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Self-management and regular health monitoring of diabetic children base on Gamification and Artificial Intelligence

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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 [188].
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 [99].
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 [168][25].
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 [150].
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 [226].
Gamifying disease management can help children, adolescents, and adults with diabetes to better cope with their lifelong condition [46].
In this perspective, this Graduation Project will aim at highlighting main children diabetes self-management issues, reviewing state-of-the-art Diabetes and Gamification methods and heart failure, and proposing patient care and heart attack detection through the use of artificial intelligence (AI) algorithms, and gamification in a mHealth/e-health context.

Acknowledgments

I dedicate this work to my mother. Her spirit in times of struggle and hope for a better tomorrow, inspires me every day.
I would like to especially thank my supervisor, Prof.Ioannis Chatzigiannakis for this opportunity and for encouraging me to pursue my interests. I will be forever grateful for your guidance, support, optimism, and confidence in me.
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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 [80].
Many factors contribute to this widespread emergence of diabetes. These include population growth, urbanization, socioeconomic developments and the changes in lifestyle [238].
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 [160]. Diabetes affects the glucose level in the blood. Patients could suffer from hyperglycemia or/and hypoglycemia [142].
According to the latest IDF [176] 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 [237].
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 [210][139].
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 [30].
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 [77].
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 [167].
Therefore, the purpose of this research is to design and develop a mobile application that can help Child T1DM patients better manage their disease [160].
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 [149].
A user-centered design process was followed, with an emphasis on features involving data visualization, social communities, and game-based design (gamification) [160]. 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 [149].
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 [20].
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 [19].
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 [197].
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 [197].
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 [188].
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 [187].
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 [197][21].
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.
In Chapter 3 we discuss what games are, what's definition of a game and gamification and why gamification is so crucial for driving user behavior and present the MDA framework, which helps software architects design gamified solutions.

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 [103] (Figure .1.1).

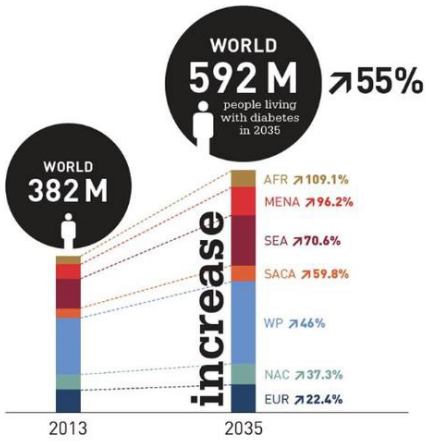

Figure 1.1. *IDF Diabetes projections [77]. Note that three quarters of people with diabetes live in low and middle income countries [167]. Legend: AFR; Africa. MENA: Middle East and North Africa. SEA: South-East Asia. SACA: South and Central America. WP: Western Pacific. NAC: North America and Caribbean. 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 [66].
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 [23].
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 [10].
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 [92]. 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 [46].

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 [46].
The majority of existing self-management tools are one-dimensional and focus on tracking diabetes-related measures, such as blood glucose readings [61]. They do not provide frequent, personalized, or actionable feedback on the impact of daily lifestyle behaviors on glycemic control or motivate positive behavior change [99].
Compared to traditional paper-based tools, mobile phones offer a unique opportunity to deliver highly personalized and dynamic behavioral interventions [111].
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 [111][61]. and consequently are not highly impactful in improving the overall health of the individual living with diabetes [99].

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 [178](Figure.1.2).

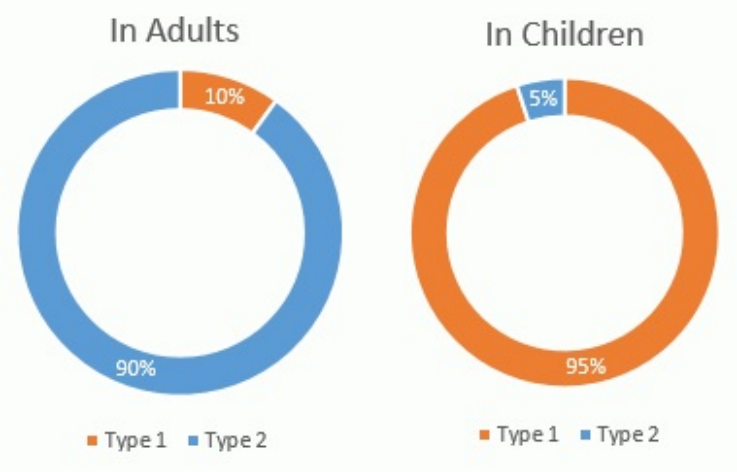

Figure 1.2. *Type 1 vs Type 2.*

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 [178].

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 [231].
The role of the individual affected by the chronic illness, previously understated, is central in the prevention, management, and maintenance of chronic disease [36].
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).

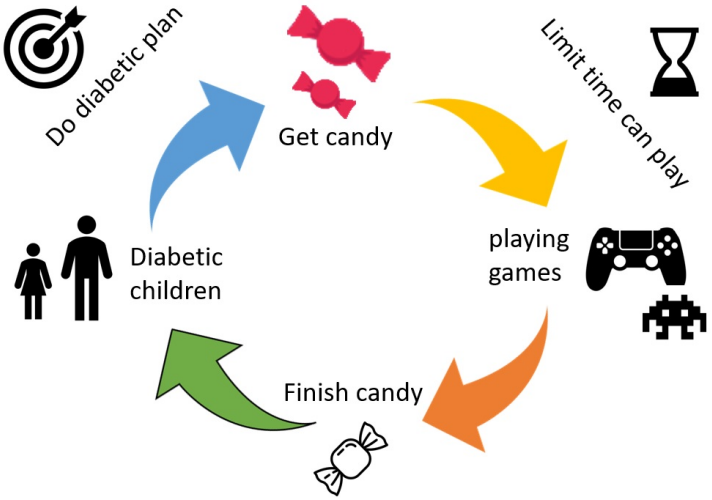

Figure 1.3. *Product overview and motivation.*

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 [36].
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 [223][102].
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 [46].
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 [90].

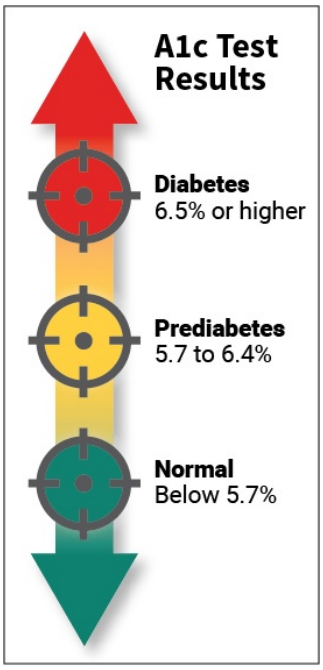

Figure 1.4. *The "gold standard" lab test for blood glucose control is called the Hemoglobin A1C. It's usually conducted in a clinic or hospital lab, although all that's really needed is one big drop of blood for an accurate test. It produces an average level of BG control over roughly the past three months, expressed as a percentage [155].*

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 [90].

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 [132].

mHealth applications thus serve an important role in better facilitating self-care[159]. A burgeoning feature of mHealth applications very recently being leveraged to improve self-management behaviors is gamification[159].
Gamification is defined as the implementation of the most common and enjoyable mechanics of video games, in non-video game contexts [69][81].
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 [248].
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 [40][1]., which suit each person according to how she interacts and reacts when playing a game [96].

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.[96]

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 [113].

1.2.1 The need for patient empowerment

Importance of lifestyle behavior
According to [177] and [179], 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?[105]

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 [177].

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 [49][95].

Empowerment scale
Empowerment efficiency is not easy to measure. However, [26] 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 [114].

Empowerment through gamification

The best way to empower a diabetic patient is a personal face-to-face coaching [177], 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. [105]

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 [52], 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 [107].

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 [102]. 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. [96]

Gamifying disease management can help children, adolescents, and adults with diabetes to better cope with their lifelong disease [159][38]. 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 [55][215]. 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[46].
Games can also be used to educate and train health care professionals about various aspects of diabetes [72].

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 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. [23]

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 [19].

There is evidence that heart rate variability [62] and insufficient sleep [209][212][182] are significantly related to/affect the blood glucose. Note that such variables could be tracked, in a non-invasive and unobtrusive way, by wearing sensors. As suggested such a device could be the Sense Wear, it has been shown that the approach of multisensor technology with integrated data analysis can provide satisfying estimates of plasma glucose concentration in diabetes [208], without necessitating continuous blood glucose measures.

This thesis had six 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 Gamification Method and Heart Failure.
3) to evaluate the effectiveness of self-management diabetes prototype through Expert-based evaluation techniques and User-based evaluation.
4) to Implement a self-management diabetes mobile app.
5) to heart rate monitoring for detect heart attack.
6) Comparison of Sleep Trackers and Heart rate monitors through used the comfort rating scales.

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 [105].
Diabetes is a metabolic disorder that results from different conditions [249]. 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 [30]. 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 [105].
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 [105].
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 [142].
Diabetes has two main types:

- insulin-dependent diabetes mellitus (IDDM), which is known as Type 1 diabetes [22].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 [203][44].

- noninsulin-dependent diabetes mellitus (NIDDM), which is known as Type 2 diabetes [22]. 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 [44][151].

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 [245][30].
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 [30]. Even though both types have different causes, they have very similar symptoms such as polyuria, polydipsia, weight loss, and blurred vision [22].
Given the numbers of diabetic patients in the world and its high prevalence, it has been called an "epidemic" by some papers [42] [22].

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 [23].

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 [30]. 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 [30]. 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 [144].

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

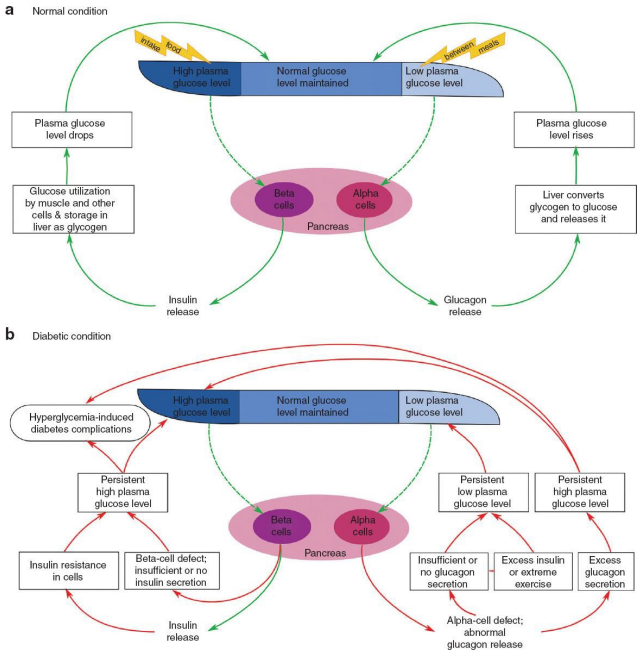

Figure 2.1. *General overview of the glucose homeostasis mechanism under normal and diabetic condition. Plasma glucose level is maintained within a narrow range through the combined antagonistic action of two pancreatic hormones: insulin and glucagon. (a) In normal individuals, high plasma glucose level 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) [18].*

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 [18]. 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 [164].

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 [68].

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 [105].
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 [93].
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 [200]. 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 [105].

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 [105].

This difficulty can be illustrated based on personal experience of Adam Brown [51], 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 [240].
   - **Protein** Though protein typically has little effect on blood glucose, a protein-only meal, in the absence of insulin, can raise blood glucose [206][91].
   - **Cafeine** Many studies have suggested that caffeine increases insulin resistance and stimulates the release of adrenaline [131].
   - **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 [122].

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 [15].

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 [193].
   - **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 [110].
   - **Insufficient sleep** Many studies have found that not getting enough sleep leads to worse diabetes control, insulin resistance, weight gain, and increased food intake [209][212][182]. 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 [33][29].
   - **A higher glucose level** Hyperglycemia can lead to a state known as "glucotoxicity," which can actually increase insulin resistance [126][230].
   - **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 [59].

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 [97].

   - **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 [97].

Self-management training has been acknowledged as a key component of the clinical treatment of diabetes since the 1930's [167]. Although many interventions have been developed and evaluated, there still exists a significant deficit of diabetes knowledge and skills amongst patients [167].
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 [112].
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 [183]. 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[183].
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 [55].

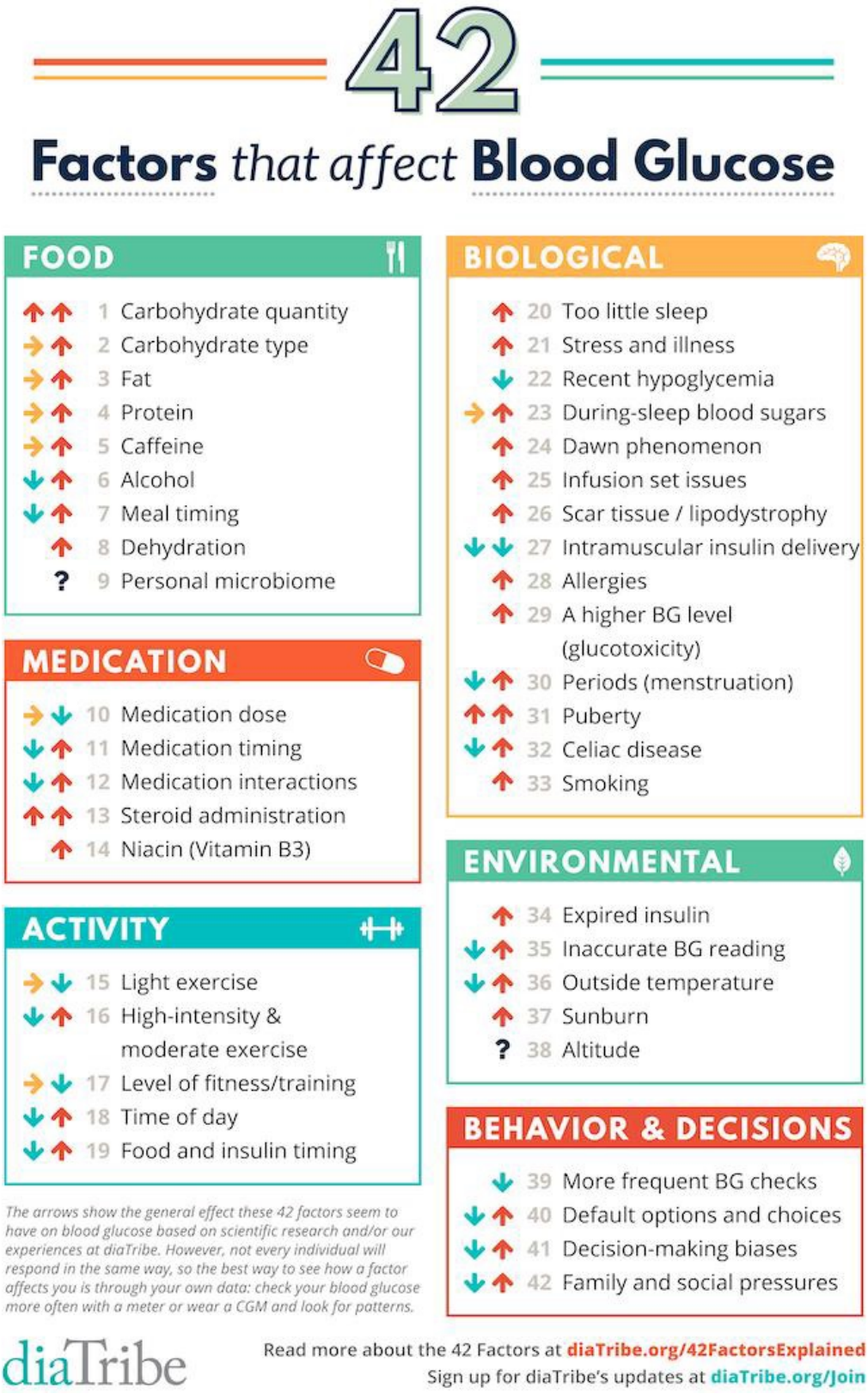

Figure 2.2. *42 Factors That Affect Blood Glucose [51].*

Chapter 3

Gamification

3.1 What is gamification?

Gamification is defined as the application of game-design elements in non-game contexts with the intention of modifying behaviors, increasing fidelity or motivating and engaging people, by leveraging human motivations present in games [71].
Thus, encouraging changes in behavior or motivating users to learn new skills. The concept of gamification is not new; it exists in many aspects of our lives. For instance, in school children are awarded a gold star for giving a correct answer or being good in class.
Nonetheless, it is an old topic in human-computer interaction. Actually, 'the attempts to derive heuristics for enjoyable interfaces from games reach back to the early 1980s' [71].
Gamification supports changes in behavior [71]. This makes it a powerful tool if used in the education and health fields. Moreover, there is a large volume of published studies that prove that intangible rewards give people subjective feelings of liking and pleasure [194].
To better understand what gamification is, it is first necessary to distinguish between play and game [37]. Play comes from the Greek word Paidia which means "child", and can be seen as a carefree, spontaneous act, which have no or a few rules. Game, on the other hand, comes from the Latin word ludus, which means playing attending standards and objectives. In addition, we also have to distinguish between serious games and gameful design [69].
Playing video games is a favorite leisure time activity of many people worldwide. Globally, nearly 667 million people play video games [154].
The serious games are intended to be more than entertainment, having a purpose, e.g., the digital game-based learning and the simulation games. The gameful design, in contrast, does not create a game, but uses parts of games to incorporate them into other contexts in order to encourage certain actions or behaviors. Hence, the concept of gamification refers to the gameful design of tasks in non-game contexts [96].
In addition, B. F. Skinner, the American psychologist, and behaviorist coined the term "operant conditioning"; this means the changes in behavior that result from reinforcement. In his experiment, he studied the behavior of a rat in what is known

as “Skinner’s box” [205].
Therefore, when applied in gamification, positive reinforcement can be used in terms of rewarding users for doing a certain task. [23]
Gamification aims to encourage people to engage with applications more than they would without applying these techniques. It engages users to start using applications more easily, leads them throughout the learning curve to mastery and autonomy. It also helps solving otherwise tough or uninteresting problems and makes the technology in general more appealing and easier to grasp [149].
Games for health and game-based approaches (gamification) can provide strategies to motivate patients in health promotion, prevention, or chronic disease self-management behaviors [150].
Integrating gamification features into health-based technology may prove to influence consumer’s health behavior [150].
A variety of techniques are used in gamification. Some of the popular video game techniques utilize achievement badges, levels, leader boards and progress bars [124]. Others also contain virtual currency, systems of awarding, redeeming, trading, gifting and exchanging points. Moreover, most video games have techniques used in apps and websites which create challenges against other players in order to shift users’ behavior. This is a key factor in the popularity of gamification. Furthermore, the challenge, fantasy and curiosity in video games are important [146].

3.2 The Gamification Trend

In recent years, gamification, which can be defined as the application of game-design elements and game principles in non-game contexts, has become a trending topic in many fields (see Figure.3.1). Among other examples, gamification attempts to improve user engagement, organizational productivity, education, communication or physical exercise [105].

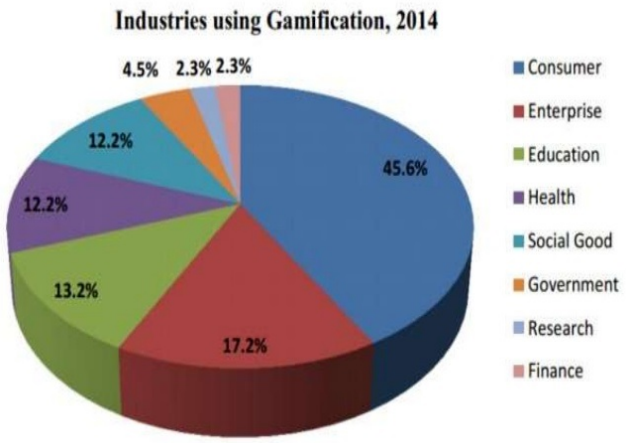

Figure 3.1. *In recent years, gamification has become attending topic in many fields. Key industries-suchas enterprise, healthcare and education are showing great promise [9].*

Gamification market is growing fast and is expected to worth approximately $5.5 billion in 2018 [137] (see Figure.3.2).

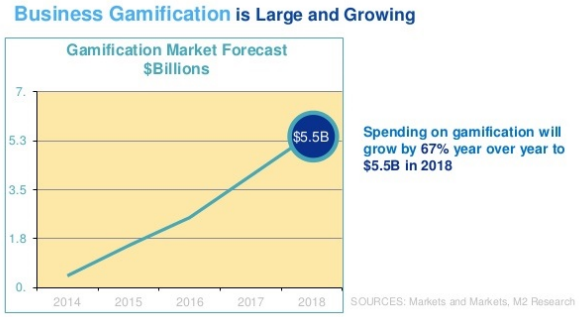

Figure 3.2. *Spending on gamification is expected to grow by 67% year over year and reach $5.5B in 2018 [35].*

Global gamification market will grow at a rate of over 30% during the forecast period 2019-2025 and will be valued more than $32 billion by 2025.The market for gamification is driven by the increasing number of mobile devices and internet penetration [241].
According to the gamification market analysis, North America accounted for the largest share of the global gamification market in 2018. With the presence of the highest number of technology innovators and increasing adoption of gamification to reorganize business operations, this region is expected to dominate the market during the forecast period. The Asia Pacific region is expected to witness the fastest growth rate due to the rise in the adoption of Bring Your Own Device (BYOD), especially among SMEs to enhance employee satisfaction and consumer retention [241].

3.3 Game design elements

The research paper [70] proposes a classification of the GDEs (Game design elements) into five different abstract levels:

1)Interface design patterns, such as badges, levels, or leaderboards.
2)Game design patterns: reoccurring interaction relevant to game play. An example is a well-known Paper rock scissors pattern, sometimes also referred to as triangularity.
3)Design principles or heuristics: guidelines for approaching a design problem.
4)Conceptual models of game design units, such as the MDA framework, Malone's challenge,fantasy, and curiosity, or the game design atoms described in Braithwaite and Schreiber .
5)Game design methods, including game design-specific practices such as playtesting and design processes like playcentric design or value conscious game design.

3.4 MDA framework

We decided to follow a proposal from Robin Hunicke and colleagues who propose usage of the so-called MDA (Mechanics, dynamics, aesthetics) framework [118].

This framework called MDA: A formal approach to game design and game research. The goal of this framework is to make it easier to understand and design translation of all aspects of the game design theory [149].
It helps to bridge the gap between the outcomes (which is an engaged user of an application) and the inputs, which as in every software application are the architecture and common patterns that software architects can use and work with [149]. Let us look at the MDA framework from the perspective of software development. One hand we have the set of requirements that specify the final behavior, components and constraints of the given system. This is how we, as software architects, envision the final product. On the other hand, there is the working product, which is essentially code that brings the whole system into reality. In the middle lies the process of executing that code and making the system working. We can look at games or software applications on a higher conceptual level through a similar prism [149]. Requirements become enjoyment, joy and engagement of the user. On the other hand, there are rules that set the whole application in motion. Aesthetics is the top layer, layer that the user interacts with and the way it makes him feel about the application.

MDA framework composed of three aspects, namely Mechanics, Dynamics, and Aesthetics [118] (see Figure.3.3):

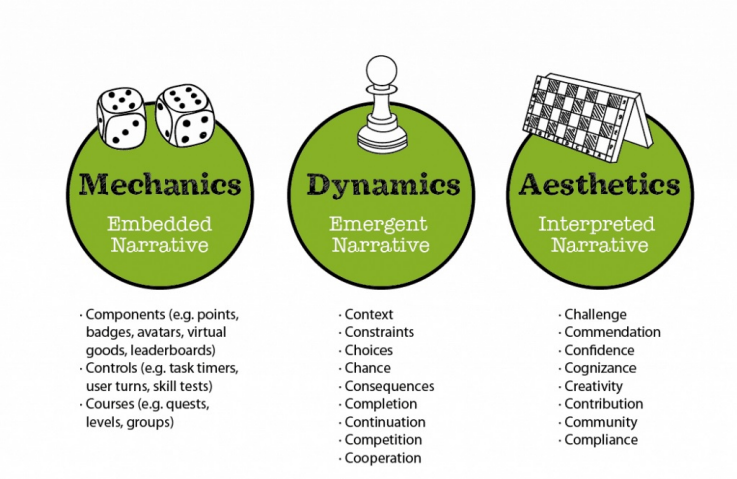

Figure 3.3. *The MDA Framework. This framework, which was originally used to describe games, "aims to explicate the connections between end-user motivations, interactive gameplay elements, and technology features and functions that constitute effective gamification interventions in the enterprise. . . .and (it) details the key success factors for enterprise gamification." [185].*

- **Mechanics:** describe the particular components of the game, at the level of data representation and algorithms. Mechanics are the various actions, behaviours and control mechanisms afforded to the player within a game context.Together with a game content (levels, assets and so on) the mechanics support overall gameplay dynamics.For example, the mechanics of shooters include weapons, ammunition and spawn points,which sometimes produce dynamics like camping and spinning. Adjusting the mechanics of a game helps us fine-tune the game's overall dynamics.
- **Dynamics:** work to create aesthetic experiences, and describe the run-time behaviour of the mechanics acting on one player's inputs and each other's outputs over time. For example:
  - o"Challenge is created by things like time pressure and opponent play."
  - o"Fellowship can be encouraged by sharing information among certain members of a session, or by supplying winning conditions that are more to achieve."
  - o"Expression comes from dynamics that encourage individual users to leave their marks: purchasing, building or earning game items,designing,constructing and changing levels or unique characters."
  - o"Dramatic tension comes from actions that encourage rising tension, a release,and a denouement."
- **Aesthetics:** describes the desirable emotional responses evoked in a player, when she interacts with the game system. Each game pursues multiple aesthetic goals, in varying degrees. For example:
  - o "Sensation. Game as sense-pleasure."
  - o "Fantasy. Game as make-believe."
  - o "Narrative. Game as drama."
  - o "Challenge. Game obstacle course."
  - o "Fellowship. Game as social framework."
  - o "Discovery. Game as uncharted territory."
  - o "Expression. Game as self-discovery."
  - o "Submission. Game as pastime."

