paul James Barr, Isabelle Scholl, Glyn Elwyn, and Marion McAllister. Conceptualising patient empowerment: a mixed methods study. *BMC health services research*, 15(1):252, 2015.

[27] A. Brown. "42 factors that affect blood glucose?! a surprising update.". . Accessed: 2019-07-09.

[28] Brian Burke. "gartner redefines gamification.". 2014. Accessed: 2019-10-19.

[29] Joseph A Cafazzo, Mark Casselman, Nathaniel Hamming, Debra K Katzman, and Mark R Palmert. Design of an mhealth app for the self-management of adolescent type 1 diabetes: a pilot study. *Journal of medical Internet research*, 14(3):e70, 2012.

[30] Heather Chaplin. Guide to journalism and design. , 2016. Accessed: 2019-10-29.

[31] Arnaud Chiolero, David Faeh, Fred Paccaud, and Jacques Cornuz. Consequences of smoking for body weight, body fat distribution, and insulin resistance. *The American journal of clinical nutrition*, 87(4):801–809, 2008.

[32] Jiyoung Choi. Creating an evaluation system for a mobile application design to enhance usability and aesthetics. 2012.

[33] Taridzo Chomutare, Luis Fernandez-Luque, Eirik Årsand, and Gunnar Hartvigsen. Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-based guidelines. *Journal of medical Internet research*, 13(3):e65, 2011.

[34] Lawrence Chung and Julio Cesar Sampaio do Prado Leite. On non-functional requirements in software engineering. In *Conceptual modeling: Foundations and applications*, pages 363–379. Springer, 2009.

[35] Simon Lebech Cichosz, Jan Frystyk, Ole K Hejlesen, Lise Tarnow, and Jesper Fleischer. A novel algorithm for prediction and detection of hypoglycemia based on continuous glucose monitoring and heart rate variability in patients with type 1 diabetes. *Journal of diabetes science and technology*, 8(4):731–737, 2014.

[36] Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *New England journal of medicine*, 329(14):977–986, 1993.

[37] Charles A Coonradt and Lee Nelson. *The game of work*. Gibbs Smith, 2007.

[38] Brian Cugelman. Gamification: what it is and why it matters to digital health behavior change developers. *JMIR serious games*, 1(1):e3, 2013.

[39] Miriam F Delaney, Ariel Zisman, and William M Kettyle. Diabetic ketoacidosis and hyperglycemic hyperosmolar nonketotic syndrome. *Endocrinology and metabolism clinics of North America*, 29(4):683–705, 2000.

[40] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. From game design elements to gamefulness: defining gamification. In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*, pages 9–15. ACM, 2011.

[41] Leandro Arthur Diehl, Rodrigo Martins Souza, Juliano Barbosa Alves, Pedro Alejandro Gordan, Roberto Zonato Esteves, Maria Lúcia Silva Germano Jorge, and Izabel Cristina Meister Coelho. Insuonline, a serious game to teach insulin therapy to primary care physicians: design of the game and a randomized controlled trial for educational validation. *JMIR research protocols*, 2(1):e5, 2013.

[42] K Doyle. Do we have a winner? gamification in healthcare. *Healthbiz Decoded*, 2013.

[43] Leonard E Egede, Deyi Zheng, and Kit Simpson. Comorbid depression is associated with increased health care use and expenditures in individuals with diabetes. *Diabetes care*, 25(3):464–470, 2002.

[44] emmanuel ziyera. “swot analysis”. , 2019. Accessed: 2019-10-18.

[45] Michael M Engelgau, KM Venkat Narayan, Jinan B Saaddine, and Frank Vinicor. Addressing the burden of diabetes in the 21st century: better care and primary prevention. *Journal of the American Society of Nephrology*, 14(suppl 2):S88–S91, 2003.

[46] Kai Erenli. The impact of gamification: A recommendation of scenarios for education. In *2012 15th International Conference on Interactive Collaborative Learning (ICL)*, pages 1–8. IEEE, 2012.

[47] expert program management. “business model canvas explained with examples”. , 2019. Accessed: 2019-10-18.

[48] S Franc, A Daoudi, S Mounier, B Boucherie, D Dardari, H Laroye, B Neraud, E Requeda, L Canipel, and G Charpentier. Telemedicine and diabetes: achievements and prospects. *Diabetes & metabolism*, 37(6):463–476, 2011.

[49] Marion J Franz. Protein: metabolism and effect on blood glucose levels. *The diabetes educator*, 23(6):643–651, 1997.