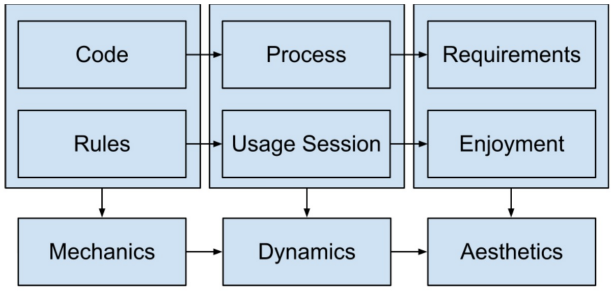

Figure 3.4. *Visual translation of different components of the MDA framework.*

the Figure.3.4 from the perspective of both the software architect and the user. It is far more crucial for us to think and deeply understand the software architect's point of view; where specific mechanics lead and engage certain dynamics that in the end

invoke required aesthetics.

3.5 Game Element Hierarchy

Although the prospect of a game designer is to create mechanics to develop dynamics and foster aesthetics, the user perceives the game in the opposite direction so the designer must consider both ways since any change in any of three levels of abstraction impacts on the other, and may change the end user experience. Another formal approach is the Game Element Hierarchy [234], shown in Figure .3.5. This Approach is not so general, and focuses specifically on three relevant categories in gamification: components, mechanics, and dynamics, which are arranged in descending order of abstraction. In this case, mechanics evoke one or more dynamics, and each component form several mechanics and/or evokes one or more dynamics [96].

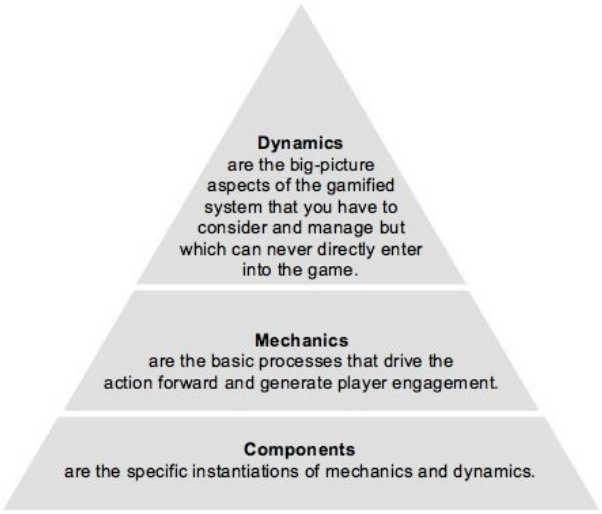

Figure 3.5. *The hierarchy of game elements (Werbach & Hunter, 2012) [63].*

Components are the most-specific forms that mechanics or dynamics can take. Each component ties to one or more higher-level elements. The fifteen important game components are achievements, avatars, badges, boss fights, collections, combat, content unlocking, gifting, leader boards, levels, points, quests, social graphs, teams, or virtual goods [96].
Mechanics are the basic processes that drive the action forward and generate player engagement. Each mechanic is a way of achieving one or more of the dynamics described. Ten important game mechanics are challenges, chance, competition, cooperation, feedback, resource acquisition, rewards, trading, turns, or win states [96].
Dynamics are the big-picture aspects of the gamified system that you have to consider and manage but which you can never directly enter into the game [96]. For example:

- "Constraints. Limitations or forced trade-offs."

- "Emotions. Curiosity, competitiveness, frustration, happiness."
- "Narrative. A consistent, ongoing storyline."
- "Progression. The player's growth and development."
- "Relationships. Social interactions generating feelings of camaraderie, status,altruism."

All of that is above and beyond the elements, all of that is certainly extremely important in games and often important in gamification. Putting all these things together is the central task of gamification design. It is necessary to use a design process to apply these elements that constitute games.
Game Element Hierarchy can be considered equivalent to the MDA as follows:

- The Components correspond to the mechanics of MDA framework.
- The Mechanics correspond to the dynamics of MDA framework.
- The Dynamics correspond to the aesthetics of MDAframework.

3.6 Player Type

Why do we care what types of users/players engage with our application? Given that each user has different motivations it is necessary to define user or player types to enclose their needs, desires and concerns. The player types have allowed the games to reach a larger number of people by adapting the preferences of each player. The challenge is to ascertain whether mechanics, dynamics and aesthetics that are assumed for each player type are correct and if they are well implemented in a particular domain [96]. So, it is crucial for every game designer or gamification specialist to know their users or more specifically different types of users [149]. One of the most widely accepted categorizations is that proposed by Richard Bartle [41], one of the first who studied the multiplayer online video games, which are capable of supporting large numbers of players simultaneously.

Figure 3.6. *Bartle's Player Types (Bartle, 1996).*

In the Bartle's model four main player types are defined in terms of two dimensions, expressed in two coordinate axes as shown in Figure 3.6. The first dimension – the horizontal axis– indicates whether a player is more interested in other players (left) or in the virtual world around her (right), while the second dimension –the vertical axis– indicates if the interest is focused on acting (up) or interacting (below). He studied MMOG (Massively multiplayer online game) players, particularly players who played MUDs (Multi-user dungeon games), and identified four specific types:

- **The achievers** are interested in acting on the environment in which they dominate the features it provides and tend to be goal oriented. They like to achieve goals and feel particularly frustrated if they fail to do so. Moreover,they seem to lose their interest in playing the game that they do not win."Achievers are proud of their formal status in the game built-in level hierarchy,and of how short a time they took to reach it."
- **The explorers** are interested in interacting with the environment, exploring all the existing targets, and experiment with them later on. Explorers are always seeking new things, adventures, secrets. "Explorers are proud of their knowledge of the game's finer points, especially if new players treat them as founts of all knowledge."
- **The socializers** are interested in interacting with other players, encouraging their social relationships. "Socializers are proud of their friendships, their contacts and their influence."
- **The killers** are interested in strengthening its superiority over other players acting with their consent or without it, regardless they harm the later. "Killers are proud of their reputation and of their oft-practiced fighting skills."

It is more common that we are all a combination of all of them, just with different distributions. Therefore, Nick Yee, a researcher of self-representation and social interaction in virtual environments, has conducted a thorough research [243] on MMORPG (Massively multiplayer online role-playing game) players. It resulted in an updated model of Bartle's model with three main components and ten subcomponents:

- achievement: advancement, mechanics, competition
- social: socialising, relationship, teamwork
- immersion: discovery, role-playing, customization, escapism.

3.7 What can we learn from games?

what makes the games so fun and can we, as system architects, learn anything from them?" Fun is all about our brains feeling good - the release of endorphins into our system." That is how Raph Koster put it in his book A Theory of Fun [130]. But what makes the brain feel good? Research that Raph Koster uses tells that the brain constantly needs motivation to do something. It is on a constant search for achievement, for a moment in time, when we learn something or master a certain task. This is where the fun comes from in the games. Our brain is constantly trying to find the right pattern to solve the mystery or the task and when it finally finds

it has a small moment of satisfaction. But soon afterwards the brain needs a new challenge and that is also the reason why some games become boring so quickly – we master the pattern and if the game is not challenging us into finding a new one, it becomes tiresome and repetitive.
So, if games are teachers of patterns and if we like to play or learn them when we are having fun in a fair and not boring way, then subsequently this means that the more fun and engaging the experience is, the more we learn. If we can apply techniques from great games to software applications, they can become fun to use: in other words, users will stay longer and have more fun using them [149].

3.8 Psychology of motivation

What is engagement really, and why is it so significant and important in our case? Engagement signifies a special connection between the user and product, service, or software application [149]. The psychology of motivation is related with the aesthetics of the MDA framework, human brains need constant stimulus for it to stay engaged and have fun. Fun is when we are trying hard and staying immersed in the experience. And to achieve this constant fun, the user needs constant gratification and for that games for example use a technique called reward schedule. Reward schedule, as the name refers, aims to deliver rewards and new challenges just at the optimal time [96]. Why are people so motivated to play games? Why do they keep coming back to them?
According to the Self-Determination Theory (SDT) [75], We distinguish two core motivations: those that arise from within users or intrinsic motivation and those that are triggered by some external mechanics and are called external motivators. we can distinguish between extrinsic and intrinsic motivations based on the different reasons or goals that give rise to an action.

Extrinsic motivation
Extrinsic motivation refers to the type of individual motivation that comes from favoring the outcome of a successfully completed task, as opposed to just completing a task for the pleasure of doing it. What do the game designers do in this kind of cases to make the experience lasts longer? They motivate players by giving them time limited tasks and throw more and more obstacles on the road (e.g. chasing police cars). An extrinsic motivation comes from an activity aimed to achieve a result derived from completing a task, e.g., studying a subject to pass a course or to gain some knowledge, but not for the fact of finding it interesting [149].

Intrinsic motivation
Intrinsic motivation is driven by interest or enjoyment that derives from doing a task itself. It comes from within an individual rather than relying on some external triggers. It heavily relies on taking pleasure in the activity itself.
An intrinsic motivation, in contrast, comes from an activity performed for the satisfaction of doing it. The SDT states that intrinsic motivations can be divided into three categories [96]:

- Relatedness. Meeting the human social needs; feeling part of a group with

which one is identified and belongs to.

- Autonomy. Satisfying the desire of each individual to be independent, innovating and creating, encouraging the sense of freedom and personal development.
- Mastery/Competence. Satisfying the desire to surpass oneself and others up to the maximum level of perfection, increasing one or more skills as the challenges become more complicated.

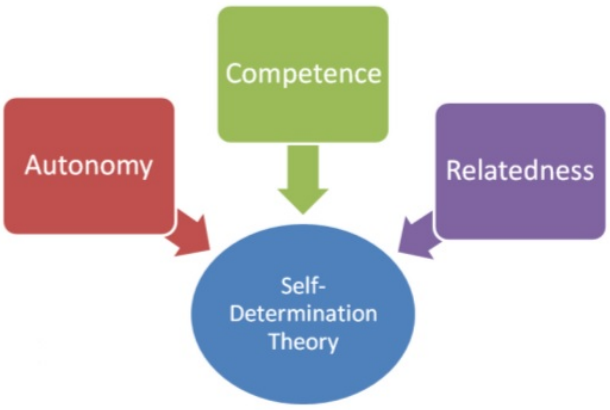

Figure 3.7. *three elements of self-determination theory [75].*

What is the best kind of motivation?
There is a popular belief that intrinsic motivation is somewhat better than extrinsic, and it creates more value. Game designers would love it if all players would be intrinsically motivated to play in their "sandboxed" worlds. It would be easier to create this kind of environments.
But they, as game designers, and us, as information architects, cannot rely solely on the user's inner needs to engage with our product. With extrinsic motivators, we can more surely predict users actions and drive their activity in a processed manner. The greatest thing about it is: if we use game mechanics in a systematic and smart way, they dissolve in the experience and users might even perceive them as intrinsic [149].

3.9 Kind of fun

The 4 Keys 2 Fun model designed by Nicole Lazzaro [134], [46], describes four types of fun.
Each of the four types of fun unlock different types of player experiences. Nicole Lazzaro states that games that use emotions from four types of interactions are more likely to capture attention and motivate play [171].

- People Fun. "Provides the excuse to hang out with friends." Actions like communicate, cooperate or compete, arouse emotions like amusement ,admiration, social bounding, or friendship.

- Easy Fun. "Inspires exploration and role play." Actions like exploration, fantasy, or creativity, arouse emotions like curiosity, surprise, wonder, or
  awe.
- Hard Fun. "Provides the opportunity for challenge, mastery, and feelings of accomplishment." Actions like goals, obstacles, or strategy, arouse emotions like frustration, pried, or relief.
- Serious Fun. "Purposeful play changes how players think, feel, behave, or make a difference in the real world." Actions like repetition, rhythm, or collection, arouse emotions like excitement, zen focus, or relaxation.

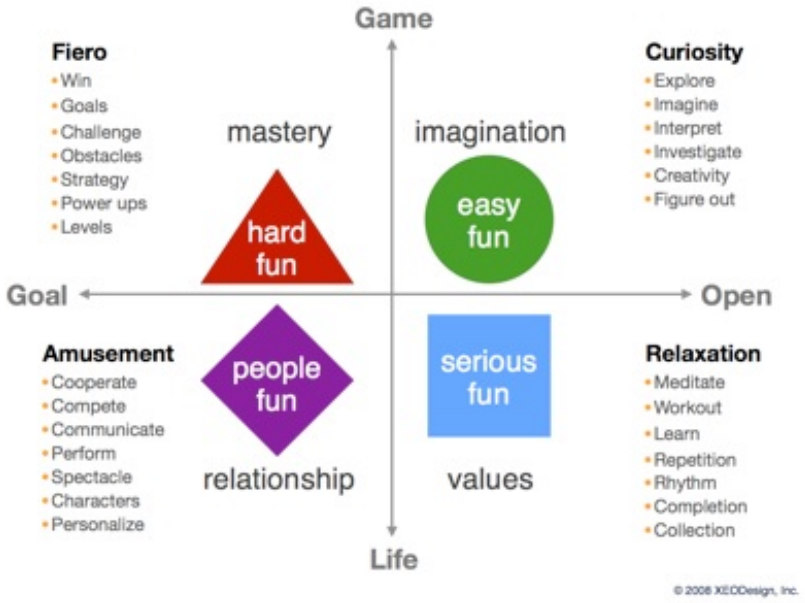

Figure 3.8. *Nicole Lazzaro's 4 Kinds of Fun [171].*

3.10 Mechanics

There are many game mechanics and we have been identified. One of the most complete collections is the one given by Andrzej Marczewski, which considers 52 gamification elements [147]. we summarize the mechanics assigned to each of the intrinsically motivated player types.
The list of various elements and mechanics that support different User Types and contexts and can enhance your gamification designs.
For the General Player type:

- **On-boarding / Tutorials.** "No one uses manuals anymore! Help people get used to your system with a nice tutorial or a gentle introduction on how everything works."
- **Signposting.** "Sometimes, even the best people need to be pointed in the right direction. Signpost next actions to help smooth early stages of a

journey.
Use "just in time" cues to help users who are stuck."

- **Loss Aversion.** "No one likes to lose things. Fear of losing status, friends, points, achievements, possessions, progress etc can be a powerful reason for people to do things."
- **Progress / Feedback.** "Progress and feedback come in many forms and have many mechanics available. All User Types need some sort of measure of progress or feedback, but some types work better than others."
- **Theme.** "Give your gamification a theme, often linked with narrative. Can e anything from company values to werewolves. Add a little fantasy, just make sure users can make sense of it."
- **Narrative / Story.** "Tell your story and let people tell theirs. Use gamification to strengthen understanding of your story by involving people. Think like a writer!"
- **Curiosity/ Mystery Box.** "Curiosity is a strong force.Not everything has to be fully explained, a little mystery may encourage people in new directions."
- **Time Pressure.** "Reducing the amount of time people have to do things can focus them on the problem. It can also lead to different decisions."
- **Scarcity.** "Making something rare can make it all the more desirable."
- **Strategy.** "Make people think about what they are doing, why they are doing it and how it might affect the outcomes of the game."
- **Flow.** "Getting the perceived levels of challenge and skill just right can lead to a state of Flow. Balance is the key."
- **Consequences.** "If the user gets things wrong, what are the consequences? Do they lose a life, points or items they have earned?"
- **Investment.** "When people invest time, effort, emotions or money, they will value the outcomes all the more."

For the Schedules player type:

- **Random Rewards.** "Surprise and delight people with unexpected rewards. Keep them on their toes and maybe even make them smile."
- **Fixed Reward Schedule.** "Reward people based on defined actions and events. First activity, level up, progression. Useful during on-boarding and to celebrate milestone events."
- **Time Dependent Rewards.** "Events that happen at specific times (birthdays etc.) or are only available for set period of time (e.g. come back each day for a reward). Users have to be there to benefit."

For the socializer player type:

- **Guild/Team.** "Let people build close-knit guilds or teams.Small groups can be much more effective than large sprawling ones.Create platforms for collaboration but also pave the way for team based competitions."
- **Social Networking.** "Allow people to connect and be social with an easy

to use and accessible social network. It is can be more fun to play with other people than to play on your own."

- **Social Status.** "Status can lead to greater visibility for people, creating opportunities to create new relationships. It can also feel good.You can make use of feedback mechanics such as leader boards and certificates."
- **Social Discovery.** "A way to find people and be found is an essential to building new relationships. Matching people based on interests and status can all help get people started."
- **Social Pressure.** "People often do not like feeling they are the odd one out. In a social environment this can be used to encourage people to be like their friends. Can demotivate if expectations are unrealistic."
- **Competition.** "Competition gives people a chance to prove themselves against others. It can be a way to win rewards, but can also be a place where new friendships and relationships are born."

For the free **spirit player type**:

- **Exploration.** "Give your Free Spirits room to move and explore.If you are creating virtual worlds, consider that they will want to find the boundaries and give them something to find."
- **Branching Choices.** "Let the user choose their path and destiny. From multiple learning paths to responsive narratives. Remember, choice has to be or at least feel meaningful to be most effective and appreciated."
- **Easter Eggs.** "Easter eggs are a fun way to reward and surprise peopl for just having a look around."
- **Unlockable/Rare Content.** "Add to the feeling of self-expression and value, by offering unlockable or rare content for free spirits to make use of. Link to Easter eggs and exploration as well as achievement."
- **Creativity Tool.** "Allow people to create their own content and express themselves. This may be for personal gain, for pleasure or to help other people (teaching materials, levels, gear, FAQ, etc)."
- **Customization.** "Give people the tools to customize their experience. From avatars to the environment, let them express themselves and choose how they will present themselves to others."

For the **achiever player type**:

- **Challenge.** "Challenges help keep people interested, testing their knowledge and allowing them to apply it. Overcoming challenges will make people feel they have earned their achievement."
- **Certificate.** "Different from general rewards and trophies, certificates are a physical symbol of mastery and achievement. They carry meaning, status and are useful."
- **Learning/New Skill.** "What better way to achieve mastery than to learn something new? Give your users the opportunity to learn and expand."
- **Quests.** "Quests give users a fixed goal to achieve. Often made up

from a series of linked challenges, multiplying the feeling of achievement."

- **Level/Progression.** "Levels and goals help to map a users progression through a system. It can be as important to see where you can go next as it is to see where you have been."
- **Boss Battle.** "Boss battles are a chance to consolidate everything you have learned and mastered in one epic challenge. Usually signals the end of the journey – and the beginning of a new one.

For the **philanthropist player type**:

- **Meaning/Purpose.** "Some just need to understand the meaning or the purpose of what they are doing (epic or otherwise). For others they need to feel they are part of something greater than themselves."
- **Care-taking.** "Looking after other people can be very fulfilling. Create roles for administrators, moderators, curators etc. Allow users to take a parental role."
- **Access.** "Access to more features and abilities in a system can give people more ways to help others and to contribute. It also helps make them feel valued.More meaningful if earned."
- **Collect & Trade.** "Many people love to collect things.Give them a way to collect and trade items in your system. Helps build relationships and feelings of purpose and value."
- **Gifting/Sharing.** "Allow gifting or sharing of items to other people to help them achieve their goals. Whilst a form of altruism, the potential for reciprocity can a strong motivator."
- **Sharing Knowledge.** "For some, helping other people by sharing knowledge with them is its own reward. Build the in the ability for people to answer questions and teach others.

For the **Disruptor player type**:

- **Innovation Platform.** "Disruptors think outside the box and boundaries of your system. Give them a way to channel that and you can generate great innovations."
- **Voting / Voice.** "Give people a voice and let them know that it is being heard. Change is much easier if everyone is on the same page."
- **Development Tools.** "Think modifications rather than hacking and breaking. Let them develop new add-ons to improve and build on the system."
- **Anonymity.** "If you want to encourage total freedom and lack of inhibitions, allow your users to remain anonymous. Be very, very careful as anonymity can bring out the worst in people!"
- **Light Touch.** "Whilst you must have rules, if you are encouraging disruption, apply them with a light touch. See how things play out before jumping in. Keep a watchful eye and listen to the feedback of users."
- **Anarchy.** "Sometimes you just have to burn it all to the ground and start again. Sit back, throw the rule book out of the window and see what happens! Consider running short "no rules" event."

For the **Player type**:

- **Points / Experience Points (XP).** "Points and XP are feedback mechanics. Can track progress, as well as be used as a way to unlock new things. Award based on achievement or desired behaviour."
- **Physical Rewards / Prizes.** "Physical rewards and prizes can promote lots of activity and when used well, can create engagement. Be careful of promoting quantity over quality."
- **Leaderboards / Ladders.** "Leaderboards come in different flavours, most commonly relative or absolute. Commonly used to show people how they compare to others and so others can see them. Not for everyone."
- **Badges / Achievements.** "Badges and achievements are a form of feedback. Award them to people for accomplishments.Use them wisely and in a meaningful way to make them more appreciated."
- **Virtual Economy.** "Create a virtual economy and allow people to spend their virtual currency on real or virtual goods. Look into the legalities of this type of system and consider the long term financial costs!"
- **Lottery / Game of Chance.** "Lotteries and games of chance are a way to win rewards with very little effort from the user. You have to be in it, to win it though!"

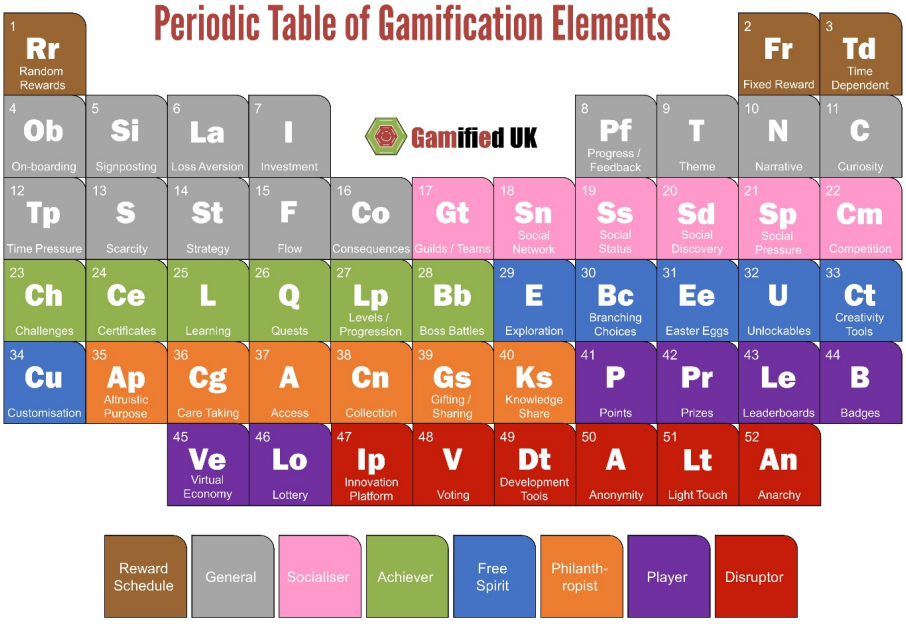

Figure 3.9. *Andrzej Marczewski, 52 gamification elements [147].*

As we said before, mechanics in the gamified system, are functioning components. As Gabe Zichermann and Christopher Cunningham state in their book Gamification

by Design [248], components, when used correctly, "promise to yield a meaningful response (aesthetics) from the players". Mechanics should always be chosen for the specific experience if they are to result in the appropriate aesthetics.
They provide the design strategy and tactics you need to integrate game mechanics into any kind of consumer-facing website or mobile app. So, let us look at some of the most suitable and often used mechanics when designing gamified software applications [149].

Point systems:

We have all experienced point systems before as they form the basis of a lot of video games.
Points and levels are implemented to inform the user of their level of familiarity, and reward continued expertise and knowledge using the system [248].
They have proven to be an extremely powerful motivator. Just look at the sports for example. Most of them are based on some kind of point system. Points, however, may sound terribly boring and not compelling at all for a gamified system today.
Nonetheless, they are still crucial when designing a gamified system; even if we do not expose them directly to users, it is extremely important to have a simple experience point system in place (even if it is just in the back-end of our application). It logs down every interaction with the system and tells valuable information about the usage – that way we can then go back and tweak the system and make it better or more engaging. The other vital part of every point system is always assigning the right points value for specific tasks. Point values for a given task are not really important, but become really important when the system has a set of different tasks with different associated point values.
This metaphor for user experience is important to driving social user engagement, as new and potential users are more likely to engage with more experienced users, as evidenced through their point and level values [67]. This forms a hierarchy between them and signals the importance of a specific task in relation to others. It is super hard to get this relations right in the first try and that is where observing the system and subsequent tweaking come into play.
In addition, point should be appropriate to the goals of the application. For example, mHealth users should not be rewarded for poor behavior or failing to meet objectives as they are defined by the application. A dashboard should provide a summary of all badges obtained [159].
We have identified three most crucial types of points that should be considered when building a gamified application:

- experience point system. Experience (XP) point system Most basic point system, It can not be maxed out (it is limitless), and it can not be used to "purchase" or redeem anything: its sole purpose is to measure a specific metric or a set of actions. They mainly serve to show-off and attract the achiever type of users. However, it can be reset on a regular basis to attract users to engage more often and constantly chase new points.
- Karma point system. This is a pretty unique system, that does not find its way too often into video games. On the contrary, it can be (and it has

already proven to be) powerful system in non-gaming gamified context. How does it work? Users are rewarded by the system for accomplishing specific tasks, which is no different from any other point system. But instead of "spending" points for some other virtual objects they can award other users with the points they have earned.

- Redeemable point system. This is a hugely popular point system that we interact with almost on a daily basis. Real life examples are frequent flyer points or loyalty shopping points. All those points are earned for finishing specific tasks within the system and can at certain thresholds be exchanged for another item. Therefore they form a virtual economy, which means that the application architect may be constrained in the implementation, because of certain legal and regulatory issues.

Onboarding

Onboarding is the process of user's first experience with the system and the way the gamified application leads users to accomplish specific tasks to get to know the system. It can sometimes also be referred to as the application signup process or sign-up flow. This process is becoming immensely crucial for all new web and mobile applications as users are bombarded with hundreds of new services and do not have much time to study every new application.
It has proven that it is way more valuable to hide the complexity of the service and then slowly reveal all the possibilities when user goes down the onboarding funnel and becomes an active user. Moreover, it is particularly crucial not to make user fail and give him very quick positive feedback on every action.

Levels

Traditional levels that most of us know from video games are not quite possible and viable solution for gamified experiences. There are a few elements that we can take from the knowledge base of levels: progress bars, for example. We have learnt how valuable positive feedback is to users and how tempting it is to fill up half accomplished tasks. That is why progress bars that we see in essentially every software application should be utilized to drive user behavior.

Leaderboards

Leaderboards are designed to present the user's score (for example his overall experience points) against other users and to make clear visual comparisons from it.
Leaderboards dynamically rank individual user progress and achievements as compared to their peers. Leaderboards can represent to a user their position relative to others, providing them a sense of how well they are using the application as compared to their peers [244].
In a gamified application, they mostly serve the purpose of incentivizing the user; showing his position always in the middle no matter where on the social leaderboard he stands.
We also mentioned social – that is because usually this kind of leaderboards show the player against his peers (especially now when social context is becoming ubiquitous). Thus, the player always knows where he stands, what he has to accomplish to climb up (the steps should be obvious), and that there are also people that are performing

worse.

Achievements
Achievements stand for visually representing a task or a group of tasks. The power of clear visual achievements has been well known for a while: just think about military and boy scouts badges. They are easily identifiable on uniforms and achievers take pride in wearing and showing them off. In the last years, the achievement badges have become widely popular in the gamification scene, especially after the global success of Foursquare, which was one of the first mobile applications to use them in an appealing and highly effective way. The achievements are colorful and engaging with different images on each achievement, and there are a sufficient number of badges available to incentivize continued use in motivating the user to attempt to earn them all [159].

Customization
Customization of the application experience is a pretty old and widely used mechanic that we have all encountered and probably even see and use every day. It is basically allowing and enabling the user to change and modify some parts of the experience, usually visual representation of his online presence within the context of the given application. Examples include customizable avatars, skinning of the experience.
These kind of techniques have proven to be really successful in keeping users excited, more engaged and giving them a chance to show off their creativity, personality and commitment to the application.

Challenges
Challenges or quests from games are powerful drivers of behavior. Users or players crave to be led and to know what to accomplish or do next, and this kind of mechanics are widely present in games.
Challenges and quests may keep users motivated to continue using to continue using an application, especially where these challenges validate their understanding of the goals of the application [248].
Through continued challenges and quests, users may be motivated to continue using a system or application, especially where these challenges validate their understanding of the goals of the application [248].
When thinking about software applications, it is sometimes hard to think about challenges – they are not as obvious as in games. Recently challenges, or just user behavior changing tasks, have become widely used as a part of the onboarding process where software architects strive to lead users through a few most crucial steps.
Challenges and quests are effective methods to drive other gamification mechanics. For example, they can be nested within badges, assigned point values for a leveling system, or quantified to sort users on a leaderboard [105].
Challenges and quests are effective methods to drive other gamification mechanics [248].

Social engagement loop
We have all heard the term viral loop and it is one of the most studied and funda-

mental concepts in modern software applications. Its quality and whether it is a part of the core experience in many cases determines the success of modern social applications.
By enabling data and information sharing between patients, the integration of social media platforms, such as Facebook and Twitter, have the capacity to motivate continued user compliance [138][53].
It is crucial nowadays for the application designer not only to think about how user uses the core functionalities of the system, but also what brings him back, how he interacts with other users and what motivates him to engage with the application in the long-term.
Thus, there are four parts to the social engagement loop process as described by Zicherman and Cunningham (2011) that have to be present (and of course effective) to complete the social engagement loop [150]:

- motivating emotion
- (e.g., a Twitter user posting a message),
- social call to action
- (e.g., a Twitter user mentioning another user's tweet, resulting in user re-engaging with the system)
- player re-engagement
- (e.g., further tweets or comments),
- visible progress/reward.
- (e.g., number of Twitter followers)

Social engagement loops are sophisticated mechanics and cannot be effectively easily added to an existing product. Rather, they have to be present in the core of the product itself. Social engagement loop also embodies some of the other more simple mechanics, such as onboarding, leaderboards, leveling, customization etc.
Implementing social media interface facilitates social engagement loops in two notable ways. First, users may wish to share personal data and achievements from their application so as to build social capital with other peers using the same application, as well as to garner support from these peers [135]. Furthermore, these loops mediate onboarding, whereby new users are brought into the system via invites from existing users, with new users being further compelled by other implemented gamification mechanics and the inherent benefits they gain by using social media. In turn, these new users may invite peers from their respective social networks to join and participate, thus perpetuating this social engagement loop [248].

3.11 Dynamics

Dynamics describe the run-time behavior of the mechanics acting on user's inputs and each other's outputs over time. We could, therefore, say that they form a feedback loop between game mechanics and the user and form the actual art of playing or using in our case. Here are some of the dynamics that may take place during a user session [149]:

- Pacing: pacing of user progression.
- Appointments: rewards for using the system in a specified time frame.
- Progressive unlocks: serendipitous, unexpected unlocks of achievement.
- Rewards schedules: specific schedules of rewarding the user.
- Dynamic systems: dynamic adjustment of the events based on player's usage characteristics.
- Peer pressure: individual user within a group of other users striving toward a common goal is more motivated as he knows that other users depend on him achieving the goals.

3.12 Aesthetics

Aesthetics of the system represent how the game or a gamified experience makes the user feel during the interaction with the given software application.
Game aesthetics can be viewed as the composite outcome of the mechanics and dynamics as they interact with and create emotions. To boil it down to the simplest form – it is everything that makes an experience using the software application "fun" or engaging. Software architects, implementing gamification techniques, try to invoke several emotional states by Hunicke [118]. Although these emotional states derive directly from game design, they can be useful when planning gamified systems:

- Sensation: game as sense pleasure.
- Fantasy: game as make-believe.
- Narrative: game as drama.
- Challenge: game as obstacle course.
- Fellowship: game as social framework.
- Discovery: game as uncharted territory.
- Expression: game as self-discovery.
- Submission: game as pastime.

The above list of aesthetics is sometimes also referred to as eight kinds of fun. Although it is worth noting that these models do not capture all of the positive human emotions, which researchers have discovered lately by observing players.
This is an extremely interesting topic for every software architect as more and more design approaches now start from the user's perspective. This is why we should know as much as possible about the motivations behind why people engage with applications.

One of the most intriguing researches in this field was done by Nicole Lazzaro, a researcher in the field of player experience design. She did an extensive observation and consecutive analysis [134], [133], on what motivates players to play and engage in games. She found out there are four main keys to why people enjoy playing games that might be helpful when designing gamified software applications:

- Hard fun: players were particularly engaged in overcoming a structured

problem/challenge.
- Easy fun: players enjoyed intrigue and curiosity while discovering and exploring the game.
- Altered states: players enjoyed games that made them feel better or less bored.
- The people factor: players expressed different emotions while playing within a group or competing against each other.

We can see many similarities between these four keys from Lazzaro's research and the above mentioned eight aesthetics by Hunicke.
Let us try and see how we can connect each one of the keys with the related aesthetics and see if eventually researches can merge these relations into knowledge that we can use further:

- Hard fun: challenge
- Easy fun: sensation, narrative, discovery
- Altered states: expression, submission
- The people factor: fellowship.

3.13 What gamification is not?

Firstly, it tries to distinguish between game and play. It says, "games are characterized by rules, and competition or strife towards specified, discrete outcomes or goals by human participants." On the other hand, it defines play as "a free activity standing quite consciously outside ordinary life as being not serious but at the same time absorbing the player intensely and utterly." [149]
As discussed by Kapp [124]:

- Gamification is not only using game mechanics as badges, points, or rewards. The gamification is not simply applying these game-design elements in any system. These elements may lose interest quickly for users if their use does not really pursuit the achievement of certain dynamics and aesthetics.Hence, for example, gamification has to be a serious approach to accelerate the experience and knowledge curve of students in an e-learning tool, and the engagement and loyalty curve of customers in an e-commerce site.
- Gamification is not perfect for every situation and domain. One has to first consider or assess whether the game-design elements to be incorporated into a system are needed, and if they provide desired results. If such items do not contribute to the user experience, by increasing their motivation and fun,they will quickly become trivialized and non-relevant.

Gabe Zichermann, a gamification expert, responded saying that "gamification is here to stay (and it is not bullshit)." [247]
"We must recognize that the fundamental purpose of all organizations is to create as much value as possible. This value may be measured in assets or lives saved, children made healthier or kilos of trash diverted from landfill." For example, "in

Nike+18, players are provided with clearly disclosed encouragement to improve their physical fitness using a gamified system. And while Nike would like for you to buy more shoes, they do not trick you into doing so by any other method than wearing them out from exercise." "The question is really more subtle – hinging on issues of truth, disclosure and self-determination rather than who designed the product and what it is advocating." "Gamification is helping real people with real issues – promoting fitness, reducing waste and helping improve education are only the start."

3.14 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 [60].

3.15 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 [60].
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 [166]." 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 [60].
According to the article, "What is beautiful is useful", Tractinsky [220] 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 4

Heart Failure

Introduction Good diabetes management has been shown to reduce the risk of complications [211]. But when diabetes is not well managed, it is associated with serious complications including heart disease, stroke, blindness, kidney disease, nerve damage and amputations leading to disability and premature mortality.
There is also a substantial financial cost to diabetes care as well as costs to the lives of people with diabetes [227].
Cardiovascular Disease (CVD) risk factors are more common in children with T1DM than in the general pediatric population [54].
Populationbased studies estimate that 14% to 45% of children with T1DM have greater than 2 CVD risk factors [186][195].
Moreover, insulin resistance and undiagnosed glucose abnormalities are common in heart failure patients [28][78].
Diabetes mellitus and heart failure are two multifaceted entities characterised by high morbidity and mortality. Early epidemiological and prospective studies have observed the frequent co-existence of both conditions. Importantly, diabetes mellitus can precipitate or worsen heart failure due to the accumulation of advanced glycation end products, oxidative stress, inflammatory status impairment, decay of intracellular calcium, changes in microRNAs expression, not to mention atherosclerosis progression and coronary artery disease. Heart failure also impairs glucose metabolism through less well-known mechanisms [219].
Some severe diseases and disorders e.g. heart failure needs close and continual monitoring procedure after diagnosis, in order to prevent mortality or further damage as secondary to the mentioned diseases or disorders. Monitoring these types of patients, usually, occur at hospitals or healthcare centers. Heart arrhythmias for instance, in many cases, need continual long-term monitoring. However, the patients are often too early released, owing to need of hospital bed for another patient on the waiting list, who needs to be hospitalized immediately [34].
Poor diet is also a modifiable risk factor that can have an impact on cardiovascular health. Research has shown high cholesterol high blood pressure, and obesity can lead to a decrease in cardiovascular health [127].
Likewise, high cholesterol, high blood pressure and obesity are also strongly correlated to dietary habits [145]. Due to the correlation between poor diet and cardiovascular health, it is important to consider on-duty and off-duty dietary intake with regards

to CVD risk [127].

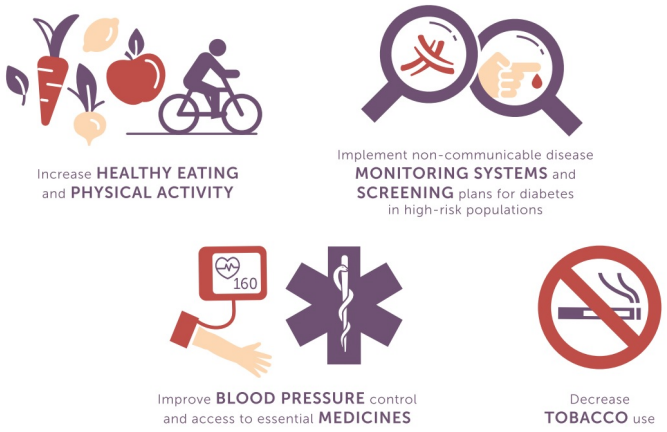

Figure 4.1. *Strategies to decrease the impact of Diabetes and Cardiovascular Diseases [82].*

Despite the emphasis by clinicians in the prompt control of DM several cardiovascular diseases such as hypertension, coronary heart disease, stroke, peripheral vascular disease, etc., have been linked to impaired glucose management [213].
Heart Failure (HF) is a clinical syndrome that is caused by structural or functional impairment of ventricular filling or ejection of blood. HF is known as the main cause of morbidity and mortality in North America [242]. Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve patient's health status. Telemedicine is a newest technology which combining telecommunication and information technology for medical purposes [207]. It gives a new way to deliver health care services when the distance between the doctor and patient is significantly away. Rural area will get the benefit from this application. Patient monitoring is one of the telemedicine, which always needs improvement to make it better. It is vital to care in operating and emergency rooms, intensive care and critical care units. It is also important for respiratory therapy, recovery rooms, out-patient care, radiology, ambulatory, home and sleep screening applications [34].
Currently heart rate measurement and monitoring is being performed in clinical setting. However, Wireless Body Area Networks (WBANs) facilitate unobtrusive ambulatory health monitoring for extended periods of time while providing real-time feedback to the user and healthcare personnel [125]. The recent advancements in sensors, low-power integrated circuits, and wireless communications technologies led to the design of low-cost, miniature, lightweight, intelligent physiological sensor platforms which could be included into a body area network for health monitoring [173].
It is essential to consider the importance of the following parameters for a clinically acceptable monitoring system: early detection of unhealthy conditions, reliable decision support, along with high quality and real-time patient data acquisition. In addition, the designed system should be user-friendly, easy to wear and understand, as well as being highly acceptable to patients and clinicians [214].

In this fast moving busy world, wearable wireless health monitoring system is the most important system, which can continuously monitor the health of the patients/people,The health monitoring system is designed with the wearable (smart watch) approach,through which the above parameters are monitored that shows the variation from which the disease can be detected and diagnosed initially [175].
With this engineering technology (both hardware and sref295oftware), the health monitoring has been made easy and initiates the decrease in number of death caused by the cardiac arrest [175].
Furthermore, implement of patient monitoring in hospitals might reduce the costs in terms of installation and also maintenance of wiring According to World Health Organization WHO, 17 million people die from CVD Which makes up to 31% of the deaths worldwide.

Statistical report on cardiovascular disease
A report by American Heart Association says that According to "Heart Disease and Stroke Statistics – 2015 Update : A Report from American Heart Association", the heart disease remains the No. 1 reason for the global cause of death which was compiled over from more than 190 countries with 17.3 million deaths per year and the current figure is expected to rise to 23.6 million by 2030 [32].
Heart failure and diabetes is a common combination. In the presence of diabetes heart failure prognosis becomes very serious.
In addition, several million people are disabled by cardiovascular disease. The delay between the first symptom of any cardiac ailment and the call for medical assistance has a large variation among different patients and can have fatal consequences. One critical inference drawn from epidemiological data is that deployment of resources for early detection and treatment of heart disease has a higher potential of reducing fatality associated with cardiac disease than improved care after hospitalization. Hence new strategies are needed in order to reduce time before treatment. Monitoring of patients is one possible solution [34].
Since the system is continuously monitoring the patient and in case of any abnormal in the heartbeat rate of the patient the system will immediately send message to the concerned doctors and relatives about the condition of the patient and abnormal details [34].
Vital signs derive its significance from the fact that they can be considered as an indication of the person's health. Any change in the measurements of these signs indicates an abnormality in the physical condition of the patient. A considerable number of medical conditions can be detected from variations in one or more of the vital signs. The specialized devices for measuring the vital signs are not portable and can't be found anywhere [34].
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.
Statistical analysis has identified the risk factors associated with heart disease to be age, blood pressure, smoking habit, total cholesterol, diabetes [204], hypertension, family history of heart disease, obesity, and lack of physical activity [24].
Coronary heart disease (CAD) is a common type of heart disease. This condition results from a build-up of plaque on the inside of the arteries, which reduces blood flow

to the heart and increases the risk of a heart attack and other heart complications. Other forms of heart disease include irregular heartbeat (arrhythmias), congenital heart defects, weak heart muscles (cardiomyopathy), heart valve problems, heart infections and cardiovascular disease [115].

Remote Patient Monitoring
Regular reassessment of a patient's status and the continued monitoring of said patient while they are outside the hospital falls under the broader umbrella of telemedicine [83] and is formally termed Remote Patient Monitoring (RPM).
RPM, as a specific application of telemedicine, is of particular interest for patients with chronic conditions [108][83]. An acute exacerbation of a chronic condition can often bring patients into costly hospital emergency rooms for post-hoc care instead of less costly pre-emptive care/management that might have prevented the exacerbation in the first place. This leads to both suboptimal care for the patient as well as misallocation of resources in an already and increasingly strained health sector [121][191][108][233]. "HT has been shown to reduce mortality and HF hospitalizations and improve clinical outcomes in HF patients. Despite this evidence, significant heterogeneity exists in the design of HT interventions, the implementation context, and outcomes of individual studies, leading to ambiguity about the true effect of HT on HF outcomes. HT is not one, but rather a collection of complex interventions for which success or failure is linked to a range of contextual factors. These factors cannot be ignored if we are to design studies that will offer more definitive answers about the effect of HT on HF outcomes. [86]"

4.1 Cardiovascular Disease

The term cardiovascular disease (CVD) includes heart disease, stroke and all other diseases of the heart and circulation.
Cardiovascular diseases (CVDs) are disorders of the heart and blood vessels which they include:

1. Coronary heart disease which is a disease of the blood vessels supplying the heart muscle;
2. Cerebrovascular disease which is a disease of the blood vessels supplying the brain;
3. Peripheral arterial disease which is a disease of blood vessels supplying the arms and legs;
4. Rheumatic heart disease which is a damage to the heart muscle and heart valves from rheumatic fever, caused by streptococcal bacteria;
5. Congenital heart disease which is malformations of heart structure existing at birth;
6. Deep vein thrombosis and pulmonary embolism which is blood clots in the leg veins, which can dislodge and move to the heart and lungs.

Heart attacks and strokes are usually acute events and are mainly caused by a

blockage that prevents blood from flowing to the heart or brain. The most common reason for this is a build-up of fatty deposits on the inner walls of the blood vessels that supply the heart or brain. Strokes can also be caused by bleeding from a blood vessel in the brain or from blood clots. The cause of heart attacks and strokes are usually the presence of a combination of risk factors, such as tobacco use, unhealthy diet and obesity, physical inactivity and harmful use of alcohol, hypertension, diabetes and hyperlipidemia [34].
People with diabetes have an increased risk of CVD compared with those without diabetes. The reason is prolonged, poorly controlled blood glucose levels, which increases the likelihood of furring up of the vessels leading to CVD. Research shows that you can reduce the overall chance of developing CVD by improving dietary habits, managing weight and keeping active. Using medication where required will also help to control risk factors such as diabetes, high cholesterol, triglyceride levels and high blood pressure [64].
The Framingham Study demonstrated that diabetes mellitus is associated with a two to five-fold increase in CVD and related death [123]. Individuals with diabetes lack the ability to make insulin or cannot facilitate their own insulin production and glucose becomes abundant in the blood [156]. The abundance of glucose results from defects in insulin secretion from the β- cells or insulin action/resistance. With glucose build up, arteries become damaged perpetuating CVD. Some of the increased risk for CVD seen in diabetic individuals is attributable to the concurrent presence of other risk factors such as dyslipidemia, HTN, and obesity [141]. Management of these risk factors has been shown to effectively reduce the incidence of major coronary events in persons with diabetes [141].
Cardiovascular disease is a major cause of death and disability in people with diabetes, accounting for 44 per cent of fatalities in people with Type 1 diabetes and 52 per cent in people with Type 2 [163][217].

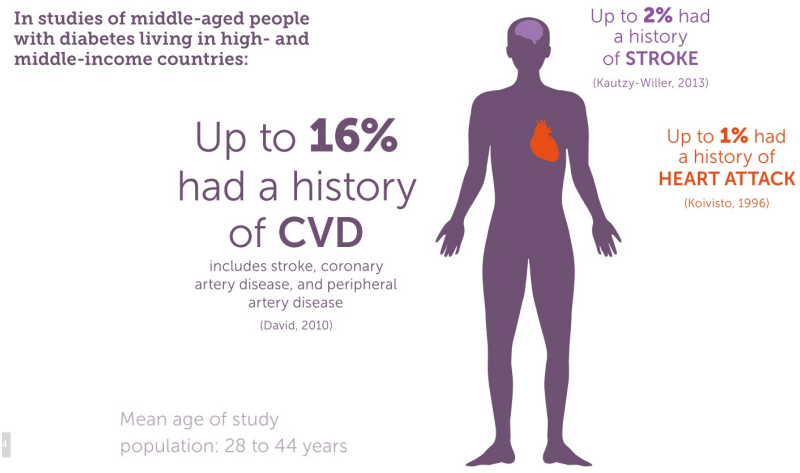

Figure 4.2. *Prevalence of Cardiovascular Disease in Younger People with type 1 Diabetes in High- and Middle- Income Countries [82].*

CVD is a major cause of death and disability among people with diabetes. People with diabetes are at increased risk of CVD, and these events generally occur at an

earlier age compared to people without diabetes. As the number of people with diabetes is predicted to increase, the outlook for CVD becomes even more alarming [82].

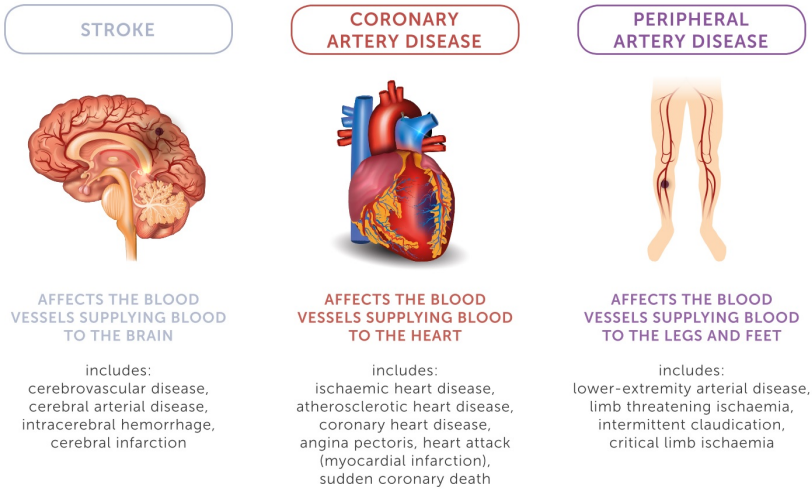

Figure 4.3. *The Main type of Cardiovascular Disease [82].*

In 2012, it was estimated that over 37.9 million people worldwide died from non-communicable diseases, of which 17.5 million were due to CVD. In 2015, approximately 5.0 million were estimated to have died from diabetes, the majority of these as a result of cardiovascular complications [82].
Over time, CAD can weaken the heart muscle and lead to heart failure; an often-acute condition where the heart is unable to pump blood the way that it should. An initial sign of this is irregular heartbeat/heart rhythm which is called arrhythmia [169][43].

4.2 Coronary heart disease

Impaired blood flow to the coronary artery is classified as CHD. With the occurrence of either, heart tissue is damaged often leading to heart disease and potential death [2].
Coronary heart disease (CHD) is a narrowing of the coronary arteries that supply blood and oxygen to the heart. CHD usually results from a buildup of fatty material and plaque on the inner lining of the wall of the coronary arteries known as atherosclerosis [48][14].

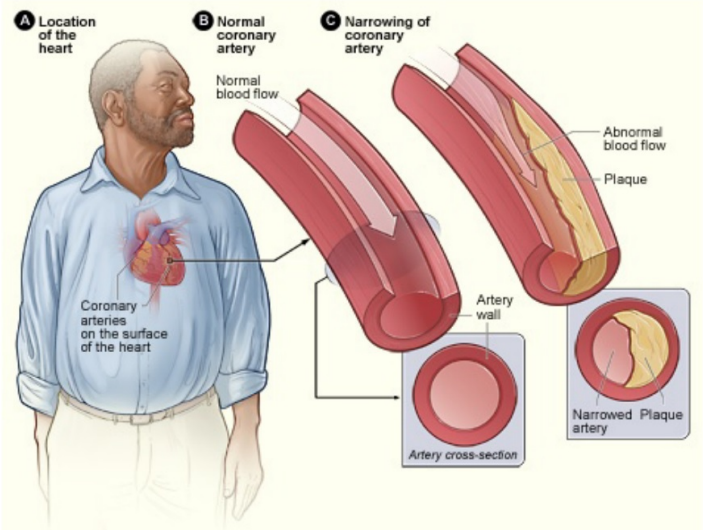

Figure 4.4. *Figure (A) shows the location of the heart in the body. Figure (B) shows a normal coronary artery with normal blood flow. The inset image shows a crosssection of a normal coronary artery. Figure (C) shows a coronary artery narrowed by plaque. The inset image shows a cross-section of the plaque-narrowed artery. [24].*

With enough impaired blood flow to the coronary arteries, caused by plaque accumulation, angina, myocardial infarction and sudden death can result.

The incidence of CHD is high; 700,000 Americans had a new coronary attack and 500,000 had a recurrent attack in 2000 [145].
The heart provides the force needed to circulate blood to the systemic organs by the coordinated pumping action of its chambers. The orderly sequence of atrial and ventricular contraction is possible only when a healthy electrical conduction system is present. Heart disease such as CHD that disturbs this electrical conduction system can lead to any one of several potentially life-threatening dysrhythmias, such as heart blocks. A common cause of heart block is coronary heart disease (CHD) resulting from coronary atherosclerosis. Atherosclerosis is a disease characterized by a narrowing of the arteries or stenosis caused by a buildup of fatty deposits on the inside wall of the artery [48].
Symptoms of CHD may or may not be detected. If symptoms are present, they include chest pain and discomfort from the heart not receiving enough oxygen, shortness of breath and fatigue with exertion [2].
The greatest problem with CHD is an imbalance between oxygen supply and demand. When myocardial oxygen demand increases, coronary arteries that are stenosed with lesions are unable to increase blood supply to the heart muscles [153].
This leads to ischemia, a reversible state of inadequate blood flow, which can result in insufficient oxygen delivery to the tissues. Prolonged ischemia leads to tissue death, or necrosis. The ischemic death of the heart muscle or myocardium is known as myocardial infarction (MI) [153].