[50] Donna Freeborn, Carol A Loucks, Tina Dyches, Susanne Olsen Roper, and Barbara Mandleco. Addressing school challenges for children and adolescents with type 1 diabetes: The nurse practitioner’s role. *The journal for nurse practitioners*, 9(1):11–16, 2013.

[51] Brian M Frier. Morbidity of hypoglycemia in type 1 diabetes. *Diabetes research and clinical practice*, 65:S47–S52, 2004.

[52] Martha M Funnell and Robert M Anderson. Empowerment and self-management of diabetes. *Clinical diabetes*, 22(3):123–127, 2004.

[53] Borja Gil Pérez et al. Applying gamification to education: A case study in an e-learning environment. Master's thesis, 2015.

[54] Barry H Ginsberg. Factors affecting blood glucose monitoring: sources of errors in measurement. *Journal of diabetes science and technology*, 3(4):903–913, 2009.

[55] Shivani Goyal. *Influencing Behaviour to Improve Diabetes Self-Management: The Design and Evaluation of Mobile Health Applications*. PhD thesis, 2017.

[56] Hank Grebe. Ux process and skills diagrams. , 2015. Accessed: 2019-10-29.

[57] UK Prospective Diabetes Study (UKPDS) Group et al. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (ukpds 33). *The lancet*, 352(9131):837–853, 1998.

[58] Leonor Guariguata, David R Whiting, Ian Hambleton, Jessica Beagley, Ute Linnenkamp, and Jonathan E Shaw. Global estimates of diabetes prevalence for 2013 and projections for 2035. *Diabetes research and clinical practice*, 103(2):137–149, 2014.

[59] Guillaume Gustin and Benoît Macq. Diabetes management through artificial intelligence and gamification: blood glucose prediction models and mhealth design considerations.

[60] Juho Hamari, Jonna Koivisto, Harri Sarsa, et al. Does gamification work?-a literature review of empirical studies on gamification. In *HICSS*, volume 14, pages 3025–3034, 2014.

[61] Mary Beth Hamel, Nathan G Cortez, I Glenn Cohen, and Aaron S Kesselheim. Fda regulation of mobile health technologies. *The New England journal of medicine*, 371(4):372, 2014.

[62] Lutz Heinemann and Lars Krinelke. Insulin infusion set: the achilles heel of continuous subcutaneous insulin infusion. *Journal of diabetes science and technology*, 6(4):954–964, 2012.

[63] Evelien Heinrich, Nicolaas C Schaper, and Nanne K de Vries. Self-management interventions for type 2 diabetes: a systematic review. *European Diabetes Nursing*, 7(2):71–76, 2010.

[64] Nathaniel D Heintzman. A digital ecosystem of diabetes data and technology: services, systems, and tools enabled by wearables, sensors, and apps. *Journal of diabetes science and technology*, 10(1):35–41, 2016.

[65] Michele Heisler, Reynard R Bouknight, Rodney A Hayward, Dylan M Smith, and Eve A Kerr. The relative importance of physician communication, participatory decision making, and patient understanding in diabetes self-management. *Journal of general internal medicine*, 17(4):243–252, 2002.

[66] Eric B Hekler, Predrag Klasnja, Jon E Froehlich, and Matthew P Buman. Mind the theoretical gap: interpreting, using, and developing behavioral theory in hci research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 3307–3316. ACM, 2013.

[67] Melba A Hernandez-Tejada, Jennifer A Campbell, Rebekah J Walker, Brittany L Smalls, Kimberly S Davis, and Leonard E Egede. Diabetes empowerment, medication adherence and self-care behaviors in adults with type 2 diabetes. *Diabetes technology & therapeutics*, 14(7):630–634, 2012.

[68] Corporate Finance Institute. "business model canvas examples". , 2019. Accessed: 2019-10-18.

[69] MM Joosten, JWJ Beulens, S Kersten, and HFJ Hendriks. Moderate alcohol consumption increases insulin sensitivity and adipoq expression in postmenopausal women: a randomised, crossover trial. *Diabetologia*, 51(8):1375–1381, 2008.

[70] David Kerr. Poor numeracy: the elephant in the diabetes technology room, 2010.

[71] Jeong-a Kim, Monica Montagnani, Kwang Kon Koh, and Michael J Quon. Reciprocal relationships between insulin resistance and endothelial dysfunction: molecular and pathophysiological mechanisms. *Circulation*, 113(15):1888–1904, 2006.

[72] Jon Kolko. "storyboarding & prototyping". , 2019. Accessed: 2019-10-18.

[73] Hsiang-Ching Kung, Donna L Hoyert, Jiaquan Xu, Sherry L Murphy, et al. Deaths: final data for 2005. *Natl Vital Stat Rep*, 56(10):1–120, 2008.