4.3 Congestive heart failure

Congestive Heart Failure (CHF), or Heart Failure (HF), as previously stated, is a complex chronic terminal phase of many cardiovascular diseases and is slowly becoming a worldwide silent pandemic [158][192].
Heart failure is when the heart suffers a reduced ability to pump blood, and by extension is unable to adequately supply the body with the nutrients and oxygen it requires [158][109][192].
CHF is a sign and symptom resulting from impairment of systolic and/or diastolic functioning of the myocardium or can also be described as inefficient heart pumping. Those individuals with CHF often experience shortness of breath, chest discomfort, exercise capacity limitations, peripheral edema, anorexia and can become fatigued easily [47].
it is the "end result of all cardiac disease. You get heart failure from everything that goes wrong with your heart – all roads lead to heart failure" [109].
Risk factors of CHF include but are not limited to hypertension (HTN), obesity, diabetes, atherosclerosis, CHD and dyslipidemia along with excess sodium intake [145].
Recent estimates would suggest that in 2016 at least 50,000 new Canadians will have officially joined an existing cohort of more than 600,0000 Canadians, and 26 million persons globally, living with heart failure [109][192]. Of course, these numbers are only expected to grow as the population of persons at high risk of developing cardiac disease and, almost inevitably, the prevalence of cardiac disease in general, continues to increase. Globally, the prognosis of HF patients is bleak [192][158].
This inability of the heart to pump blood is sometimes termed cardiac insufficiency. This term helps to avoid the popular misconception that heart failure is when a person's heart has stopped as in the case of a heart attack [109][65]. While cardiac insufficiency has the, likely obvious, effect of reducing a person's ability to perform demanding physical activities at any given moment, the full effects of heart failure are rather more insidious [39].

4.4 Heart attack

The heart muscle requires a constant supply of oxygen-rich blood to nourish it. This critical blood supply provided by the coronary arteries. If there is a coronary artery disease, those arteries become narrow and blood cannot flow as well as they should. The accumulation of fat, cholesterol and other substances that form deposits in the arteries that feed the heart causes stop of the flow of the blood. The plaque deposits are hard on the outside and soft and mushy on the inside.
When the plaque is hard, the outer shell cracks, platelets come to the area, and blood clots from around the plaque. If the artery totally blocked by a blood clot, the heart muscle becomes starved for oxygen. Within a short time, death of heart muscle cells occurs, causing permanent damage. This is called a "heart attack" [34].
A heart attack occurs by either a block in the coronary artery with can be triggered by heavy physical exertion due to an increase in heart rate and blood pressure or a

decrease in arterial circumference as a result of atherosclerotic plaque. Chest and upper body discomfort in the arms, neck and back, shortness of breath, nausea, vomiting, lightheadedness, fainting, or breaking out in a cold sweat are symptoms of a heart attack and should elicit help to decrease damage to the heart [2] Heart attack prevention is linked to diet, exercise and stress factors, all of which can be modified.

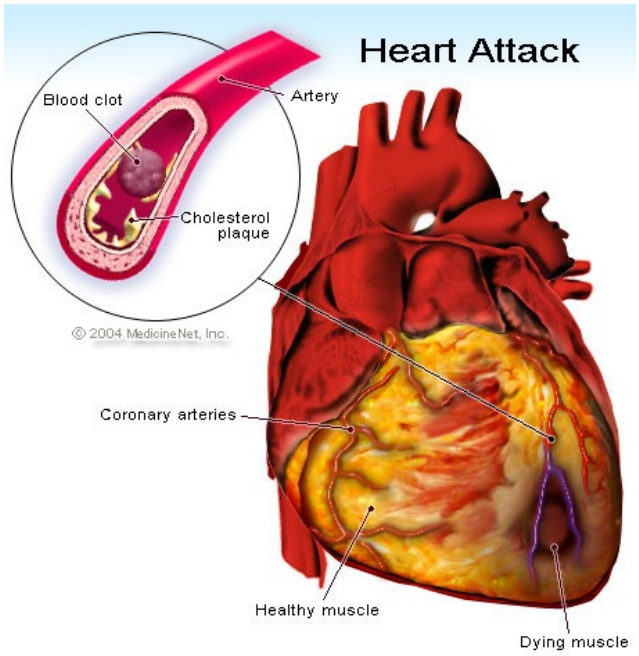

Figure 4.5. *Heart attacks [101].*

Each year, about 1.1 million people in the U.S. have heart attacks, and almost half of them die. CHD, which often results in a heart attack, is the leading killer of both men and women in the U.S. [2].

Symptoms of Heart Attacks:

Heart attack has several signs and symptoms which includes chest pain, jaw pain, toothache, headache, shortness of breath, nausea(less common but possible symptom), vomiting, general discomfort, sweating, heartburn and indigestion, arm pain(more commonly the left arm), upper Sometimes there are no symptoms, this case called “silent heart attack” which is occurring with mild symptoms and may seem unrelated to the heart [76].
The person may experience difficulty in breathing or shortness of breath; feeling sick or vomiting; feeling light-headed or faint; breaking into a cold sweat; and becoming pale. Women are more likely to have shortness of breath, nausea, vomiting, and back or jaw pain [34].

Heart attack detection

Heart attack detection based on patient's signs and symptoms, medical and family histories, and test results. There are several diagnostic tests used to detect the heart attack such as [34]:

1. **EKG (Electrocardiogram)** An EKG is a simple, painless test that detects and records the heart's electrical activity. The test shows how fast the heart is beating and its rhythm (steady or irregular). An EKG also records the strength and timing of electrical signals as they pass through each part of the heart. An EKG can show signs of heart damage due to coronary heart disease(CHD) and signs of a previous or current heart attack [232].
2. **Blood Tests** During a heart attack, heart muscle cells die and release proteins Blood Testsinto the bloodstream. Blood tests can measure the amount of these proteins in the bloodstream. Higher than normal levels of these proteins suggest a heart attack. Commonly used blood tests include troponin tests, CK or CK–MB tests, and serum myoglobin tests. Blood tests often are repeated to check for changes over time [232].
3. **Coronary Angiography** Coronary angiography (an-jee-OG-ra-fee) is a test that uses dye and special x rays to show the insides of your coronary arteries. This test often is done during a heart attack to help find blockages in the coronary arteries. A thin, flexible tube called a catheter is put into a blood vessel in your arm, groin (upper thigh), or neck. The tube is threaded into your coronary arteries, and the dye is released into your bloodstream [232].

4.5 Arrhythmia

Arrhythmia is a problem with the rate or rhythm of the heartbeat. It means that the heart beats too quickly, too slowly, or with an irregular pattern. When the heart beats faster than normal, it is called tachycardia. When the heart beats too slowly, it is called bradycardia. The most common type of arrhythmia is atrial fibrillation, which causes both an irregular and fast heartbeat [157].
Many factors can affect the heart's rhythm, such as having a heart attack, smoking, congenital heart defects, and stress. Some substances or medicines may also cause arrhythmia [157]. Symptoms of arrhythmias include: fast or slow heartbeat, skipping beats, lightheadedness or dizziness, chest pain, shortness of breath and sweating [157].
Arrhythmia analysis is a quite complex task since not only does every person on earth have his or her own individual ECG, distinct from all others, but one person's ECG can look very different from one moment to the next. It is inadequate to memorize some of the most common ECG patterns and trying to recognize them in the future. This type of ECG analysis is called pattern recognition and is a common but accidental way to approach arrhythmias. A much more reliable way to approach an EKG tracing is to take it apart, wave by wave, and interpret exactly what's happening within the heart [196]. The process of identifying and classifying arrhythmias can be very troublesome for a human being because sometimes it is

necessary to analyse each heartbeat of the ECG records, acquired by the patient wearing a Holter monitor over several hours, or even days. In addition, there is the possibility of human error by the person performing the ECG records analysis, owing to fatigue. An alternative is to use computational techniques for automatic classification [143].

Arrhythmias Types

Arrhythmias can be categorized into groups according to which pacemaker site initiates the rhythm. The most common sites, and thus the major categories of arrhythmias, are:

- Sinus
- Atrial
- Junctional
- Ventricular

The most common cardiac rhythm is sinus in origin, because the sinus (SA) node is the usual pacemaker of the heart . Therefore, a normal, healthy heart would be in Normal Sinus Rhythm (NSR) because the rhythm originated in the SA node [196].

- **Bradycardia (i.e. slow heartbeat)** This term is used to describe when the heart beats too slowly; generally, less than 60 beats per minute. It is serious when the heart beats so slowly that it can't pump enough blood to meet the needs of the body. Untreated, bradycardia can cause excessive tiredness, dizziness,light-headedness or fainting, because not enough blood reaches the brain. A slow heartbeat may be normal, and can be associated with improved physical fitness[24].
- **Sick sinus syndrome** This term describes when the natural pacemaker in the heart malfunctions and 'fires' too slowly, telling the heart to beat slowly. It can be caused by age or by fatty tissue in the arteries that take blood to the heart [24].
- **Heart block** When the signal passing from the collecting chambers (atria) to the pumping chambers (ventricles) of the heart is delayed or blocked this is called heart block. It is uncommon but can be serious. Symptoms can be mild or severe,depending on the location and seriousness of the blockage [24].
- **Tachycardia (a fast heartbeat)** Tachycardia is when the heart beats too fast, generally more than 100 beats per minute. Some forms of tachycardia are easily treated and not serious, while others can be life-threatening [24].
- **Supraventricular tachycardia** A rapid heartbeat that starts in the collecting chambers of the heart, the atria, or the electrical pathway from the atria is called "supraventricular tachycardia" (SVT). Common types of SVT are atrial flutter and atrial fibrillation [24].
- **Atrial flutter** An extra or early electrical signal which travels around the atria in a circle instead of along the normal signal pathway is called "atrial flutter". This 'overstimulation' causes the atria to contract quickly or 'flutter' at a much higher rate than normal. Most of this fluttering is blocked out by the electrical pathway from the atria to prevent the pumping chambers of the heart, the ventricles, from beating too fast. Atrial flutter is usually not life-threatening but can still cause chest pain, faintness or more serious heart problems [24].

- **Atrial fibrillation** The most common form of SVT is "atrial fibrillation". This is when 'waves' of uncontrolled electrical signals, rather than the normal regulated signals, travel through the atria from the sinus node. These uncontrolled signals cause muscle fibres in the atria to contract out of time with each other, so that the atria 'quiver' or 'fibrillate'. Some of this abnormal electrical activity reaches the ventricles, causing a rapid and irregular heartbeat. When the heart is in atrial fibrillation, it does not pump regularly or work as well as it should. Atrial fibrillation can cause a 'fluttering' heartbeat, an irregular pulse, chest pain or tightness, weakness and dizziness. Atrial fibrillation can also increase the risk of stroke, because blood trapped in the atria can clot. These clots may break loose from the heart, enter the bloodstream and travel to the brain, causing a stroke [24].

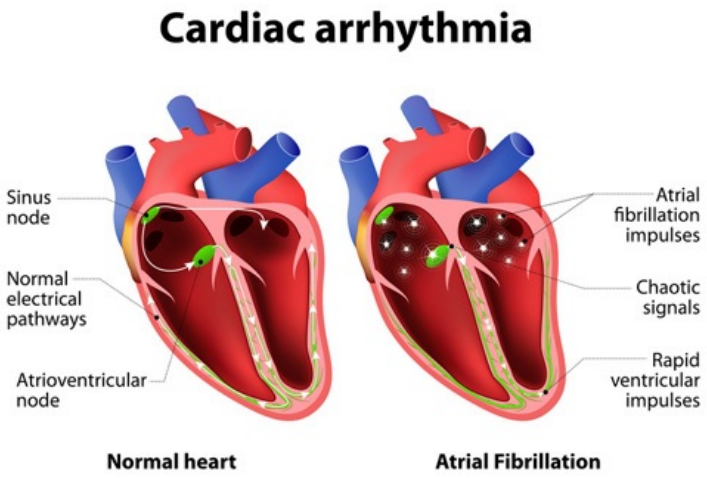

Figure 4.6. *Atrial fibrillations [57].*

- **Paroxysmal supraventricular tachycardia** A 'short circuit' caused by an extra electrical connection or pathway in heart making the heart prone to episodes of sudden regular rapid heartbeats that may last for minutes or even hours is called "paroxysmal supraventricular tachycardia" (PSVT). Although these episodes may be frightening, they are rarely dangerous and can be very effectively treated [24].
- **Wolff-Parkinson-White syndrome** An extra or abnormal electrical pathway connecting the atria to the ventricles, causing attacks of SVT is called "Wolff-Parkinson-White syndrome" [24].
- **Ventricular tachycardia** When the ventricles beat too fast, called "ventricular tachycardia", it is potentially very dangerous. Ventricular tachycardia that becomes so severe that the ventricles can't pump effectively can lead to ventricular fibrillation. Ventricular fibrillation is when the electrical signal that should trigger the heartbeat splits away in uncontrolled 'waves' around the ventricles. This life-threatening situation must be corrected immediately [24].

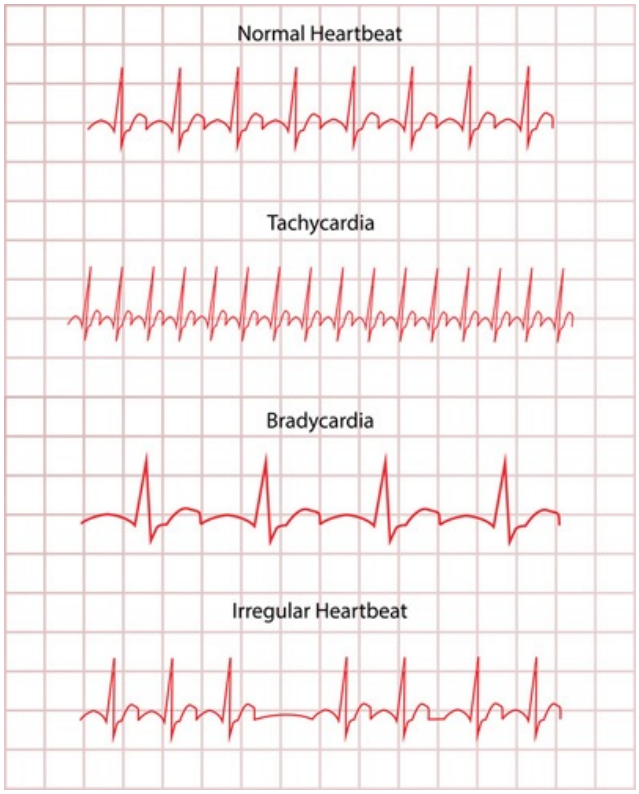

Figure 4.7. *Types of Arrhythmias [57].*

Arrhythmias Causes
Arrhythmias are caused by a problem in the electrical system of the heart. Some causes of arrhythmias include [169]:

- Irritable heart cells Sometimes heart cells begin to malfunction and start sending out abnormal electrical signals. Signals from these malfunctioning heart cells interfere with the proper signals from the natural pacemaker within the heart.This 'confuses' the heart causing an irregular heartbeat
- Blocked signals The electrical signals that tell the heart to beat may get 'blocked'. This makes the heart beat very slowly.
- Abnormal pathway Sometimes the electrical signals start at the right place and time, but get interrupted and misdirected so they don't follow the right path through the heart and cause an arrhythmia.
- Medicines and stimulants In some cases, medicines and other substances, such as caffeine, nicotine and alcohol, can cause an arrhythmia.

4.6 Heart Rate

Heart rate is defined as the number of heartbeats per unit of time and mostly stated in beats per minute (bpm). Human's heart beats to pump oxygen and nutrient-rich blood to body muscles and also move cell waste products away from tissues [5]. Heart

rate fluctuates according to muscle demands for absorbing oxygen and excreting carbon dioxide [6].
The most prominent areas for the pulses are wrist (Radial artery), neck (Carotidartery), inside of the elbow (Brachial artery), behind the knee (Popliteal artery) and ankle joint (Posterior artery). The HR changes according to age and the physical and psychological impacts on the body. Higher pulse rate indicates the presence of abnormality in the body which can also be caused by other reasons such as anxiety, anger, excitement, emotion, and heart isorders. The pulse rate of an individual can help in determining various problems within the body, but it cannot be used lone to diagnose an abnormality [8].
Normal resting heart rate is about 70bpm for male adults and 75bpm for female adults [4]. HF is a chronic condition in which the heart muscle is unable to pump enough blood to supply the body with enough oxygen-rich blood. As a result, the heart becomes enlarged through the development of more muscle mass to pump faster and keep up with the workload [7].
Normally, healthy adults who are reasonably fit and overweight, and do not smoke or drink heavily, will have resting heart rates between 60 and 100 beats per minute (bpm). Average, healthy teenager heart rates are the same as those for adults, while children under 10 years of age experience higher heart rates and pulses:

- Newborns (70-190 bpm).
- Infants (80-160 bpm).
- Toddlers (80-130 bpm).
- Preschoolers (80-120bpm).
- Elementary Age (70-115 bpm).[116]

These ranges help in determining the normality of the heart beat.
There are different methods available for heart rate measurements including: Phonocardiogram (PCG), Electrocardiogram (ECG), Photoplethysmogram (PPG) and blood pressure waveform [216].
There are also two approaches for extracting the heart rate from body signals:

1)Real-time approach, which analyzes the time and feature variations on the two abrupt signals for each input heartbeat signal, applies various algorithms to identify the heartbeats and then compute the heart rate [94][100].
2)The Non-real-time approach, which collects a longer-period of waveform and uses software to break the long signal down into different segments before making use of a software to compute the heart rate [58][181].

4.7 Heart rate variability

Heart rate variability (HRV), the beat-to-beat fluctuation of the heart rate, is a noninvasive test that measures the autonomic regulation of the heart. Assessment of HRV has been shown to predict the risk of mortality in patients after an acute myocardial infarction.

Heart Rate Variability (HRV) is a physiological phenomenon defined as variation in RR intervals (RRI) during normal sinus rhythm. The RRI is defined as the time interval between adjacent QRS complexes resulting from sinus node depolarization. Since the sinus node is subject to both sympathetic and parasympathetic efferent effects, the fluctuations of the RRI have been well accepted to reflect the effects of the autonomic nervous system [92].

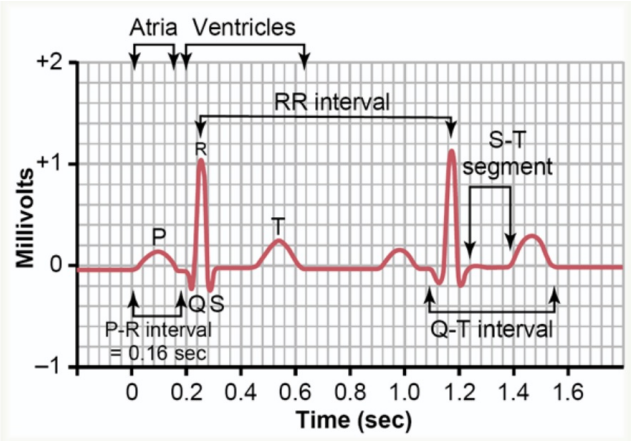

Figure 4.8. *ECG signal with the P wave, QRS complex, and T wave noted [84].*

Coronary heart disease often leads to MI, which can lead to sudden death. Powerful sympathetic reflexes often develop after a massive myocardial infarction primarily due to the inadequate blood flow into the coronary arterial tree [106]. Investigators have been studying changes in HRV indices to assess autonomic activity in patients after MI. In 1976, using facial immersion, Ryan et al. observed impaired parasympathetic response in patients 3 months after MI. Facial immersion in water 25 degrees C and 0 degrees C provoked less slowing of the heart rate in patients than in age matched controls suggestive of a decreased parasympathetic response in AMI patients [190]. Several years later, reports showed a strong link between depressed HRV and poor long-term prognosis in patients after AMI [239][128].
In 1983, Wolf et al. found that HRV measured on admission to the coronary care unit in 176 patients with AMI was a predictor of mortality [239]. They found that patients with reduced RRI variability (RRI variance less than 32 ms) in a 60 second ECG recording had a significantly higher mortality rate than patients with a higher RRI variability. In a separate study of 808 patients who survived AMI, mortality was 5.3 times more likely in the group with SDNN less than 50 ms than the group with SDNN greater than 100 ms in a 24 hour recording taken approximately 11 days after AMI [128].
The measurement of HRV is noninvasive, often reproducible and rather easy to perform and has led to its popularity as a method for the measurement of autonomic tone in varying physiological and pathological states [246].
Traditional methods of HRV analysis, often referred to as linear methods, include time and frequency domain analysis. Time domain analyses of HRV are usually obtained using simple statistical methods. The simplest time domain parameter is

the mean of the RRI (RRmean), which is the average RRI over a given time window. Another parameter commonly used is the standard deviation of the RRI (SDNN) which is sometimes regarded as an estimate of overall HRV. Other measures include RMSSD, the square root of the mean squared differences of successive NN intervals, NN50, the number of interval differences of successive NN intervals greater than 50 ms, and pNN50, the proportion derived by dividing NN50 by the total number of NN intervals. All these are based on differences between RR intervals and thus are highly correlated, and they all estimate the short-term components of HRV [184].

4.8 Heart Rate Measurements Methods

The heart rate measurement is essential for providing a person's cardiovascular fitness.There are several spots on the body that the heart rate can be taken from, at which an artery is close to the surface and a pulse can be felt. The most common places to measure heart rate is at the wrist (radial artery) and the neck (carotid artery) using the palpation method. Other places sometimes used are the elbow (brachial artery) and the groin (femoral artery) [136].

Manual Methods

Radial: It is taking the Pulse on the Wrist. By holding the palm of theright hand facing upwards, placing the tips of the middle three fingers from the left hand on the wrist joint and count the number of beats for six seconds. If we multiplied this number by ten it gives the BPM [34].

Carotid: It is taking the pulse on the Throat. By placing two fingers (first and second) lightly on the side of the throat just below the angle of the jaw. A pulse would be felt from the jugular vein. Count the number of beats for six seconds. Multiplying this number by ten will give the BPM [34].

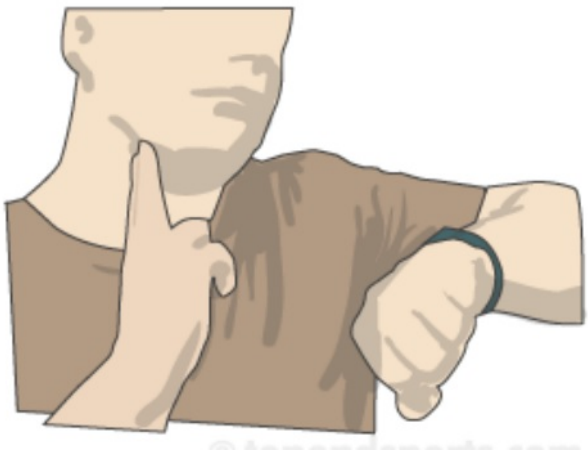

Figure 4.9. *Current Heart Rate Measurements Method [34].*

Current Heart Rate Monitors

Health Monitoring System: A health monitoring system consists of ECG, Pulse rate, SpO2, blood pressure, etc.,
These equipment are already available in commercial markets for the hospital setups and many researches are currently being held to improve the efficiency and accuracy. These equipment are massive in size that can be used only in hospitals and clinics and could not be used by the patients outside the hospitals. Since the production cost is high due to several factors, it is also expensive. Due to the above reasons, we started working towards the health monitoring system that is affordable and portable for patients to monitor their health outside the hospitals [175].

Wearable Technology implemented on Health Monitoring System: Current real-time heart rate monitors that are designed for ambulatory setting use either PPG or ECG waveforms. Several research groups are involved with the wearable and wireless technology implemented on the health monitoring system for the ease of the patients. The monitoring unit would be implanted on daily wearable. This can reduce the size of the monitoring and the production cost can also be reduced [175].

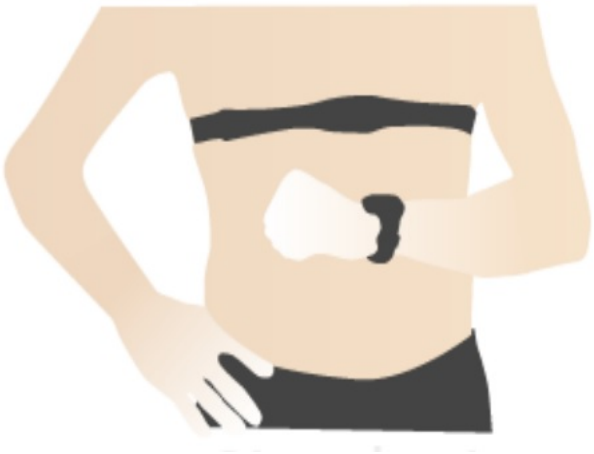

Figure 4.10. *Current Heart Rate Measurements Method [34].*

4.9 PPG and Pulse Rate Monitoring

PPG waveform is composed of two components. The first component is attributable to the pulsatile component in the vessels, arterial pulse. This is the fluctuating part (AC component) of the signal and is caused by the heartbeat, and the second component of the steady signal that is due to the blood volume and its changes in the skin. This component of the signal only changes slowly (DC component) and catches large artifacts due to motion. Only the AC component of the signal could be distinguished through the application of a band-pass filter [73].
In order to measure PPG, it is required to illuminate a tissue bed with LEDs and

measure the amount of light absorbed by the tissue using a light-sensitive photodiode. As a result, the oxygen concentration in the arterial blood, heart rate, and blood flow could be estimated. PPG signal could be measured though transmittance and reflectance mode optical sensors. In transmittance mode sensors, which are commonly used in finger clips, a photo-sensor is placed on the opposite side of a tissue bed to measure the amount of light passing through the tissue. These optical sensors could be used on body parts such as fingers and earlobes. In reflectance operating mode, the photo-sensor is positioned adjacent to the LEDs to measure the amount of reflected light. This class of optical sensors could detect the PPG signals in any part of human body where there is a reasonable concentration of blood vessels, such as wrists [218]. The figure below demonstrates an optical sensor mounted on the fingertip.

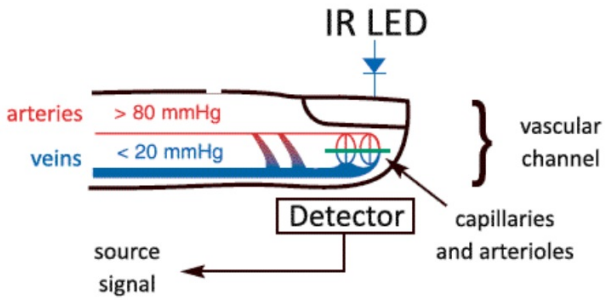

Figure 4.11. *Infrared LED and detector on terminal phalanx on finger [79].*

However, overcoming the motion artifact is a huge challenge for PPG as it is sensitive it. Adaptive noise cancellation (ANC), which uses accelerometers as a noise reference, is proposed in order to help in reducing the affection of motion artifact. [45].

4.10 ECG and Heart Rate Monitors

ECG signal measures the electrical activity of the heart over some time period. It records the strength and timing of electrical signals while they travel through the heart. Each electrical signal begins in a group of cells called sinoatrial (SA) node, which is located in the right atrium. Then, the signal travels through the right and left atria that result in the atria contraction and blood moving to ventricles. The electrical signal moving through the atria is recorded as the P wave on the ECG recording.
Afterwards, the electrical signal passes between the atria and ventricles through a group of cells called the atrioventricular (AV) node, while it slows down. The slower traveling signal gives ventricles enough time to be filled by blood. This part is represented as a flat line between the end of the P wave and the beginning of the Q wave in ECG signal [3].
After the AV node, the electrical signal travels along a pathway called the bundle of His that branches into the right and left sides of the heart. The signal spreads quickly across ventricles and causes them to contract and pump blood to the rest of

body parts. This process is recorded as the QRS waves on the ECG signal. Following the QRS wave, ventricles recover back to their normal electrical state, which is noted as T wave on the ECG is an indication of the patient's heart health by recording the electrical activity to be read by specialized doctors which able to extract vital signs from it. Hence, HR can be calculated from ECG [45].
ECG signal. Then, muscle contraction is stopped to let the heart be refilled with blood [3]. Figure below shows Electrical signal pathway in heart:

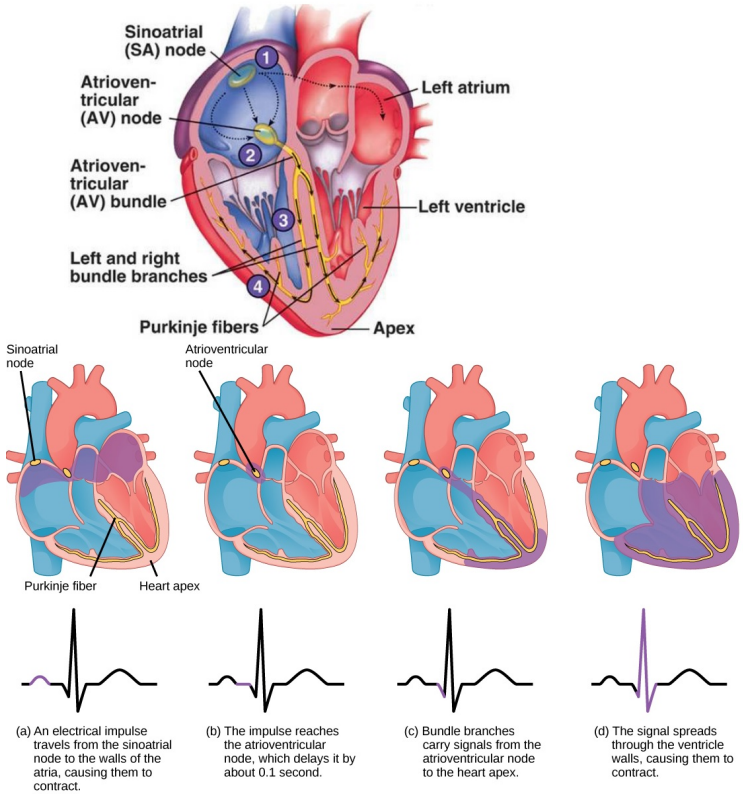

Figure 4.12. *Electrical signal pathway in heart [79][162].*

It also provides information like heart rate, size of the heart chamber, structure of the heart, blocks in the arteries and veins of the heart, damages to the heart muscles, etc., [3].
Cells that have this property can stimulate the heart to beat and are located in the SA node, parts of the atria, AV node and ventricles. The heart is usually paced by the fastest available pacemaker, the SA node that paces about 60 to 100 beats per minute (sinus rhythm). The AV node and the ventricles can pace the heart at a rate of 40 to 60 and 20 to 40 beats per minute respectively.
"If for some reason, a higher pacemaker center fails to generate an impulse, or if the impulse is not properly conducted, a pacemaker lower in the cardiac conduction system will have time to depolarize to its threshold potential and generate an impulse. Such a beat is called an escape beat. A sustained sequence of such beats is called an

escape rhythm. On the other hand, if a lower pacemaker site prematurely discharges because of local increased automaticity, the resultant beat is called an ectopic beat. A series of such beats would thus be an ectopic rhythm [148]". In a diseased heart, sometimes the electrical signal from the heart's upper to lower chambers is blocked which prevents the passage of electrical stimuli, known as heart block. Heart blocks can occur in the SA node (sinus exit block), AV node or in the larger sections of the ventricular conduction system [246].
The ECG could be measured through electrodes attached on the body surface. The ECG signal demonstrates a comparison between voltages collected by two electrodes that they are placed at different points on the body. These pairs are also termed as a leads. Standard ECG configuration applies 1, 3, 5 or 12 leads [201]. The following figure indicates the standard 12-lead ECG electrode placement.

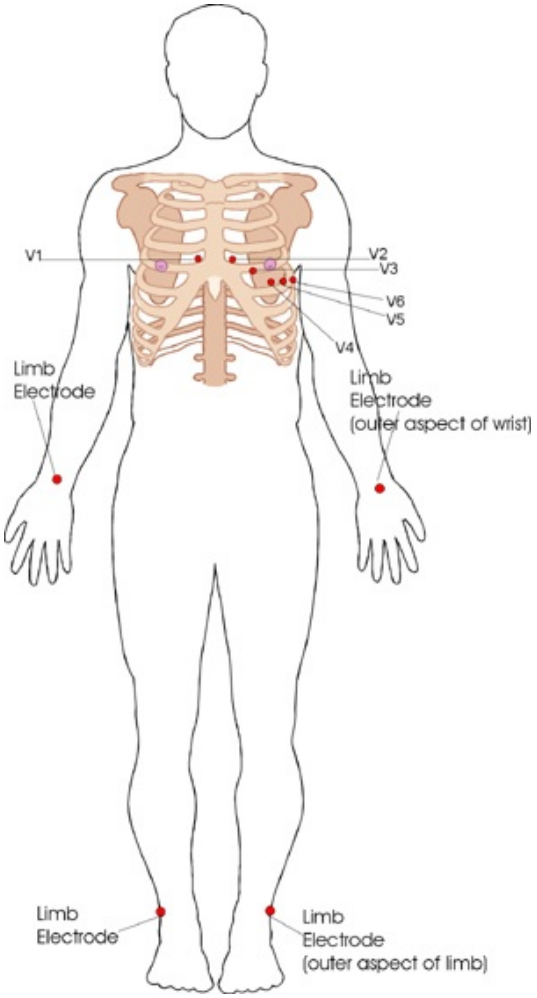

Figure 4.13. *Standard 12-lead ECG electrode placement [172].*

Chapter 5

Prototype Evaluation

5.1 Expert-based evaluation techniques

5.1.1 Heuristic Evaluation

Heuristic evaluation is a usability engineering method for finding usability problems in a user interface design, thereby making them addressable and solvable as part of an iterative design process. It involves a small set of expert evaluators who examine the interface and assess its compliance with "heuristics," or recognized usability principles. Such processes help prevent product failure post-release [88].
Typical usability evaluations of interfaces can be long, difficult, expensive and time-consuming processes that often intimidate developers. They are hence often ignored—at the cost of delivering software that suffers from usability issues and results in frustration and errors during use. To overcome the issue partially, Jakob Nielsen (pioneer of web usability) has advocated for "discount usability engineering methods"—i.e., methods that developers can adopt which are cheap, fast and easy to use. Heuristic evaluation is one of these methods [88].

a heuristic evaluation, a set of evaluators assess a designed interface for compliance against an agreed set of principles. Each evaluator works alone and goes over the interface multiple times. At length, the evaluators produce reports which are then discussed, the end result being a list of usability problems (and their causes) to be addressed. In heuristic evaluation, evaluators can supplement sets of general design principles with additional heuristics that match the product category or its characteristics, as necessary. The number of evaluators for each project may vary, but using about five of them is generally recommended, as this number has been shown to be able to discover approximately 75% of all usability issues. Because evaluators are inspecting the interface and not actually using it, heuristic evaluation is suited to early use in the development life cycle, where the interface may consist of nothing more than paper-only designs. By its nature, such evaluation facilitates catching oversights before they become truly problematic [88].

Good Reasons to Use Heuristic Evaluation [89]

- It's fast, quick and cheap to conduct a heuristic evaluation. This is especially true if you are only going to use a single evaluator.

- It provides good insight into possible usability problems that might damage the user experience.

Jakob Nielsen's 10 Usability Heuristics for User Interface Design

- Visibility of the system's status. Users should be given feedback on what is happening within a reasonable timescale.
- Match between the system and real world. Information should be presented in a means familiar to the user including language and conventions rather than terms developed for the system. Information should be presented in a logical order.
- User control and freedom. Users make mistakes. There should be an "emergency exit" which is easy to find and exit the current system state without having to jump through hoops. Undo and redo functions are essential.
- Consistency and standards. Words, actions, situations, etc. should always mean the same thing and users should be able to understand that.
- Error prevention. Preventing error is better than clear error messages. Eliminate error conditions or make users aware that they may be about to occur and ask them if they want to proceed.
- Recognition rather than recall. Reduce the load on a user's memory. Make and actions, options, and objects visible. Users shouldn't have to remember things from one screen to the next. Instructions should be easy to access when needed.
- Flexibility and efficiency of use. The use of accelerators, where appropriate, may be invisible to new users but improve the efficiency of use for experienced andusers. Actions could be customized by users.
- Aesthetics and minimalist design. Dialogue should not give irrelevant or rarely useful information. The more data in dialogue the more it diminishes the overall visibility of individual points for the user.
- Help users recognize, diagnose and recover from error. This means error messages should be in clear language and avoid the use of codes. They should explain the problem and offer a solution to that problem.
- Help and documentation. The best approach is to construct a system which needs no help or documentation but if it is necessary – it should be easy to search,be based on the tasks the user wishes to execute, offer concrete steps to follow and be kept to a minimum.

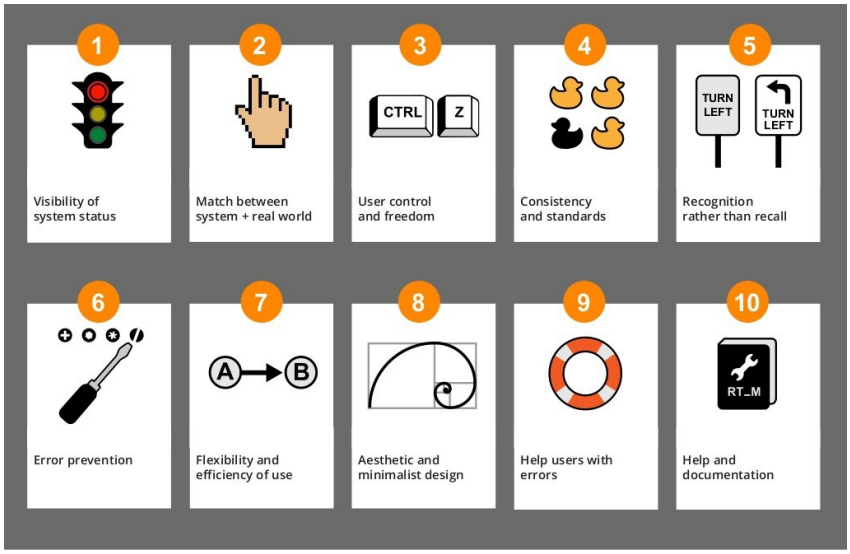

Figure 5.1. *Jakob Nielsen's 10 usability heuristics for evaluating user interfaces [198].*

Table 5.1. *Heuristic Evaluation.*

Frame	Heuristic Violated	Severity	Comment
Login Chose Account	3.User control and freedom 1.Visibility of system status	2 1	Don't have exit button Highlight the choice
Pattern Password	3.User control and freedom 1.Visibility of system status	2 3	Don't have Back button Don't show name of the logging user
Welcome	5.Error prevention	3	Show dialog box for sure of user answer
Auto Plan	6.Recognition rather than recall	2	Show extra button for select Item
Child Dashboard	6.Recognition rather than recall	3	Buttons are not visible & no title for number of candies
Static Plan	6.Recognition rather than recall	3	There are not any explain and title for items
Parent Dashboard	1.Visibility of system status 6.Recognition rather than recall	3 3	Not detectable which child selected & detail of report not enough Buttons are not visible
All	10.Help and Documentation	3	There is not Help and Guide

5.1.2 Cognitive Walkthrough

Cognitive walkthroughs are used to examine the usability of a product. They are designed to see whether or not a new user can easily carry out tasks within a given system. It is a task-specific approach to usability (in contrast to heuristic evaluation which is a more holistic usability inspection). The idea is that if given a choice – most users prefer to do things to learn a product rather than to read a manual or follow a set of instructions [87].
The biggest benefit of a cognitive walkthrough (or walkthroughs) is that it is extremely cost-effective and fast to carry out when compared to many other forms of usability testing. It can also be implemented prior to development during the design phase which can give rapid insight before budget is spent developing an unusable product [87].

How to Conduct a Cognitive Walkthrough:
A cognitive walkthrough begins by defining the task or tasks that the user would be expected to carry out. It is these tasks that the cognitive walkthrough will examine for usability – any tasks that can be performed in the product but are not subject to a cognitive walkthrough will not, normally, be assessed during the process [87].

The Four Questions to be Asked during a Cognitive Walkthrough
Blackmon, Polson, et al. in 2002 in their paper "Cognitive walkthrough for the Web" offer four questions to be used by an assessor during a cognitive walkthrough:

- Will the user try and achieve the right outcome?
- Will the user notice that the correct action is available to them?
- Will the user associate the correct action with the outcome they expect to achieve?
- If the correct action is performed; will the user see that progress is being made towards their intended outcome?

The assessor performs each action in any given task process and asks the four questions above.

Example of our Cognitive Walkthrough

Assumption: Follow Plan than suggested Automatic with Doc Hero. New user (does not sign in)
Identify the task 1: follow auto plan

Act. 1: Select Your Account
Resp. 1: Browsing Pattern Password

Act. 2: Fill Pattern Password
Resp. 2: If Password is Correct then Accept that and going to Application Welcome page
Resp. 2: If Password is wrong then Show Message of wrong password

Act. 3: Accept Doc Hero Automatic Suggestion
Resp. 3: Show Dialog Box to ensure user Answer

Act. 4: Press the "Yes" Button
Resp. 4: Give Candy to User and Doc Hero Show Dynamic Diabetic Plan

Act. 5: Select any item do you like
Resp. 5: Give Candy and going to Children Dashboard

Assumption: Parent go own dashboard and edit child's plan. New user (does not sign in)
Identify the task 2: Add new item to diabetic plan

Act. 1: Select Parent button
Resp. 1: Browsing Pattern Password

Act. 2: Fill Pattern Password
Resp. 2: If Password is Correct then Accept that and going to Parent Dashboard
Resp. 2: If Password is wrong then Show Message of wrong password

Act. 3: Select Target Child
Resp. 3: child Selected

Act. 4: Push “Manage plan” button
Resp. 4: Browsing plan
Act. 4: Add new plan
Resp. 4: updated list of plans

Act. 5: Save and back
Resp. 5: Browsing Dashboard

5.2 Prototype Evolution

With an understanding of how users are expected to interact with the mobile application, a formative usability approach was applied to design and develop the initial prototype for testing.
Formative usability is defined as a method that is iterative in nature, which means that evaluation, problem diagnosis/identification, recommendations, and changes to the design occur in a cyclical fashion [222]. Several iterations of formative usability occurred prior to finalizing the prototype for usability testing with patients.
The initial version of the prototype was developed using the design guidelines identified from the results of the requirements gathering phase.

Home Screen
When the application is first launched, it opens to the home screen. This page acts as a dashboard that summarizes the data collected throughout the day and it is also the gateway for users to enter self-measured data. As the system will allow the user to record their blood glucose, carbohydrate intake, insulin dose, activity levels, and emotion, it is important to display this data in a meaningful way to the user.
Figures 8.7 below depict the last iteration of the home page design. In an early evaluation of this design, it became clear that the tabular representation of the data in the bottom portion of the screen would not quickly convey useful information to the user.
These correspond with the requirements, allowing the user to record and track how many carbs they are consuming (carbs), how many units of insulin they are taking (bolus), the type of activity/exercise they have participated in (activity), how they are feeling (emotion), and their basal dose (basal).

The middle portion is a graph of the blood glucose measurements taken throughout

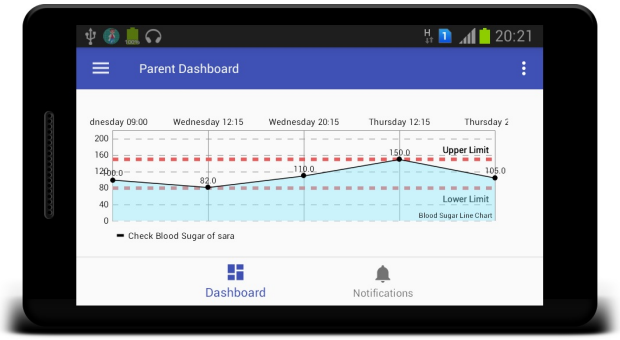

Figure 5.2. *Children Home Screen.*

the day with the time on the x-axis and mmol/l on the y-axis. The light red band through the middle indicates the target blood glucose range. This target range can be changed in the settings to accommodate individual needs.
In an early evaluation of this design, it became clear that the tabular representation of the data in the bottom portion of the screen would not quickly convey useful information to the user. It would take time to read through each line item, which is not ideal, particularly for mobile use. As a result, the bottom portion of the design changed in the second iteration to a more visual representation.

Challenges

From the identified requirements, it was clear that users set personal goals that relate to overall health and well-being. The goals section of the mobile app was named 'Challenges' in order to stay aligned with the game-based design theme. The aim of the challenges portion of this application was to incorporate these types of personal goals and incorporate them with challenges that would encourage the user to remain engaged in the app.
Review of the updated challenges section revealed that the design may be too complex and could prove to be confusing with the content of the challenges tray changing from screen to screen. This was included in usability testing to determine whether this was in fact true.

Figure 5.3. *Challenges.*

Food Database
The decision to include a food database in the application was not necessarily driven by the requirements. In fact, what was drawn from the requirements was the need to keep track of how many carbs are being consumed, not a tool to help determine the amount. Though participants didn't explicitly state they would want a food database in a diabetes app, they did mention that they used other food databases available either by book or via another mobile app.
The idea is that an integrated food database would make it easier for the patient to estimate their carbohydrate intake.

Figure 5.4. *Food Database.*

5.3 User-based evaluation

5.3.1 Think Aloud

In a thinking aloud test, you ask test participants to use the system while continuously thinking out loud that is, simply verbalizing their thoughts as they move through the user interface ("Simply" ought to be in quotes, because it's not that simple for most people to keep up a running monologue. The test facilitator typically has to prompt users to keep them talking.) [165].

To run a basic thinking aloud usability study, you need to do only 3 things [165]:
1. Recruit representative users.
2. Give them representative tasks to perform.
3. Silence and let the users do the talking.

Think-Aloud Benefits:
The method has a host of advantages. Most important, it serves as a window on the soul, letting you discover what users really think about your design. In particular, you hear their misconceptions, which usually turn into actionable redesign recommendations: when users misinterpret design elements, you need to change them. Even better, you usually learn why users guess wrong about some parts of the UI and why they find others easy to use [165].

The thinking aloud method also offers the benefits of being [165]:
Cheap. No special equipment is needed; you simply sit next to a user and take notes as he or she talks. It takes about a day to collect data from a handful of users, which is all that's needed for the most important insights.
Robust. Most people are poor facilitators and don't run the study exactly according to the proper methodology. But, unless you blatantly bias users by putting words into their mouths, you'll still get reasonably good findings, even from a poorly run study. In contrast, quantitative (statistical) usability studies are ripe with methodology problems and the smallest mistake can doom a study and make the findings directly misleading. Quant studies are also much more expensive.
Flexible. You can use the method at any stage in the development lifecycle, from early paper prototypes to fully implemented, running systems. Thinking aloud is particularly suited for Agile projects. You can use this method to evaluate any type of user interface with any form of technology .Websites, software applications, intranets, consumer products, enterprise software, mobile design: doesn't matter — thinking aloud addresses them all, because we rely on the users doing the thinking.
Convincing. The most hard-boiled developers, arrogant designers, and tight-fisted executives usually soften up when they get direct exposure to how customers think about their work. Getting the rest of your team (and management) to sit in on a few thinking-aloud sessions doesn't take a lot of their time and is the best way to motivate them to pay attention to usability.
Easy to learn. you don't need these extras to run basic tests for your own design team.

5.3.2 Cooperative evaluation

Cooperative evaluation is a variant of think aloud, in which the user is encouraged to see himself as a collaborator in the evaluation rather than just a subject. As well as getting the user to think aloud, the evaluator can ask such questions as "Why?" and "What if.....?"; likewise, the user can ask the evaluator for clarification if problems arise. This more relaxed approach has a number of advantages. It is less constrained and therefore easier for the evaluator, who is not forced to sit in solemn silence; the user is encouraged to actively criticise the system rather than simply suffer it; and the evaluator can clarify points of confusion so maximising the effectiveness of the approach. Note that it is often not the designer who is the evaluator, but an independent person [170].

Result of Think Aloud & Cooperative evaluation was add new features:
1. Add SOS button
2. Chat Between Parent And Children
3. Notification in Both App

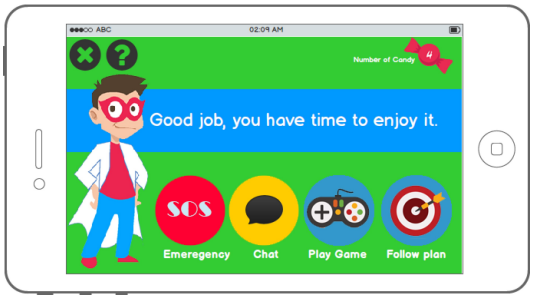

Figure 5.5. *SOS and Chat Button.*

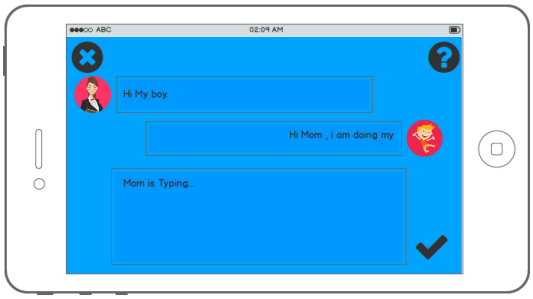

Figure 5.6. *Chat Page.*

5.3.3 Controlled Experiments (ANOVA)

Controlled experiments, an approach that has been adopted from research methods in Psychology, feature large in the arsenal of HCI research methods. Controlled experiments are a widely used approach to evaluating interfaces and styles of interaction, and to understanding cognition in the context of interactions with systems. The question they most commonly answer can be framed as: does making a change to the value of variable X have a significant effect on the value of variable Y? For example, X might be an interface or interaction feature, and Y might be time to complete task, number of errors or users' subjective satisfaction from working with the interface. Controlled experiments are more widely used in HCI research than in practice, where the costs of designing and running a rigorous experiment typically outweigh the benefits [27].

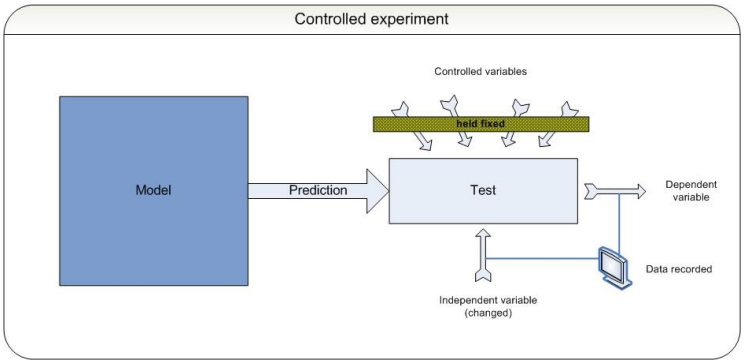

Figure 5.7. *Controlled Experiments [11].*

The ANOVA Test:
An ANOVA test is a way to find out if survey or experiment results are significant. In other words, they help you to figure out if you need to reject the null hypothesis or accept the alternate hypothesis. Basically, you're testing groups to see if there's a difference between them. Examples of when you might want to test different groups [12]:

- A group of psychiatric patients are trying three different therapies: counseling, medication and biofeedback. You want to see if one therapy is better than the others.
- A manufacturer has two different processes to make light bulbs. They want to know if one process is better than the other.
- Students from different colleges
  take the same exam. You want to see if one college outperforms the other.