[74] James D Lane. Caffeine, glucose metabolism, and type 2 diabetes. *Journal of Caffeine Research*, 1(1):23–28, 2011.

[75] Foong Li Law, Zarinah Mohd Kasirun, and Chun Kiat Gan. Gamification towards sustainable mobile application. In *2011 Malaysian Conference in Software Engineering*, pages 349–353. IEEE, 2011.

[76] Katherine D Lippa and Helen Altman Klein. Portraits of patient cognition: how patients understand diabetes self-care. *CJNR (Canadian Journal of Nursing Research)*, 40(3):80–95, 2008.

[77] Brian D Loader, Steve Muncer, Roger Burrows, Nicholas Pleace, and Sara Nettleton. Medicine on the line? computer-mediated social support and advice for people with diabetes. *International Journal of Social Welfare*, 11(1):53–65, 2002.

[78] David M Maahs, Nancy A West, Jean M Lawrence, and Elizabeth J Mayer-Davis. Epidemiology of type 1 diabetes. *Endocrinology and Metabolism Clinics*, 39(3):481–497, 2010.

[79] Meng Liu Mahomd Sharaf, Nour Fathallah. Human and computer interation. , 2014. Accessed: 2019-10-18.

[80] Jakob Marovt. *Igrifikacija programske opreme*. PhD thesis, Univerza v Ljubljani, 2012.

[81] Andrea Marrella. The workpad project. , 2014.

[82] Hannah R Marston and Amanda K Hall. Gamification: applications for health promotion and health information technology engagement. In *Handbook of Research on Holistic Perspectives in Gamification for Clinical Practice*, pages 78–104. IGI Global, 2016.

[83] Lucy Marzban, Kirily Park, and C Bruce Verchere. Islet amyloid polypeptide and type 2 diabetes. *Experimental gerontology*, 38(4):347–351, 2003.

[84] Healthline Media. "blood glucose levels: How 'glucose management' works". , 2017. Accessed: January 27, 2017.

[85] Aaron S Miller, Joseph A Cafazzo, and Emily Seto. A game plan: Gamification design principles in mhealth applications for chronic disease management. *Health informatics journal*, 22(2):184–193, 2016.

[86] Lisa Min. *Design and Evaluation of a Mobile Health Application for Adult Patients with Type 1 Diabetes Mellitus*. PhD thesis, 2013.

[87] Karen R Muñana. Long-term complications of diabetes mellitus, part i: Retinopathy, nephropathy, neuropathy. *Veterinary Clinics: Small Animal Practice*, 25(3):715–730, 1995.

[88] Valeriya Naumova, Lucian Nita, Jens Ulrik Poulsen, and Sergei V Pereverzyev. Meta-learning based blood glucose predictor for diabetic smartphone app. In *Prediction Methods for Blood Glucose Concentration*, pages 93–105. Springer, 2016.

[89] Brian D Ng and Peter Wiemer-Hastings. Addiction to the internet and online gaming. *Cyberpsychology & behavior*, 8(2):110–113, 2005.

[90] Donald A Norman. Attractive things work better. *Emotional design: Why we love (or hate) everyday things, Basic Books, New York*, 2003.

[91] Susan L Norris, Michael M Engelgau, and KM Venkat Narayan. Effectiveness of self-management training in type 2 diabetes: a systematic review of randomized controlled trials. *Diabetes care*, 24(3):561–587, 2001.

[92] Stavros Nousias, Christos Tselios, Dimitris Bitzas, Dimitrios Amaxilatis, Javier Montesa, Aris S Lalos, Konstantinos Moustakas, and Ioannis Chatzigiannakis. Exploiting gamification to improve eco-driving behaviour: The gamecar approach. *Electr. Notes Theor. Comput. Sci.*, 343:103–116, 2019.

[93] Shantanu Nundy, Anjuli Mishra, Patrick Hogan, Sang Mee Lee, Marla C Solomon, and Monica E Peek. How do mobile phone diabetes programs drive behavior change? evidence from a mixed methods observational cohort study. *The Diabetes Educator*, 40(6):806–819, 2014.

[94] A.F. Osborn. *Applied imagination; principles and procedures of creative problem-solving*. Scribner, 1963.

[95] David L Parnas. On the use of transition diagrams in the design of a user interface for an interactive computer system. In *Proceedings of the 1969 24th national conference*, pages 379–385. ACM, 1969.

[96] Misha Pavel, Holly B Jimison, Ilkka Korhonen, Christine M Gordon, and Niilo Saranummi. Behavioral informatics and computational modeling in support of proactive health management and care. *IEEE Transactions on Biomedical Engineering*, 62(12):2763–2775, 2015.