What Does "One-Way" or "Two-Way Mean?
One-way or two-way refers to the number of independent variables (IVs) in your Analysis of Variance test. One-way has one independent variable (with 2 levels) and two-way has two independent variables (can have multiple levels). For example, a one-way Analysis of Variance could have one IV (brand of cereal) and a two-way Analysis of Variance has two IVs (brand of cereal, calories) [12].

What are "Groups" or "Levels"?
Groups or levels are different groups in the same independent variable. In the above example, your levels for "brand of cereal" might be Lucky Charms, Raisin Bran, Cornflakes — a total of three levels. Your levels for "Calories" might be sweetened, unsweetened — a total of two levels.
If your groups or levels have a hierarchical structure (each level has unique sub-groups), then use a nested ANOVA for the analysis [12].

What Does "Replication" Mean?
It's whether you are replicating your test(s) with multiple groups. With a two-way ANOVA with replication, you have two groups and individuals within that group are doing more than one thing (i.e. two groups of students from two colleges taking two tests). If you only have one group taking two tests, you would use without replication [12].

Types of Tests:
There are two main types: one-way and two-way. Two-way tests can be with or without replication [12].

- One-way ANOVA between groups: used when you want to test two groups to see if there's a difference between them.
- Two way ANOVA without replication: used when you have one group and you're double-testing that same group. For example, you're testing one set of individuals before and after they take a medication to see if it works or not.
- Two way ANOVA with replication: Two groups, and the members of those groups are doing more than one thing. For example, two groups of patients from you'redifferent hospitals trying two different therapies.

Testing of the Assumptions [13]:

1. The population from which samples are drawn should be normally distributed.
2. Independence of cases: the sample cases should be independent of each other.
3. Homogeneity of variance: Homogeneity means that the variance among the groups should be approximately equal.

These assumptions can be tested using statistical software (like Intellectus Statistics!). The assumption of homogeneity of variance can be tested using tests such as Levene's test or the Brown-Forsythe Test. Normality of the distribution of the scores can be tested using histograms, the values of skewness and kurtosis, or using tests such as Shapiro-Wilk or Kolmogorov-Smirnov. The assumption of independence can be determined from the design of the study [13].

It is important to note that ANOVA is not robust to violations to the assumption of independence. This is to say, that even if you violate the assumptions of homogeneity or normality, you can conduct the test and basically trust the findings. However, the results of the ANOVA are invalid if the independence assumption is violated. In general, with violations of homogeneity the analysis is considered robust if you have equal sized groups. With violations of normality, continuing with the ANOVA is generally ok if you have a large sample size [13].

Example of our ANOVA test
Participants:
Sample of Children try to Sign-in to Application
Variables:
1.Independent variables (manipulated)

Interface Design of "Login Form"
"2 Levels"
1- Pattern Password
2- Digit Password

2. Dependent Variables (measured)

Number of Satisfaction (calculated with satisfaction rank)
Outstanding (6), Excellent (5), Very Good (4), Good (3), Average (2), Poor(1)

Hypothesis:
Children Prefer Use Pattern Password instead of Digit Password, because is faster and easy.

Null Hypothesis:
Both Designs have the same satisfaction level

Figure 5.8. *Pattern Password.*

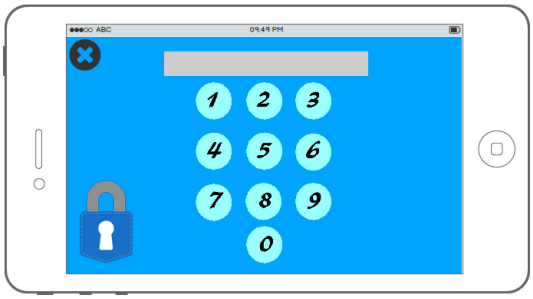

Figure 5.9. *Digit Password.*

Formula Bar

	A	B	C	D	E	F	G	H	I	J
1	Digit Password	Pattern Password								
2	3	5								
3	2	6								
4	1	4								
5	1	3								
6	2	4								
7	4	2		Anova: Single Factor						
8										
9				SUMMARY						
10				*Groups*	*Count*	*Sum*	*Average*	*Variance*		
11				Digit Password	6	13	2.166667	1.366667		
12				Pattern Password	6	24	4	2		
13										
14										
15				ANOVA						
16				*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
17				Between Groups	10.08333	1	10.08333	5.990099	0.034407	4.964603
18				Within Groups	16.83333	10	1.683333			
19										
20				Total	26.91667	11				
21										

Figure 5.10. *Result of ANOVA test.*

Analysis of data:
Results of Applying ANOVA
If **F > F crit**, we reject the null hypothesis.
This is the case, **5.990099 > 4.964603.** Therefore, we reject the null hypothesis. The means of the two populations are not equal.
This means that "Average number of satisfactions is higher when using Pattern Password".

Significance and p-value
Did the difference/effect happen by chance or was it caused by IV (Independent variables)?
Typically, significance level of 0.05
since **P< 0.05 (0.034407<0.05)**
This is a significant result; it could have been caused by the IV.

Therefore, the null hypothesis is rejected / the hypothesis is confirmed

5.4 Final Prototype

The prototype finalized for usability testing was feature rich with an emphasis on data visualization. It had a total of five main sections, contain BG readings and different methods of representing the collected data and detect heart attack, challenges/leaderboard and a food database and SOS, communication.
The goal was to keep the flow as straightforward as possible and make product easy to learn and easy to use and easy to remember.

Figure 5.11. *Final Product.*

Chapter 6

Implementation Phase

6.1 Milestone

A project milestone is a management tool that is used to delineate a point in a project schedule. These points can note the start and finish of a project and mark the completion of a major phase of work. Milestones can be used to symbolize anything that has started or finished, though it's primarily used as a scheduling tool. If a milestone focuses on major progress points in a project, you can see how it is useful in scheduling. Just as tasks break a larger project into manageable parts, milestones break off chunks of a project to make it less daunting [235].
So, when starting a project, milestones can help immensely with scheduling. Milestones are most commonly found in project management software and are represented as diamonds in the Gantt chart feature. Gantt charts are a visual representation of your schedule, laid out on a timeline, with tasks as points along the path to the successful completion of the project. Milestones divide this timeline into project phases [235].

We divided our task in two Milestone.
Authentication:

- Descriaption: You can let your users authenticate with Firebase using their Google Accounts by integrating
- Requires: Add Firebase to your Android project and Add the dependencies for Firebase Authentication and Google Sign-In to your app.
- Due: Milestone 2
- Time Estimation: 4 days

Parent Profile:

- Description: A brief description of the characteristics of parent
- Requires: Design UI and use DataBase with Google App Engine
- Due:Milestone 2
- Time Estimation: 3 days

Setting:

- Description: Parent Can Modify child's account and change application setting

- Requires: Design UI and use DataBase with Google App Engine
- Due:Milestone 2
- Time Estimation: 8 days

Parent Dashboard:
- Description: Parent Can See Short Health report and Manage Diabetes plan(Add,Edit,Remove)
- Requires:Design UI and use DataBase with Google App Engine
- Due:Milestone 2
- Time Estimation: 14 days

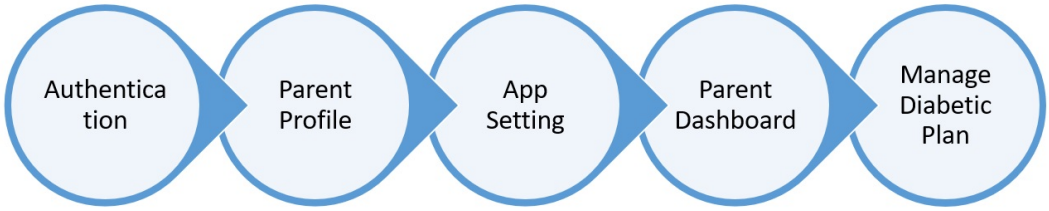

Figure 6.1. *First Milestone.*

Automatic Plan:
- Description:Automatically "dochero" make suggestion of plan
- Requires: Design UI and use DataBase with Google App Engine.
- Due: Milestone 3
- Time Estimation: 14 days

Manual plan:
- Description: Children can do and follow their plan manually
- Requires: Design UI and use DataBase with Google App Engine
- Due: Milestone 3
- Time Estimation: 7 days

Child Dashboard:
- Description: Parent Can Modify child's account and change application setting
- Requires: Design UI and use DataBase with Google App Engine
- Due:Milestone 3
- Time Estimation: 5 days

Limitation of Game:
- Description: Manage time of play game
- Requires: Create System Application
- Due: Milestone 3
- Time Estimation: 20 days

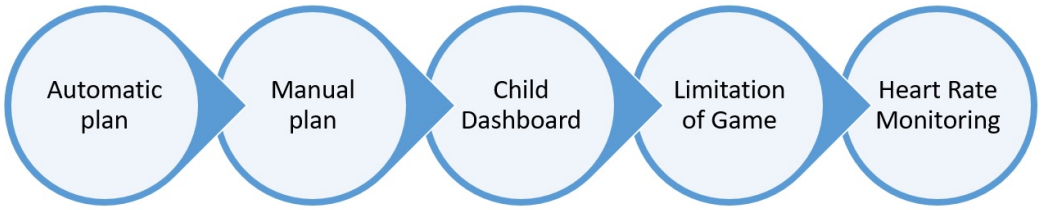

Figure 6.2. *Second Milestone.*

6.2 Development Environment and Architecture Design

Software Architecture

The software architecture of a program or computing system is a depiction of the system that aids in understanding how the system will behave [119]. Architecture serves as a blueprint for a system. It provides an abstraction to manage the system complexity and establish a communication and coordination mechanism among components [225].

- It defines a structured solution to meet all the technical and operational requirements, while optimizing the common quality attributes like performance and security.
- Further, it involves a set of significant decisions about the organization related to software development and each of these decisions can have a considerable impact on quality, maintainability, performance, and the overall success of the final product.

Software Design

Software design provides a design plan that describes the elements of a system, how they fit, and work together to fulfill the requirement of the system. The objectives of having a design plan are as follows [225]:

- To negotiate system requirements, and to set expectations with customers, marketing, and management personnel.
- Act as a blueprint during the development process.
- Guide the implementation tasks, including detailed design, coding, integration, and testing.

It comes before the detailed design, coding, integration, and testing and after the domain analysis, requirements analysis, and risk analysis [225].
When we begin the design phase, we build a conceptual model of the hardware/software system. It is in this model that we exploit as much abstraction as appropriate. The project is broken into modules or subcomponents. During this phase, we estimate the cost, schedule, and expected performance of the system [229].

Role of Software Architect
A Software Architect provides a solution that the technical team can create and design for the entire application. A software architect should have expertise in the following areas [225]:

Design Expertise
- Expert in software design, including diverse methods and approaches such as object-oriented design, event-driven design, etc.
- Lead the development team and coordinate the development efforts for the integrity of the design.
- Should be able to review design proposals and tradeoff among themselves.

Domain Expertise
- Expert on the system being developed and plan for software evolution.
- Assist in the requirement investigation process, assuring completeness and consistency.
- Coordinate the definition of domain model for the system being developed.

Technology Expertise
- Expert on available technologies that helps in the implementation of the system.
- Coordinate the selection of programming language, framework, platforms, databases, etc.

Methodological Expertise
- Expert on software development methodologies that may be adopted during SDLC (Software Development Life Cycle).
- Choose the appropriate approaches for development that helps the entire team.

Hidden Role of Software Architect
- Facilitates the technical work among team members and reinforcing the trust relationship in the team.
- Information specialist who shares knowledge and has vast experience.
- Protect the team members from external forces that would distract them and bring less value to the project.

Deliverables of the Architect
- A clear, complete, consistent, and achievable set of functional goals
- A functional description of the system, with at least two layers of decomposition
- A concept for the system
- A design in the form of the system, with at least two layers of decomposition
- A notion of the timing, operator attributes, and the implementation and operation plans
- A document or process which ensures functional decomposition is followed, and the form of interfaces is controlled

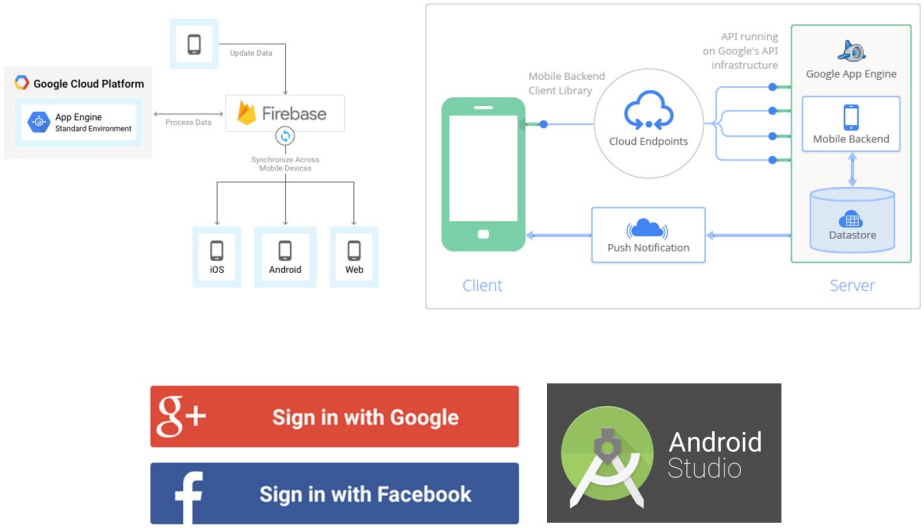

Figure 6.3. *Architect and Technology.*

Mobile Backend as a Service (MBaaS):
Mobile backend as a service (MBaaS) is a cloud computing architecture that provides mobile applications with access to the servers, storage, databases and other resources they need to run [189].
An alternative to mobile middleware, a backend as a service (BaaS) approach uses unified application programming interfaces (APIs) and software developer's kits (SDKs) to connect mobile apps to backend resources in the cloud. MBaaS can also be used to federate backend services and provide common backend features such as push notifications, social networking integration and location services. This is a departure from typical mobile application development, which requires developers to incorporate the APIs of each backend service individually [189].
MBaaS empowers mobile developers by completely abstracting the server-side infrastructure. Developers can assemble the required building blocks and just write the code that connects them. This lets developers focus on delivering rich user experiences instead of dealing with mundane backend infrastructure [189].
Firebase is the perfect choice for this project as development tool for several reasons. Firebase is a back end as a service solution that has far more features than its competitors. It is a set of tools offered by Google to build excellent scalable applications in the cloud. It is a powerful service that helps in building applications quickly without reinventing the components or modules. Services like analytics, authentication, databases, configuration, file storage, push messaging are provided by firebase thereby making it easy for the developers to focus on the user experience of the application [161].

Key interesting features and benefits of Firebase:
Authentication
Firebase Auth product provides various methods to authenticate that includes email and password. Additionally, more methods are available to authenticate 3rd party

providers like Google. You can either create your own interface or use the open source customizable user interface. Firebase offers easy to use SDK and ready-made UI libraries to authenticate the apps [161].

Real time database

This feature ensures that the data between the users are stored and synchronized in real time with the help of the NoSQL database. When you want the app data to remain available even if the app goes offline, firebase will be the right choice. It updates the data syncs in just a few milliseconds. Firebase for mobile app development is scalable and accessible from client devices [161].

Dynamic links

With dynamic links, firebase ensures a customized user experience for your application across all the platforms. You can use dynamic links to drive the native app conversions. The user opening the dynamic link will be prompted to install the app in case the application is not already installed. By this, many people can install your application easily [161].

Cloud Messaging

The firebase cloud messaging (FCM) allows you in delivering the push messages to indicate something of interest to the users of your app. You can send a message through two easy ways. First, you can write code on the backend to ping your app every time something gets updated, for example, direct users notifications. Another option is you can compose a message with the help of firebase console to ping users with information of interest. This is direct user notification which is commonly used. It is always better to send a message to members of analytics audience. This helps you in targeting users with information which interest them instead of blasting irrelevant messages to everyone [161].

Automatic Scaling

Firebase is built for performance and scalability. As and when there is a change in data, Firebase helps in the calculation of the minimum set of updates needed to keep all your clients synchronized. Additionally, the API functions of firebase are designed in order to scale linearly with the size of data being synchronized. It handles the scaling operations. Your application will scale from its first user to its first million user without any change in the code [161].

6.3 User Interface Layout

User Interface (UI) Design focuses on anticipating what users might need to do and ensuring that the interface has elements that are easy to access, understand, and use to facilitate those actions. UI brings together concepts from interaction design, visual design, and information architecture [228].

Best Practices for Designing an Interface

Everything stems from knowing your users, including understanding their goals, skills, preferences, and tendencies. Once you know about your user, make sure to consider the following when designing your interface [228]:

- Keep the interface simple. The best interfaces are almost invisible to the user. They avoid unnecessary elements and are clear in the language they use on labels and in messaging.
- Create consistency and use common UI elements. By using common elements in your UI, users feel more comfortable and are able to get things done more quickly. It is also important to create patterns in language, layout and design throughout the site to help facilitate efficiency. Once a user learns how to do something, they should be able to transfer that skill to other parts of the site.
- Be purposeful in page layout. Consider the spatial relationships between items on the page and structure the page based on importance. Careful placement of items can help draw attention to the most important pieces of information and can aid scanning and readability.
- Strategically use color and texture. You can direct attention toward or redirect attention away from items using color, light, contrast, and texture to your advantage.
- Use typography to create hierarchy and clarity. Carefully consider how you use typeface. Different sizes, fonts, and arrangement of the text to help increase scanability, legibility and readability.
- Make sure that the system communicates what's happening. Always inform your users of location, actions, changes in state, or errors. The use of various UI elements to communicate status and, if necessary, next steps can reduce frustration for your user.
- Think about the defaults. By carefully thinking about and anticipating the goals people bring to your site, you can create defaults that reduce the burden on the user. This becomes particularly important when it comes to form design where you might have an opportunity to have some fields pre-chosen or filled out.

6.4 Feature of System

6.4.1 Managing Diabetes

One of the main features of the our Mobile Application is that it acts as a management tool for diabetic Children. In order to do that, Follow Plans, Add/pdate/Delete Plan functionalities were implemented.

Follow plans: This is automatic recommendation plan from doc hero and recommendation is based on time. If recommend plan have multi item, you can choose one of them, they are optional.
At time of schedule, system show notification to child for follow their diabetic plan.For example, time is 19 and it is dinner time, so show notification to children to follow dinner plan.

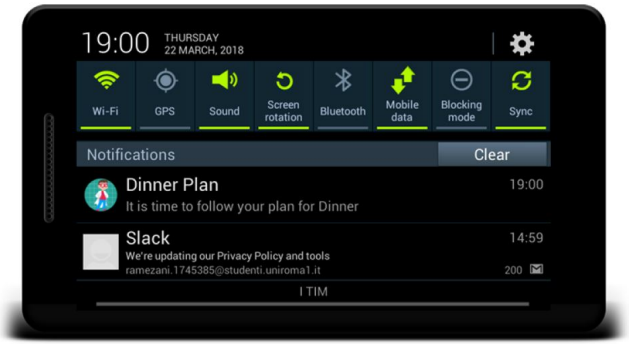

Figure 6.4. *Notification for plan time.*

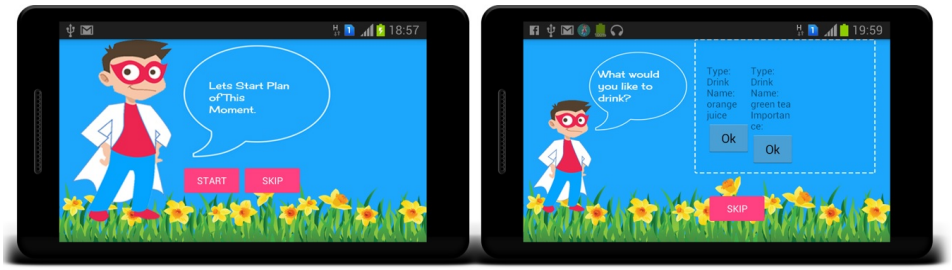

Figure 6.5. *Follow Automatic plans.*

Add Plan: Parent can Fill the form according of their plan.Main means in this plan is mandatory and optional means can be alternative of another plan.If you make plans just for one week, this plan automatically repeated for another week.Count field is dependent on type of your plan.Number of Week means which week of month is your target.
Plan type is contained check blood sugar, inject insulin, use drug, food, fruit, drink and snack. Food type is contained starch, protein, vegetables and dairy. Meal type is contained breakfast, before noon, lunch, after noon, dinner and before sleep.

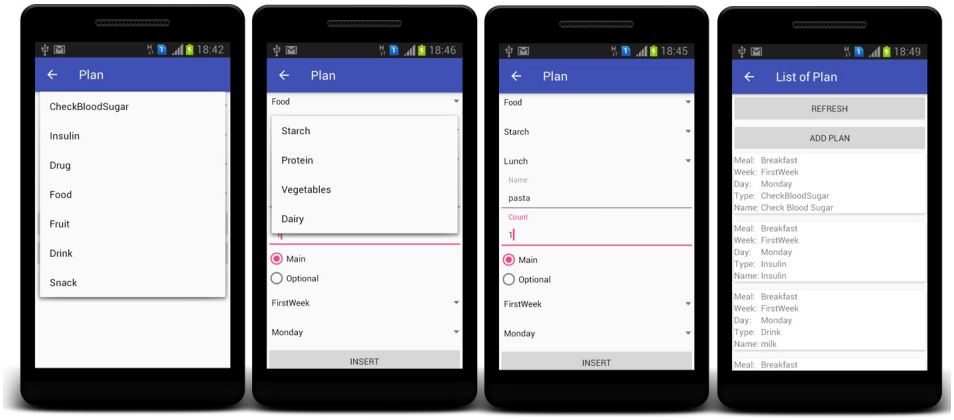

Figure 6.6. *Add plans.*

Time schedules: We set default time schedule, but user can change it according on Her own lifestyle. Update time from and time to according on choose. For example, here we change breakfast time, start from 8 o'clock and finished in 9 o'clock.

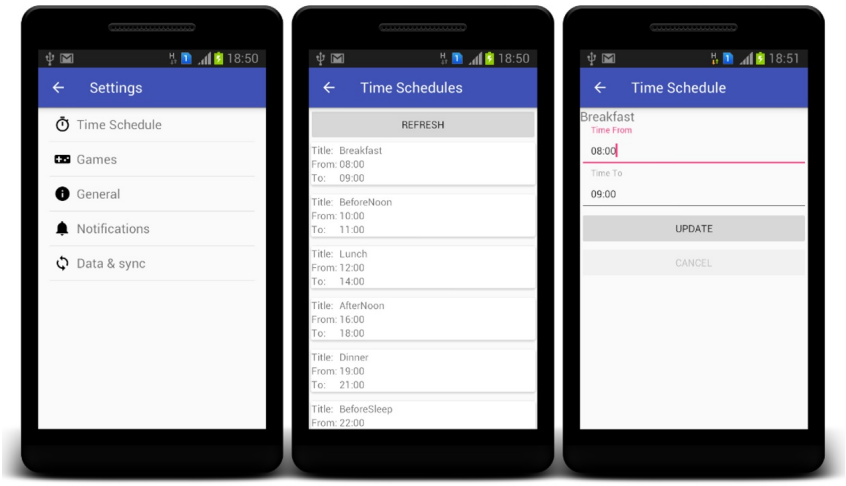

Figure 6.7. *Time schedules.*

6.4.2 Logbook

This is a logbook that helps diabetic patients in recording their blood glucose test readings. The logbook also stores information other than the blood glucose results. All these fields are important for the user to monitor progress and manage his/her condition better. However, the only field that is required to be filled in by the user is the blood glucose level; others are optional.

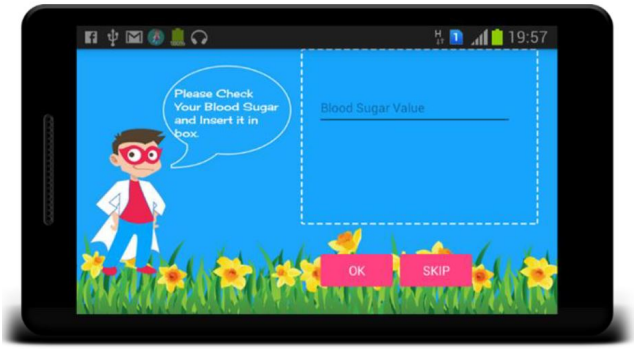

Figure 6.8. *Logbook.*

6.4.3 Graph

A graph is created based on the user's logbook entry to give the user a visual record of their progress. This will allow users to identify trends. Therefore, they could

adjust their diet according to the information they get from the chart. Moreover, the visual record would encourage them to keep their chart balanced.
We provide different Report based on Time Duration.

Figure 6.9. *Graph.*

6.4.4 Profile

The system has two types of profiles, Children profiles and Parents profiles. Every Parent registered on the App has their own profile. They can add children and They can enter their information and personalize it with pictures.

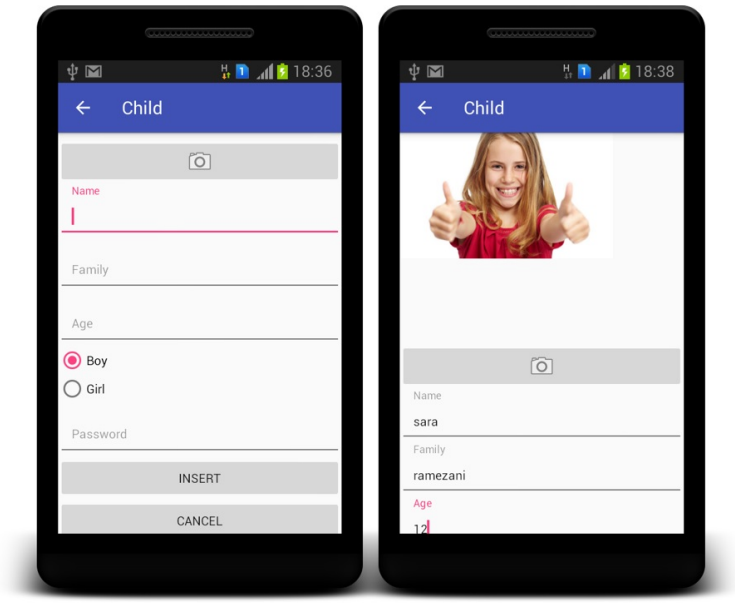

Figure 6.10. *Children's Profile.*

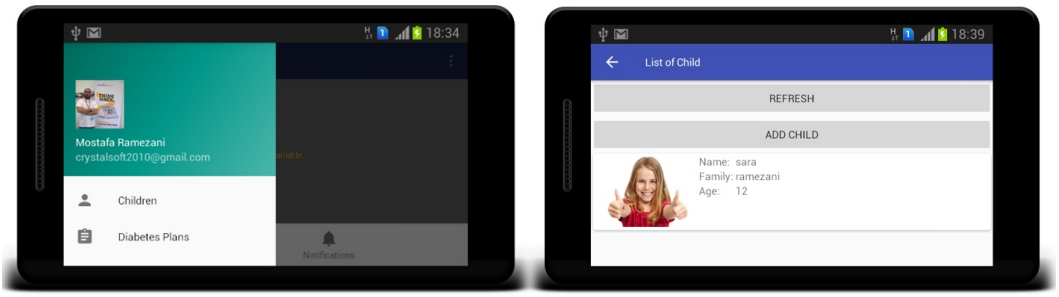

Figure 6.11. *Add Children.*

6.4.5 Gamification

The difficulty in managing childhood diabetes occurs largely during school time, which forms a large proportion of the day and is a period during which the child is not supervised by the parent [46].
Future iterations would revise the use case to accept this difficulty, that many children are currently limited to playing the game on their parents' mobile phones outside school time. Achieving "optimum" diabetes control can lead to a heightened risk of hypoglycemia. Designers of game apps should be mindful of this when attempting to influence a patient's self-management, to avoid iatrogenic hypoglycemia, although this has not been reported so far with any of the presented games [46].
For every goal and task in plan we created a number of points. The aim of the point system is to engage users and reinforce positive behavior. The points are shown on each user's profile page.
Children need candy for play any video game in phone. Candy is virtual money and they can spend candy to get time for play video game.
When children play the game or use application, during playing they get notification about number of candies and candy number decrees base on time usage of game. If candy become finish they get notification to stop playing game or stop using application. Therefore, children should follow their plan to get new candy.

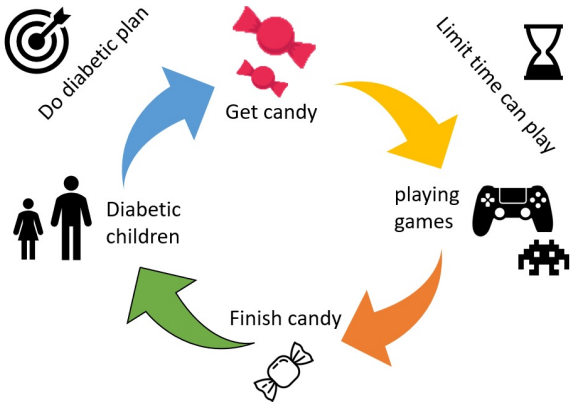

Figure 6.12. *Product overview and motivation.*

During playing game we show notification of remain number of candies. We propose to children to stop playing before finishing candy.

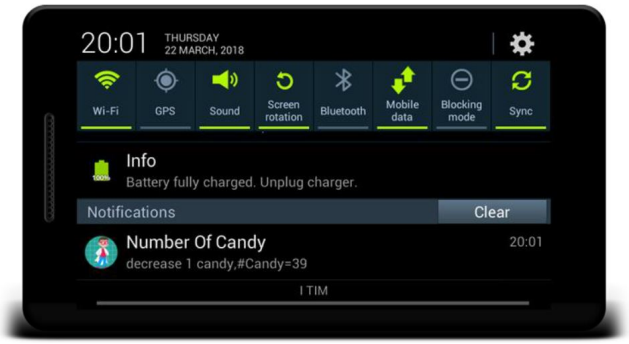

Figure 6.13. *Candy Notification.*

If thier candy become finish but they still playing game, they must stop play the game else notification send to their parent.

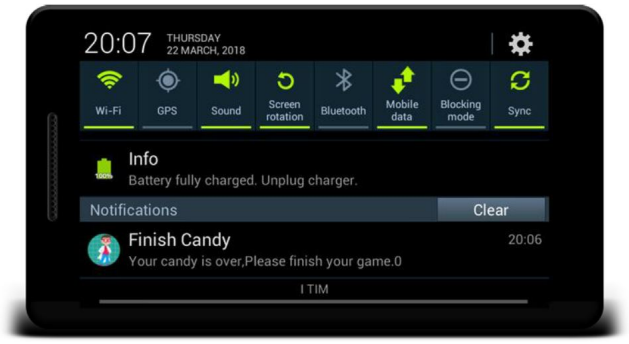

Figure 6.14. *Finish Candy.*

Parent get Game Time management message when the candy is finished or their children without candy playing game.

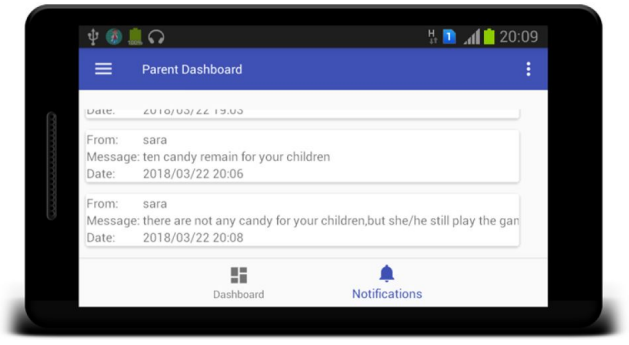

Figure 6.15. *Notification of Game Time management.*

Parent can Choose the application they want limit to use. This application is runnable when children have candy (Time to play). For example, we select Facebook

app or Angry bird game.
When children play the game or use application, during playing they get notification about number of candies. And if candy become finish, they get notification to stop playing game or stop using application.

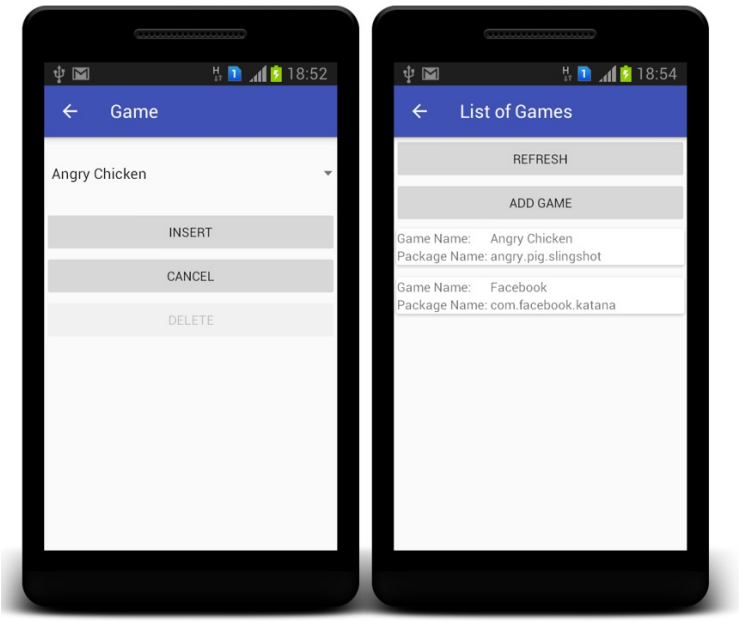

Figure 6.16. Add App or Game for Limitation.

6.4.6 Chat

Parents and children can send private messages to each other on the system.

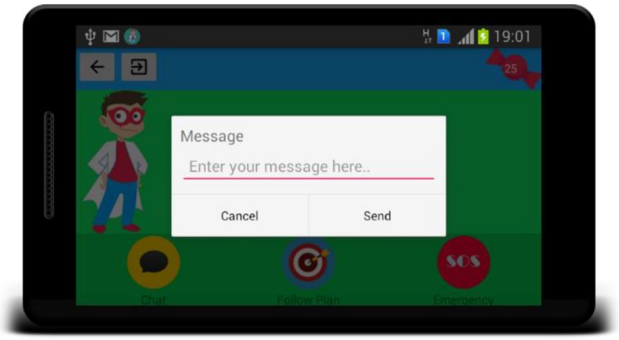

Figure 6.17. *Add App or Game for Limitation.*

6.4.7 SOS

After push SOS button, we will send children emergency need with their current location to their parent.

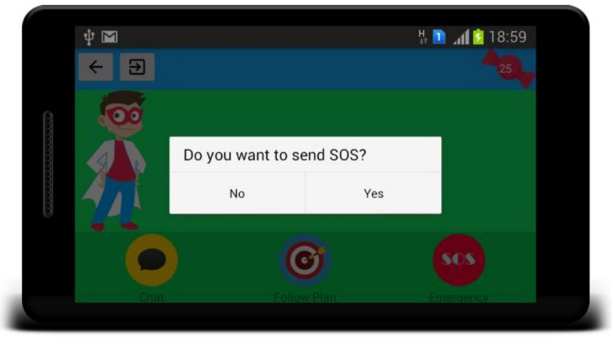

Figure 6.18. *Emergency SOS.*

6.4.8 Login in Using Social Networks

This feature gives users the option to login using their existing accounts in one of the big social networks (Facebook, Twitter and Google . . .), instead of creating a new account using their email addresses. This was implemented to encourage users to use the website and to simplify the registration process for them. It was implemented using Firebase Authentication module.

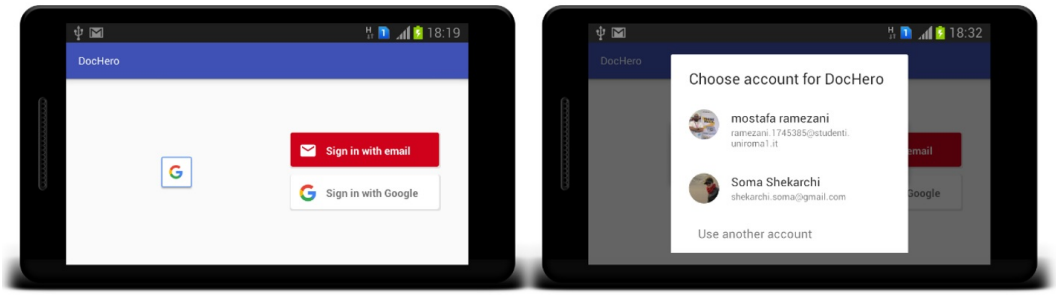

Figure 6.19. *Sign up with Google Account.*

6.5 Heart Attack Detection

Low blood sugar levels, known as hypoglycemia, in people with diabetes may cause potentially dangerous changes in heart rate, according to a small new study [98].This study's findings may help explain why a large scale study found that very tight control of blood sugar levels in people with type 2 diabetes led to higher-than-expected death rates. It may also help explain why some otherwise healthy people with type 1 diabetes die during their sleep, sometimes called "dead-in-bed syndrome" without an apparent cause, researchers say [98].These periods of hypoglycemia were associated with a high risk of marked slow heart rates [bradycardia] accompanied by [abnormal] beats. We have therefore identified a mechanism which might contribute to increased mortality in individuals with type 2 diabetes and high cardiovascular risk during intensive insulin therapy [98].

To reduce the probability of death of diabetic children when they sleep and to analyze the data of the body condition for the betterment of life, A wireless health monitoring system can be introduced. This health monitoring system is required for all ages of the diabetic people. Wearable wireless health monitoring system is the most important system, which can continuously monitor the health of the patients, which avoids the situation for the patients to be present at the hospital each and every time for the check up and emergency.
We describe the design, development and evaluation of a wearable heart rate and physical activity monitoring system, that is able to capture and stream ECG and heart rate values in real-time via using a Polar H10 Heart Rate Sensor and a smartphone application, We can analysis data to shows the variation from which the disease can be detected and diagnosed initially.

Figure 6.20. *Architecture of heart rate monitoring.*

We choice Polar H10 and Polar H7 heart rate for monitor heart rate because with Polar, heart rate monitoring is more accurate and adaptable than ever. The chest strap, that can monitor the body condition in real time and can send the data to the mobile phone via Bluetooth. We can send data to cloud via phone where the doctors can monitor their patients.

6.5.1 Get heart rate from Bluetooth low energy

Bluetooth Low Energy (BLE)
Bluetooth Low Energy is the intelligent, power-friendly version of Bluetooth wireless technology. It is already playing a significant role in transforming smart gadgets to smarter gadgets by making them compact, affordable, and less complex [74].
The challenges classic Bluetooth faced were fast battery draining and frequent loss of connection, requiring frequent pairing and re-pairing. Being able to successfully

address these is one of the reasons for BLE's rapid growth. Further driving adoption is the phenomenal growth in smartphones, tablets, and mobile computing [74].
A BLE piconet is typically based on a master connected to a number of slaves. A device is either a master or a slave, but never both. The master controls how often the slaves are allowed to communicate, and the slave only communicates by request from the master. A new feature BLE adds compared to classic Bluetooth technology is "advertising" functionality. With this feature, a device acting as a slave can announce that it has something to transmit to the master. An advertisement message can also include an event or a measurement value [74].

Generic Attribute Profile (GATT)
The Bluetooth GATT (Generic Attribute Profile) is the foundation for the design of any BLE system and defines the way a smartphone application (or any central device) interacts with the end-device (the peripheral device) [17].
Keep in mind that GATT is used exclusively after a connection has been established between the two devices. The Bluetooth SIG defines quite a few standard Profiles, Services, and Characteristics [17].

Just as the GAP layer handles most connection-related functionality, the GATT layer of the Bluetooth low energy protocol stack is used by the application for data communication between two connected devices. Data is passed and stored in the form of characteristics which are stored in memory on the Bluetooth low energy device. From a GATT standpoint, when two devices are connected, they are each in one of two roles [104].

- **The GATT server:** the device containing the characteristic database that is being read or written by a GATT client [104].This is the device that exposes the data it controls or contains, and possibly some other aspects of server behavior that other devices may be able to control. It is the device that accepts incoming commands from a peer device and sends responses, notifications, and indications [17].
- **The GATT client:** the device that is reading or writing data from or to the GATT server [104].This is the device that interfaces with the server with the purpose of reading the server's exposed data and/or controlling the server's behavior. It is the device that sends commands and requests and accepts incoming notifications and indications [17].

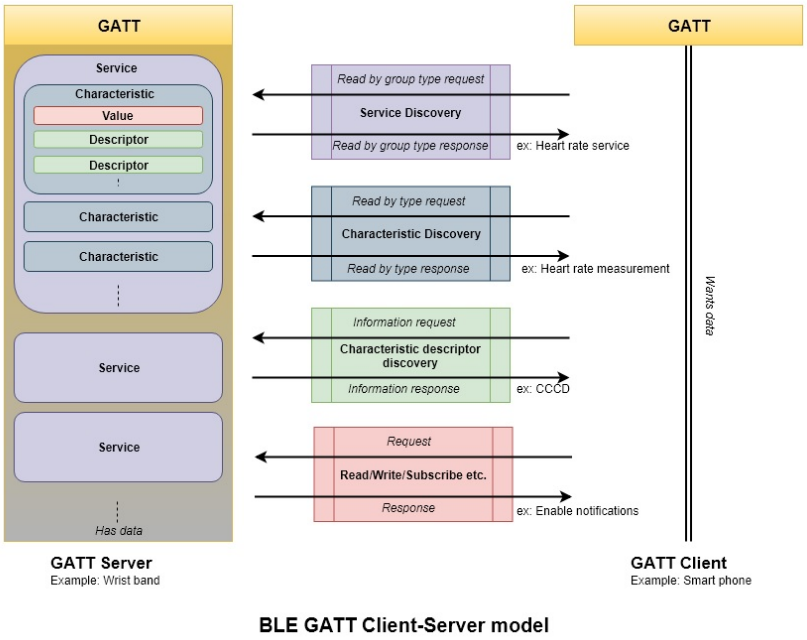

Figure 6.21. *BLE GATT Client-Server model [152].*

Communicate with BLE device

A BLE device can have one or more GATT profiles for multiple purposes like Temperature measurement and Heart Rate measurement. Each GATT profile contains a Service and each service has some Characteristics. Each of these attributes is uniquely identified by a Universally Unique Identifier (UUID), which is a standardized 128-bit format for a string ID used to uniquely identify information [174].
To communicate with BLE device, we should know from which service and characteristic, the data can be retrieved [174].
We use BluetoothAdapter and object to identify if the Bluetooth is enabled on device in Android, It represents the device's Bluetooth adapter. We Used BluetoothGattCallback to deliver results to the client, such as connection status, as well as any further GATT client operations.

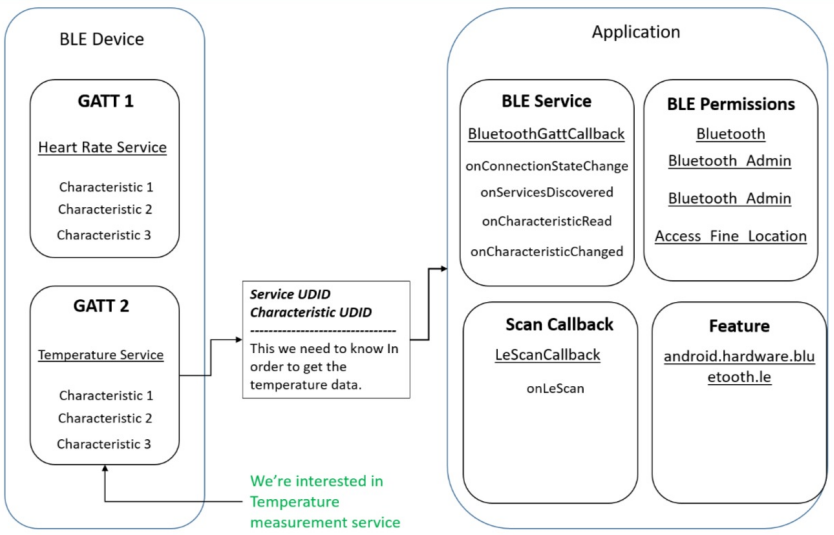

Figure 6.22. *Android Bluetooth Low Energy Communication components [174].*

6.5.2 Detect a Heart Attack

Monitoring ECG and performing automatic diagnosis become particularly important. In cardiology, the electrical actions of a human's heart are simply and painlessly recorded by electrocardiogram (ECG) via single or multiple-lead detections [120]. The real-time ECG sequence of a patient represents one of the most useful clinical diagnostic features on cardiovascular diseases, reflecting the electrophysiological activity of cardiac excitement, and indicating great importance on the aspects of basic heart functions and related pathological research [117]. Meanwhile, ECG is of crucial importance for analyzing and identifying various arrhythmias, which reflect the degree of myocardial damage, the corresponding development process, and the functional structure of both atria and ventricles [117].

We use two approach to monitor hear beat and detect heart attack:

1. **Consider a Dangerous Heart Rate:**
   Heart rates can vary from person to person, both tachycardia and bradycardia can be indicators of an underlying health condition. If children are experiencing either, you could have an underlying condition that requires medical evaluation and treatment. When your heart rate is too fast, it's called tachycardia. For adults, a fast heart rate is generally defined as a heart rate over 100 beats per minute. However, what's considered too fast may also depend on your age and overall health. When your heart rate is too slow, it's referred to as bradycardia. Bradycardia is typically defined as a heart rate that's less than 60 beats per minute.For athletes and people that exercise regularly, a heart rate of under 60 beats per minute is normal and even healthy [199]. Children's heart rates are normally faster than those of adults. According to Cleveland Clinic, the normal resting heart rate for a child aged six to 15 is between 70 to 100 beats per minute.If you experience a heart rate

that's too high or too low for an extended period of time, it can lead to a variety of potentially serious health complications, including [199]:

- blood clots
- heart failure
- recurring fainting spells
- sudden cardiac arrest

Resting heart rate can vary from person to person and be influenced by a variety of factors. A normal resting heart rate for an adult is between 60 and 100 beats per minute. Both tachycardia and bradycardia can be indicators of other health conditions. If left untreated, they can lead to potentially serious health complications. If you're experiencing a heart rate that's consistently too high or too low, you should make an appointment with your doctor [199]. Other factors that can affect resting heart rate include [199]:

- **Age.** You may find that your resting heart rate decreases as you get older.
- **Temperature.** Your heart rate may increase slightly when you're exposed to hot temperatures.
- **Medication side effects.** For example, medications such as beta-blockers can lower your resting heart rate.
- **Emotions.** If you're anxious or excited, your heart rate may increase.
- **Weight.** People who are obese may have a higher resting heart rate. This is because the heart has to work harder to supply the body with blood.
- **Body positioning.** Heart rate can increase temporarily when you move from a sitting to a standing position
- **Smoking.** Smokers tend to have a higher resting heart rate. Quitting smoking can help bring it back down.

How does it work:
Base on children age we monitor heart rate, if it is too fast or too slow then we will make alarm and we will send message and call to parent/attendant.

2. Arrhythmia Detection Using Machine Learning techniques: Arrhythmias can take place in a healthy heart and be of minimal consequence, but they may also indicate a serious problem that may lead to stroke or sudden cardiac death. For this reason, automatic arrhythmia detection is crucial in clinical cardiology especially when performed in real time, and that is the point in which the field of machine learning comes in handy [196].

What is Atrial Fibrillation (AFib or AF)?
Atrial fibrillation is a quivering or irregular heartbeat (arrhythmia) that can lead to blood clots, stroke, heart failure and other heart-related complications [31]. It means your heart's normal rhythm is out of whack. Because your blood isn't moving well, you're more likely to have heart failure. That's when your heart can't keep up with your body's needs. Blood can also pool inside your heart and form clots. If one gets stuck in your brain, you can have a stroke [140].

What happens during AFib?

Normally, your heart contracts and relaxes to a regular beat. In atrial fibrillation, the upper chambers of the heart (the atria) beat irregularly (quiver) instead of beating effectively to move blood into the ventricles. If a clot breaks off, enters the bloodstream and lodges in an artery leading to the brain, a stroke result. About 15–20 percent of people who have strokes have this heart arrhythmia. This clot risk is why patients with this condition are put on *blood thinners. Even though untreated atrial fibrillation doubles the risk of heart-related deaths and is associated with a 5-fold increased risk for stroke, many patients are unaware that AFib is a serious condition [31].

What is K-Nearest Neighbors Algorithm?
K-nearest neighbors (KNN) algorithm is a type of supervised ML algorithm which can be used for both classification as well as regression predictive problems. However, it is mainly used for classification predictive problems in industry [224]. The following two properties would define KNN well [224]:

- **Lazy learning algorithm:** KNN is a lazy learning algorithm because it does not have a specialized training phase and uses all the data for training while classification.
- **Non-parametric learning algorithm:** KNN is also a non-parametric learning algorithm because it doesn't assume anything about the underlying data.

Working of KNN Algorithm
K-nearest neighbors (KNN) algorithm uses 'feature similarity' to predict the values of new datapoints which further means that the new data point will be assigned a value based on how closely it matches the points in the training set [224]. We can understand its working with the help of following steps [224]:

Step 1) For implementing any algorithm, we need dataset. So, during the first step of KNN, we must load the training as well as test data.

Step 2) Next, we need to choose the value of K i.e. the nearest data points. K can be any integer.

Step 3) For each point in the test data do the following:

3.1) Calculate the distance between test data and each row of training data with the help of any of the method namely: Euclidean, Manhattan or Hamming distance.The most commonly used method to calculate distance is Euclidean.

3.2) Now, based on the distance value, sort them in ascending order.

3.3) Next, it will choose the top K rows from the sorted array.

3.4) Now, it will assign a class to the test point based on most frequent class of these rows.

Step 4) End

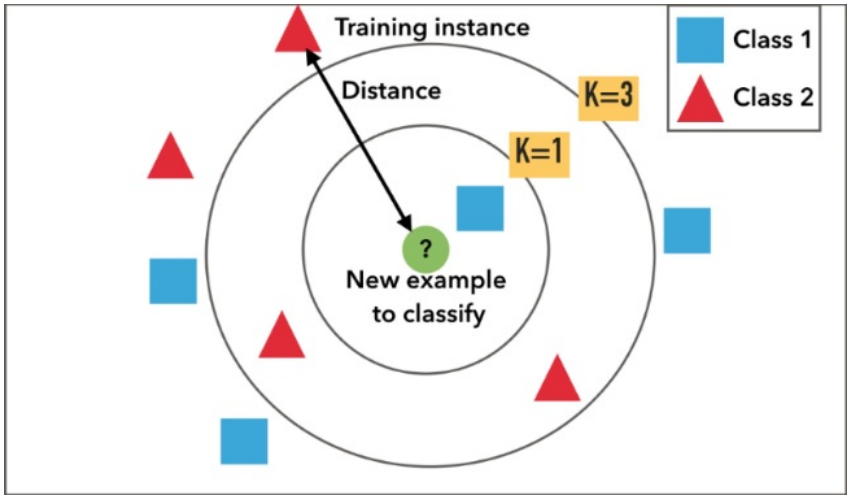

Figure 6.23. *Example of k-NN classification [50].*

The test sample (inside circle) should be classified either to the first class of blue squares or to the second class of red triangles. If k = 3 (outside circle) it is assigned to the second class because there are 2 triangles and only 1 square inside the inner circle. If, for example k = 5 it is assigned to the first class (3 squares vs. 2 triangles outside the outer circle) [50].

Some pros and cons of KNN [50]

- Pros:
  - o No assumptions about data — useful, for example, for nonlinear data
  - o Simple algorithm — to explain and understand/interpret
  - o High accuracy (relatively) — it is pretty high but not competitive in comparison to better supervised learning models
  - o Versatile — useful for classification or regression
- Cons:
  - o Computationally expensive — because the algorithm stores all of the training data
  - o High memory requirement
  - o Stores all (or almost all) of the training data
  - o Prediction stage might be slow (with big N)
  - o Sensitive to irrelevant features and the scale of the data

How does it work:

The Polar sensor detects heartbeats. They are pre-processed and then elaborated from Machine learning algorithm, android application that shows the BPM in screen and make alarm when it is affected by atrial fibrillation.