[97] pharmacy researcher. Diabetes prevalence - a statistics report. , 2019. Accessed: 2019-10-29.

[98] Stanisław Piłaciński and Dorota A Zozulińska-Ziółkiewicz. Influence of lifestyle on the course of type 1 diabetes mellitus. *Archives of medical science: AMS*, 10(1):124, 2014.

[99] Marc Prensky. Digital game-based learning. *Computers in Entertainment (CIE)*, 1(1):21–21, 2003.

[100] Naresh M Punjabi, Eyal Shahar, Susan Redline, Daniel J Gottlieb, Rachel Givelber, and Helaine E Resnick. Sleep-disordered breathing, glucose intolerance, and insulin resistance: the sleep heart health study. *American journal of epidemiology*, 160(6):521–530, 2004.

[101] Charlene C Quinn, Michelle D Shardell, Michael L Terrin, Erik A Barr, Shoshana H Ballew, and Ann L Gruber-Baldini. Cluster-randomized trial of a mobile phone personalized behavioral intervention for blood glucose control. *Diabetes care*, 34(9):1934–1942, 2011.

[102] Veera Ranganath. brainstorming techniques and rules for creative idea. , 2019. Accessed: 2019-10-29.

[103] Anoop Rao, Philip Hou, Timothy Golnik, Joseph Flaherty, and Sonny Vu. Evolution of data management tools for managing self-monitoring of blood glucose results: a survey of iphone applications. *Journal of diabetes science and technology*, 4(4):949–957, 2010.

[104] Research2Guidance. Diabetes app market report 2014: How to leverage the full potential of the diabetes app market. , 2016. Accessed: 2016-07-31.

[105] Ignacio Rodríguez-Rodríguez, Ioannis Chatzigiannakis, José-Víctor Rodríguez, Marianna Maranghi, Michele Gentili, and Miguel-Ángel Zamora-Izquierdo. Utility of big data in predicting short-term blood glucose levels in type 1

diabetes mellitus through machine learning techniques. *Sensors*, 19(20):4482, 2019.

[106] Ignacio Rodríguez-Rodríguez, José-Víctor Rodríguez, Ioannis Chatzigiannakis, and Miguel Ángel Zamora Izquierdo. On the possibility of predicting glycaemia 'on the fly'with constrained iot devices in type 1 diabetes mellitus patients. *Sensors*, 19(20):4538, 2019.

[107] Maria Ines Schmidt, Angeliki Hadji-Georgopoulos, Marc Rendell, Simeon Margolis, and Avinoam Kowarski. The dawn phenomenon, an early morning glucose rise: implications for diabetic intraday blood glucose variation. *Diabetes care*, 4(6):579–585, 1981.

[108] Alessandro Scirè, Fabrizio Tropeano, Aris Anagnostopoulos, and Ioannis Chatzigiannakis. Fog-computing-based heartbeat detection and arrhythmia classification using machine learning. *Algorithms*, 12(2):32, 2019.

[109] S Shanthi and D Kumar. Prediction of blood glucose concentration ahead of time with feature based neural network. *Malaysian Journal of Computer Science*, 25(3):136–148, 2012.

[110] Linda M Siminerio, Anastasia Albanese-O'Neill, Jane L Chiang, Katie Hathaway, Crystal C Jackson, Jill Weissberg-Benchell, Janel L Wright, Alan L Yatvin, and Larry C Deeb. Care of young children with diabetes in the child care setting: a position statement of the american diabetes association. *Diabetes care*, 37(10):2834–2842, 2014.

[111] Kimber M Simmons and Aaron W Michels. Type 1 diabetes: A predictable disease. *World journal of diabetes*, 6(3):380, 2015.

[112] BF Skinner. The behavior of organisms: an experimental analysis. appleton-century, 1938.

[113] Carmel EM Smart, Megan Evans, Susan M O'connell, Patrick McElduff, Prudence E Lopez, Timothy W Jones, Elizabeth A Davis, and Bruce R King. Both dietary protein and fat increase postprandial glucose excursions in children with type 1 diabetes, and the effect is additive. *Diabetes Care*, 36(12):3897–3902, 2013.

[114] Brian K Smith, Jeana Frost, Meltem Albayrak, and Rajneesh Sudhakar. Integrating glucometers and digital photography as experience capture tools to enhance patient understanding and communication of diabetes self-management practices. *Personal and Ubiquitous Computing*, 11(4):273–286, 2007.

[115] Carolyn Snyder. *Paper prototyping: The fast and easy way to design and refine user interfaces*. Morgan Kaufmann, 2003.