This system consists of two parts, the detection and classification of heartbeats. The system detects heartbeats through repetitive features and classifies them using a k-nearest neighbor algorithm. The system was validated with the UCI Machine Learning Repository Arrhythmia Data Set. The obtained result is that each implementation returns an accuracy approximately of the 92%.

Every instance is represented by a vector of five values, each with a class label. The values of the input vector:

1. The average of the last three beats
2. The last beat
3. The second to last beat
4. The third to last beat
5. The average of the last ten beats

The class label: 1 in case in fibrillation, 0 otherwise
After getting new Instance from Polar sensor, to classify a new instance we evaluate the input values and then the KNN returns the class label.

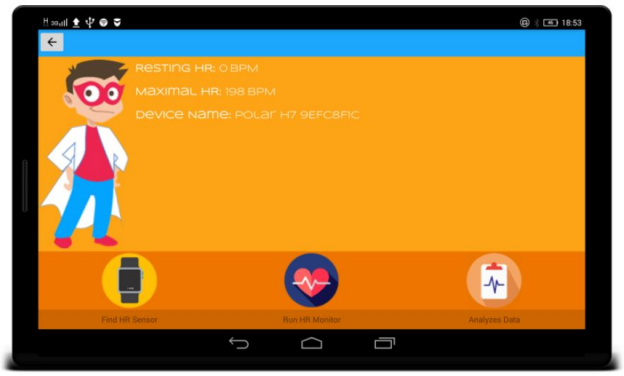

Figure 6.24. *Dashboard of Heart Rate Monitoring.*

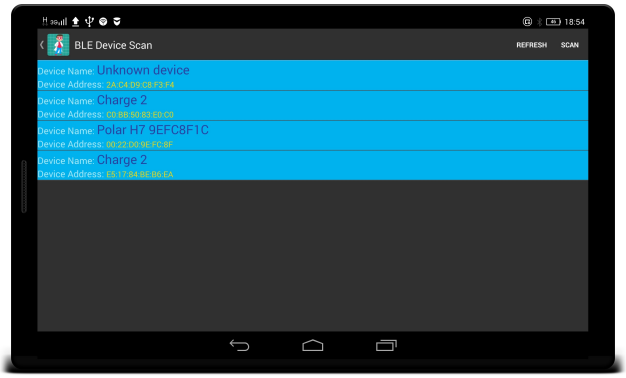

Figure 6.25. *Scan BLE Device and Connect to Device.*

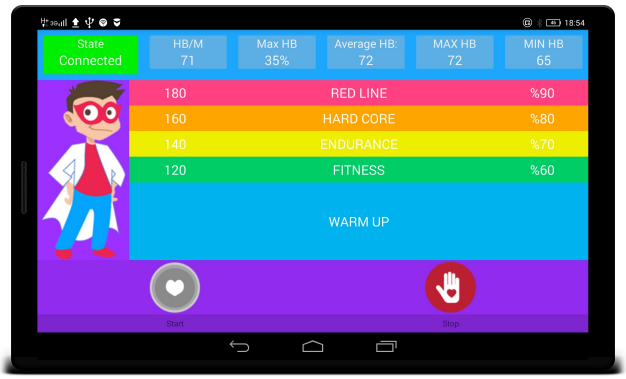

Figure 6.26. *Heart Rate Monitoring Page.*

Figure 6.27. *Run Alarm When Heart Rate Reach to Dangerous Situation or When detect Atrial Fibrillation.*

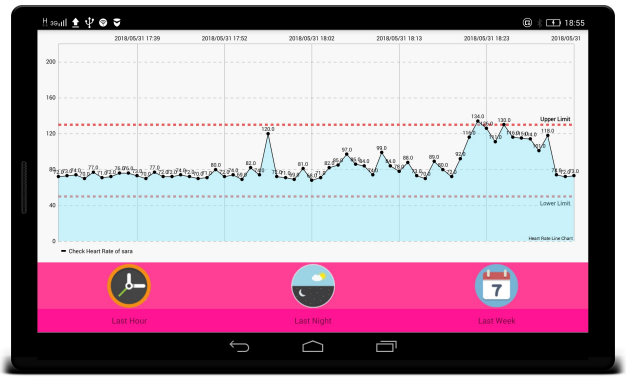

Figure 6.28. *Report of Heart Rate.*

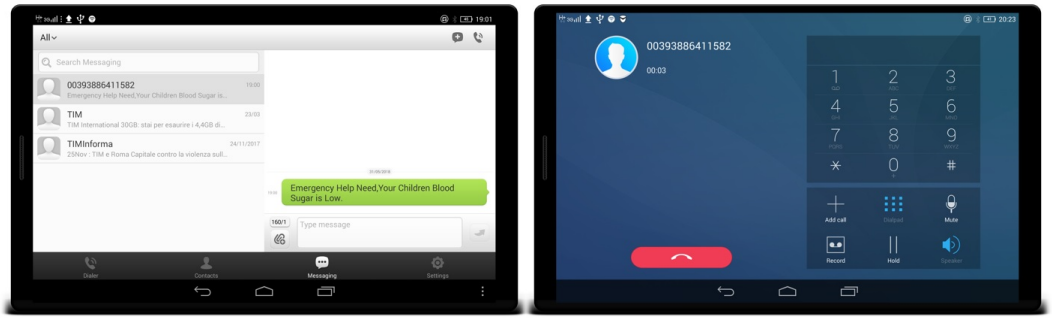

Figure 6.29. *Send Message and Call to Parrent When Heart Attack detected.*

If Parents need use more Attendant, they can add new attendant to application. The attendant information should be containing the Name of attendant and Cell phone number.

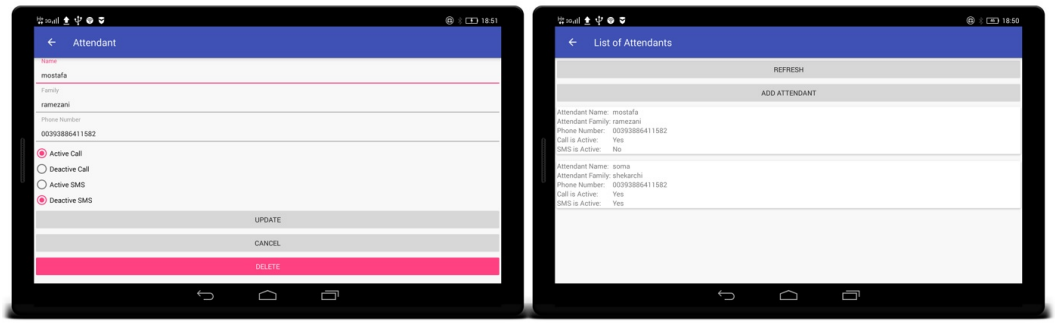

Figure 6.30. Add new Attendant to system.

6.6 The comparison of Sleep Trackerd and Heart rate monitors

A staggering 83 million Americans are sleep-deprived, and new studies come out almost daily reporting that not getting enough quality shuteye can cause both immediate and long-term health problems. If you're not getting enough of restful bedtime, you're at higher risk for a wide array of issues, including obesity, Alzheimer's disease, chronic pain, and illness. Today's busy lifestyles, long working hours and endless to-do lists mean that it's more challenging than ever to fit this activity into our schedules. And even when we do manage to get some rest, are we falling into the deep sleep that our bodies need to repair and restore? The chances are that the thoughts and stresses of the day are creeping into our bedrooms and preventing us from getting the restful nights we desperately need [16].

Sleep trackers have become very popular in recent years, particularly among those who have trouble falling or staying asleep. They measure sleep patterns based on factors like nocturnal movement and heart rate. They may also monitor snoring and

other sounds using smart listening technology, and also track ambient noise, room temperature, air quality, and light levels [221].

How to Monitor Sleep?
To monitor your sleep, you'll need a device that can monitor your movement, monitor your cycle (whether it's light, deep or REM sleep), and then report on how much and well you slept throughout the night. Armed with this data, you'll have an objective report of how well you slept and when and where you can work on improvement. When done over consistent periods, you can even begin correlating with real data the quality of your bedtime with your energy and focus throughout the day. Professional athletes also use this information to plan how they structure their workouts! Because the quality of our bedtime is now known to be a key component in achieving and maintaining a healthy lifestyle, we can expect to see these trackers become more mainstream in our culture [16].

Types of Sleep Trackers
While sleep trackers come with a wide variety of designs and features, they can typically be classified into one of two categories: wearable and non-wearable. We dive into the different varieties of wearable and non-wearable sleep trackers below:

- **Wearable:** Wearable technology is a becoming a huge trend, so it makes sense that we would now be able to wear a sleep tracker. The advantage of these wearable devices is that they serve double duty as a fitness and activity monitor and GPS.These compact, watch-like accessories often include capabilities like calorie intake,heart rate monitoring and activity and movement throughout the day [16].Just in the last few years, the technology of the wearable trackers, as well as the aesthetic,have vastly improved. They used to look like hunks of plastic bands around someone's wrist, but now they have a more streamlined and fashionable look in the form of a stylish watch, and in some cases a bracelet, that should jumpstart adoption of these devices [16].
    - **Watches.** To determine sleep quality, many smartwatches and wrist trackers monitor movement and heart rate throughout the night through the use of sensors. These trackers often connect to mobile apps to present graphs or visual displays of collected nighttime data, so you can review disturbances and get actionable advice for improving sleep the next morning [221].
    - **Rings.** Less obtrusive than your average fitness watch, sleep tracker rings typically slip around the finger to sense body temperature, pulse, and movement as you sleep. As with watches, rings often double as fitness trackers by monitoring things like calories, movement, and heart rate during the day. And like wearable watches, rings may connect to an app to provide you with graphic visual displays of sleep metrics and personalized tips based on your patterns [221].
    - **Other Wearables.** As sleep technology continues to evolve, so do wearable sleep trackers. On today's market, you can find smart eye-masks equipped with sensors that analyze and track your brainwave activity and sleep patterns while eliminating light leakage and playing soothing audio. Similarly, there are sleep headbands that

monitor brain activity and use advanced algorithms to detect sleep patterns and boost periods of deep, restorative sleep in real time by playing special tones.Like other wearables, sleep eye-masks and headbands typically connect to apps to provide insight into your sleep and tips on how to improve it [221].

- Non-wearable:Non-wearable tracking means putting a device in your bedroom to track and monitor sleep. These often consist of a thin band with a sensor that you attach to your mattress or under your sheet. The device will then measure a variety of metrics, like heart rate, respiration, as well as the standard movement both in and out of bed. Some of the products in this category also include enhancement options like special lighting effects for waking and sleeping, smart alarm clocks based on your cycle, soft music and even warming features to help keep your bed at an optimal temperature. There are also brands that don't require you to place a sensor in your bed. These are stand-alone trackers that you put on your night table, and they monitor even the most subtle of body movements [16].
    - o **Under Mattress.** These sleep trackers are typically thin enough to slip directly under your mattress without notice, where they use sensors to track data like heart rate, respiration, snoring, body movement, and sleep stage cycles. Under-mattress sensors often beam sleep data onto compatible mobile apps to provide you with a visual representation of your sleep patterns and advice on how to improve your habits for a more restful sleep [221].
    - o **Bedding and smart mattresses.** You can also find sleep trackers in the form of smart pillows, mattress covers or attachable sensors—all of which may connect with apps to provide a visual representation of your sleep habits. Beyond bedding, entire "smart" mattresses have been made into sleep trackers. These smart beds may monitor key biometrics like heart rate and breathing while auto-adjusting mattress features like firmness and temperature to enhance restorative sleep during the night [221].

How Do Sleep Trackers Work?

In the case of wearable sleep trackers, they monitor your sleep using actigraphy. Actigraphy monitors movement through the accelerometer in the wearable device. Just like the accelerometer in your smartphone, it's able to sense when you're moving and calculate how many steps you take. If you're lying still for an extended period of time, as one does when you're asleep, the accelerometer notes that lack of movement, and translates it into total sleep time [221].

Since contact-free sleep trackers are tied to your bed, they can't sense when you start walking around. Instead, these devices rely on infrared technology and movement sensors in the fabric strip to determine when you wake up. They also use ballistocardiography to measure changes in your heart rate.

Many wearable sleep trackers also include heart rate tracking capability. While its primary purpose with those devices is to assess your cardio fitness level, your heart rate does lower as you sleep and changes during the different stages of sleep [221].

Advanced sleep trackers asses your sleep quality by revealing the amount of time

you spend in each stage of sleep. Each night, we cycle through four stages of sleep, from light to deep to REM, before repeating the cycle again. Based on your total sleep time and changes in your heart rate, sleep trackers will estimate how much time you spent in each stage of sleep [221]. Whether sleep trackers are effective is still somewhat up for debate within the scientific community. Generally, scientists agree that sleep trackers are reasonably accurate at detecting whether you are asleep or not. However, they're less bullish on their ability to determine the time spent in individual stages of sleep. Either way, if you want help sticking to a regular sleep schedule and ensuring you get enough sleep each night, monitoring your sleep with a sleep tracker can be a smart way to do it [221].
To use your sleep tracker, you simply keep wearing the device as normal when you go to bed, or, in the case of no-contact sleep tracking systems, hop into bed [221].

How Accurate are Personal Sleep Monitors?
While nothing is as precise as a professional assessment, modern trackers are surprisingly accurate. Previous generations of this technology would mistakenly measure the hours you spent lying awake, but not moving, as sleep. Now, however, the applications have improved and currently utilize a heart rate monitor as a sleep indicator in addition to movement. As an added benefit, these programs also contain features like motivation and sleep coaching to help you sleep better [16].
Who needs it?
The statistics about sleep disorders and the disastrous side effects of not getting enough shuteye are staggering. In the US alone, it's estimated that between 50 and 70 million adults have a sleep disorder.
Perhaps what's even more alarming is that 100,000 deaths occur each year in US hospitals due to medical errors, and sleep deprivation has been shown to be a key contributor this number. Sleep tracking is not just a safety measure. Countless numbers of corporate professionals, athletes, and even parents rely on these trackers to know how much shuteye they're getting and what level of quality it is [16].

6.6.1 The Comfort of Sleep Trackers

We study comfort of Sleep Trackers; we gave participants Three different devices to wear and under Mattress. We used of Polar H10, MI Band and Withings Aura Sleep System.

Figure 6.31. *Polar H10, MI Band and Withings Aura Sleep System.*

Xiaomi Mi Band:
The Xiaomi Mi Band is a wearable Activity tracker produced by Xiaomi. Xiaomi Mi Band was unveiled during a Xiaomi launch event on 22 July 2014 [236].
The Mi Band resembles a bracelet in its design, and can be worn on either hand, ankle or around the neck. The band's location can be set using the official Mi Band app called Mi Fit.
The band contains the core tracker which is around 9 mm thick, and 36 mm in length. It is inserted into a hypoallergenic TPSiV wristband, which has anti-UV and anti-microbal properties. The tracker is inserted into the charger module, which can be connected to a 5.0 V external power source. It is also called "Xiaomi Fit" [236].
Specifications:

- Fitness monitor & sleep tracker
- Sleep-cycle smart alarm
- Unlock your Android without a password
- 30-day standby power
- Water resistant (IP67)
- vibrate alert(call & notification)

Polar H10:
Polar H10 is a supremely precise heart rate sensor that comes with the Polar Pro chest strap. Providing top-quality and interference-free ECG measurement, Polar H10 is considered the most accurate heart rate sensor by many sources[180].
Along with being Polar's most precise and accurate heart rate sensor to date, the H10 model also offers unprecedented connectivity, enabling two simultaneous Bluetooth connections as well as ANT+ hook-ups with compatible gym equipment, cycling computers and other training devices.
The Polar H10 has a built-in memory for heart rate data from one training session, which can then be transferred to the free Polar Beat fitness and training app. Users can also connect the sensor to a wide range of other fitness apps to customize their

experience and track personal results over time, workout to workout.
Available in two size options, all H10 orders include a soft, comfortable strap with an adjustable buckle design for a firm fit; silicone dots to prevent slipping; and high-quality electrodes that keep out interference and ensure an accurate measurement. The 5 kHz transmission means you can monitor your heart rate even while swimming, and Polar's regular over-the-air software updates keep the H10 improving in its performance and function even after you've purchased it [85].
Specifications:

- Size Options: XS-S (51-66 cm), M-XXL (65-93 cm)
- Compatibility - iOS mobile devices: iPhone 5 and later, with iOS 11 or later; Android mobile devices with Bluetooth 4.0 capability and Android 5.0 or later
- Connectivity: ANT+, Bluetooth Smart, 5 kHz
- Built-In Memory: One Training Session
- Battery: CR 2025, 400 hours of battery life with BLE and 5 kHz transmission active
- Water Resistance: 30m (Suitable for swimming)
- Strap: Soft textile material with secure buckle and slip-preventing silicone dots
- Software Updates: Via mobile phone using Polar Beat app or Polar Flow app.

Withings Aura Sleep System:
Withings Aura is a hi-tech sleep system that combines in-bed sleep monitoring, with customized sound and light effects that help you both fall asleep and wake up in the best possible way. The Withings Aura Total Sleep System consists of the bedside unit and an accompanying under-the-mattress sleep sensor. The Aura features multicolored LED lighting and a high-quality speaker system which enable the science-based built-in sleep and wake programs.
Sleep tracking comes via the pneumatic under-mattress sensor pad. Using ballistocardiography, the sensor measures heart rate, breathing and movement to detect light sleep, deep sleep and REM.

Automatic tracking means you don't have to pair your smartphone, just lie down on the bed and Withings Aura starts measuring your sleep straight away. The Aura also detects light, noise and temperature levels in your bedroom to monitor any disturbances which might be affecting your sleep patterns.
Features and Benefits:

- high-quality, scientifically validated light and sound programs for sleep and waking
- advanced, automatic sleep tracking with no manual intervention required
- use the Withings Aura to listen to Spotify and 1000s of internet radio stations
- data is synched automatically to the Withings Health platform and your app
- simple touch-sensitive operation to control light and sound levels

Comfort Measure Approach:
We used the comfort rating scales (CRS) based on those developed by Knight et al [129]. Knight et al. developed a comfort assessment tool that measured comfort along six different physical and cognitive dimensions [129]. They designed sets of statements representing the comfort dimensions of emotion, attachment, harm,

perceived change, movement, and anxiety. They suggested that comfort is a multi-faceted construct that is influenced by many factors, both internal and external to the wearer [129].

The CRSs have been developed to provide a quick and easy-to-use tool to assess the comfort of wearable computers. Using the scales may assist researchers and designers of wearable computers in measuring total wearer comfort and highlight factors that should be addressed to improve comfort [129]. The CRSs attempt to gain a comprehensive assessment of the comfort status of the wearer of any item of technology by measuring comfort across the six dimensions [56]:

- **Emotion:** Concerns about appearance and relaxation.
- **Attachment:** Comfort related to non-harmful physical sensation of the device on the body (e.g. the feel of the device either directly as pressing on the body or indirectly as it pulls on clothing or moves in relation to the body).
- **Harm :** Physical sensation conveying pain.
- **Perceived change:** Non-harmful indirect physical sensation making the wearer feel different overall with perceptions such as being awkward or uncoordinated, may result in making conscious compensations to movement or actions.
- **Movement:** Conscious awareness of modification to posture or movement due to direct impedance or inhibition by the device.
- **Anxiety:** Worries as to the safety of wearing the device and concerns as to whether the wearer is using it correctly or it is working appropriately.

Table 6.1. Comfort rating scales and statements.

Type	Statement
Emotion	I feel self-conscious having people see me wear this device.
Attachment	I feel the device moving on my body.
Harm	I feel some pain or discomfort wearing the device
Perceived Change	I feel awkward or different wearing the device.
Movement	I feel that the device affects the way I move.
Anxiety	I feel secure wearing the device.

The CRSs are 21-point scales anchored at each end with the labels low and high. A 21-point scale was used so that scoring on the scale would range from 0 at the far left to 20 at the far right. According to Knight and Baber this range was considered large enough to elicit a range of responses that could be used for detailed analysis. In rating perceptions of comfort, the scorer simply marks on the scale his or her level of agreement, from low to high [56].

Questionnaire: In our study, we modified these CRSs, we changed to 4-point scale in order to simplify the concept for participants.

Table 6.2. Our Comfort rating scales and statements.

Type	Question1	Question2	Question3	Question4
Emotion: How do you feel emotionally when you use this device?	It is strange for me, so I feel dread and worry of that, Wearing the device makes me feel physically different.	I feel it is not set (in line, harmony) with my clothes.	Think it makes me look ridiculous (comic, funny).	I feel completely relaxed.
Attachment: How was the status 's attachment of device when you wear that?	All time I feel it on my body when I wear it, I think it does not good attach to my body.	Sometimes I can feel the device moving.	I feel cramped(tense) when use that.	I feel quite comfortable.
Harm: Does the device (physically) hurt you?	The device is causing me some harm.	The device is painful to wear.	I feel some pain or discomfort wearing the device.	I feel perfectly comfortable.
Perceived change: What is impact of use device on your appearance and how does it be awkward or uncoordinated?	I have bad feel of my physical different.	I feel strange wearing the device.	I feel awkward or unusual wearing the device.	I feel completely comfortable.
Movement: How does the device effect on your daily activity and your movement?	The device inhibits and prevent my movement.	The device restricts my movement.	I cannot able to move as usual.	I feel quite comfortable.
Anxiety: Does the device Effect on Your Anxiety?	I do not feel secure and not reliable wearing the device.	I feel restless and distressed.	I feel little bit worry.	I feel comfortable.

Sample:
A total of 12 participants (8 women) volunteered in the present research (mean age 29). Participants were assigned to try on all devices. They were given instructions

on how use device and our application such as make account and connect device to app and how use app for collecting heart rate and sleep tracking.

Result:
Result of evaluating comfort of devices were identified and are summarized in Figure 6.32.

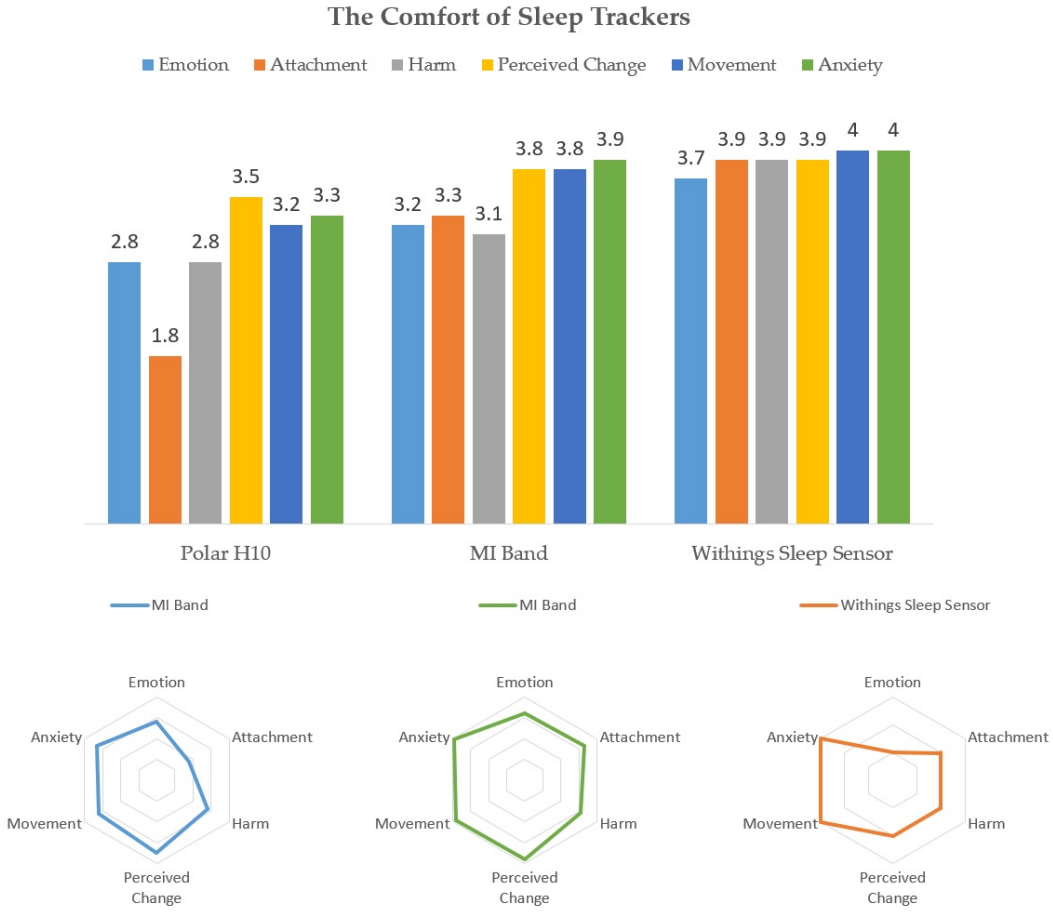

Figure 6.32. *Result of measured comfort.*

Chapter 7

7.1 Future Work and Conclusion

Design and implement this project were very important to me, because my mother had diabetes. I underattended has had difficulty controlling her blood sugar level, unfortunately, I lost my mother and she died by a heart attack, this gave me the incentive a push to work harder and implement the project.z

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 [202].
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 [202].
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 [202].

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 [105].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 [99].

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 [49][95].

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 [105][49][52].

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. We attempted to do this by developing educational tools and resources that promote healthy living through a gamified mobile application. During the 5-month allocated to the project, a gamified management tool for diabetic children was designed implemented, tested and evaluated.
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. The system was evaluated in several ways and the overall response was very positive.

Future research should include another iteration of design making changes using the feedback collected from usability testing. The food database portion of the app was not fully developed. Measuring and tracking carbohydrate intake can be an onerous task for many T1DM patients, so for the future, we will complete the implementation of the food database.

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.

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