[116] Sandra I Sobel, Peter J Chomentowski, Nisarg Vyas, David Andre, and Frederico GS Toledo. Accuracy of a novel noninvasive multisensor technology to estimate glucose in diabetic subjects during dynamic conditions. *Journal of diabetes science and technology*, 8(1):54–63, 2014.

[117] Karine Spiegel, Rachel Leproult, and Eve Van Cauter. Impact of sleep debt on metabolic and endocrine function. *The lancet*, 354(9188):1435–1439, 1999.

[118] Liz Steed, Debbey Cooke, and Stanton Newman. A systematic review of psychosocial outcomes following education, self-management and psychological interventions in diabetes mellitus. *Patient education and counseling*, 51(1):5–15, 2003.

[119] Debbie Stone, Caroline Jarrett, Mark Woodroffe, and Shailey Minocha. *User interface design and evaluation*. Elsevier, 2005.

[120] Kingman P Strohl, Ronald D Novak, William Singer, Clement Cahan, Keith D Boehm, Charles W Denko, and Victor S Hoffstein. Insulin levels, blood pressure and sleep apnea. *Sleep*, 17(7):614–618, 1994.

[121] Paul Sutcliffe, Steven Martin, Jackie Sturt, John Powell, Frances Griffiths, Ann Adams, and Jeremy Dale. Systematic review of communication technologies to promote access and engagement of young people with diabetes into healthcare. *BMC endocrine disorders*, 11(1):1, 2011.

[122] Noam Tractinsky, Adi S Katz, and Dror Ikar. What is beautiful is usable. *Interacting with computers*, 13(2):127–145, 2000.

[123] Jaakko Tuomilehto, Peter Schwarz, and Jaana Lindström. Long-term benefits from lifestyle interventions for type 2 diabetes prevention: time to expand the efforts. *Diabetes Care*, 34(Supplement 2):S210–S214, 2011.

[124] Chrysanthi Tziortzioti, Irene Mavrommati, Georgios Mylonas, Andrea Vitaletti, and Ioannis Chatzigiannakis. Scenarios for educational and game activities using internet of things data. In *2018 IEEE Conference on Computational Intelligence and Games (CIG)*, pages 1–8. IEEE, 2018.

[125] uxmatters. Hierarchical task analysis. , 2019. Accessed: 2019-10-29.

[126] Roger L Van Scoy. Software development risk: opportunity, not problem. Technical report, CARNEGIE-MELLON UNIV PITTSBURGH PA SOFTWARE ENGINEERING INST, 1992.

[127] Helena Vuorinen-Markkola, Veikko A Koivisto, and Hannele Yki-Jarvinen. Mechanisms of hyperglycemia-induced insulin resistance in whole body and skeletal muscle of type i diabetic patients. *Diabetes*, 41(5):571–580, 1992.

[128] Edward H Wagner, Brian T Austin, Connie Davis, Mike Hindmarsh, Judith Schaefer, and Amy Bonomi. Improving chronic illness care: translating evidence into action. *Health affairs*, 20(6):64–78, 2001.

[129] Anthony I. Wasserman. Extending state transition diagrams for the specification of human–computer interaction. *IEEE transactions on Software Engineering*, (8):699–713, 1985.

[130] wikipedia. Business model canvas. , 2019. Accessed: 2019-10-29.

[131] wikipedia. Feasibility study. , 2019. Accessed: 2019-10-29.

[132] wikipedia. International diabetes federation. , 2019. Accessed: 2019-10-29.

[133] Wikipedia. “storyboard”. , 2019. Accessed: 2019-10-18.

[134] Sarah Wild, Gojka Roglic, Anders Green, Richard Sicree, and Hilary King. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes care*, 27(5):1047–1053, 2004.

[135] Howard A Wolpert, Astrid Atakov-Castillo, Stephanie A Smith, and Garry M Steil. Dietary fat acutely increases glucose concentrations and insulin requirements in patients with type 1 diabetes: implications for carbohydrate-based bolus dose calculation and intensive diabetes management. *Diabetes care*, 36(4):810–816, 2013.

[136] Ji-Won Yoon and Hee-Sook Jun. Autoimmune destruction of pancreatic β cells. *American journal of therapeutics*, 12(6):580–591, 2005.

[137] Gabe Zichermann and Christopher Cunningham. *Gamification by design: Implementing game mechanics in web and mobile apps.* " O’Reilly Media, Inc.", 2011.

[138] Paul Zimmet, KGMM Alberti, and Jonathan Shaw. Global and societal implications of the diabetes epidemic. *Nature*, 414(6865):782, 2001.