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Salutem

A group-based motivational mobile application for people with diabetes

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INF-3981 Master's Thesis in Computer Science June 2021

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“If somebody shows me 5 million times respect and one time not,
What is more important?”
–Jürgen Klopp

“It’s OK to have your eggs in one basket
as long as you control what happens to that basket.”
–Elon Musk

“Your time is limited,
so don’t waste it living someone else’s life. ”
–Steve Jobs

Abstract

Diabetes is a disease defined by raised blood glucose levels, and people with the disorder have to adhere to a strict self-management regime to avoid short- and long-term complications. Today the World Health Organization reports that over 420 million people have diabetes, and the condition is one of the most common causes of death worldwide.

This thesis presents the design and implementation of a group-based motivational application for people with diabetes. The proposed application applies persuasive design techniques and aspects of motivational theory to help people stay motivated in their management of the disorder through groups. Thus, decreasing the risk for short- and long-term complications.

The result is *Salutem*, an application where users can define custom goals, participate in groups, and receive progression updates and notifications that encourage them to motivate each other.

The thesis also shows how other applications can arise from openness with user data. For example, with other application's integration to modern technologies such as HealthKit, the proposed application gathers blood glucose data from the user's CGM through HealthKit.

Because of the ongoing pandemic, an extensive user study of the implemented system is not conducted. As a result, it could not be determined if the application will affect the user's motivation. However, a user study of the application's usability is conducted on a small group of users who reported that the application had an appealing design and work as intended.

Preface

When signing up for this project, I immediately got pretty excited and got an idea of what I wanted to achieve with the project. Mobile applications is a field of computer science where I have used much of my spare time, and it was one of the reasons I was excited about the project. However, after the first few weeks of the project, it became clear that it would be a much more challenging task than just creating a mobile application.

First and foremost, the impact that diabetes has on people's lives and how much time they use to manage their disorder was overwhelming and more significant than I knew beforehand. At the start of the project, I struggled to understand what could be defined as new and innovative in a market where I felt that it existed a solution for everything. However, after some research and excellent guidance and support from my research group, I decided on a direction wherein the end, I felt that something new would arise.

One of the biggest surprises I experienced while working on the project was that it, to my understanding, seems like most of the big companies make it difficult for people with diabetes to own their data gathered by the devices they use. When I conducted the market review, all applications required that a user had an account to share their sensitive health data with the people they want. Credit goes to Dexcom to integrate their application with technologies like HealthKit, enabling other applications to use the user's data without any effort. From the unavailability of user's data, projects like *Nightscout* exist, and they have all my respect for all the solutions they create to enable any people affected by diabetes to have the digital solutions that they deserve.

I want to show my uttermost thankfulness to Professor Gunnar Hartvigsen for being my supervisor during this project. When I at periods have felt lost, you have always had the right words that encouraged me to continue working with the project. Your tips in the relevant literature, books, and writing a thesis have been of much appreciation. Further, I want to direct a special thanks to Professor Eirik Årsand for being my co-supervisor. Your personal insight and engagement in the field as someone with diabetes have been insightful, and I appreciate that you would share everything with me. Lastly, I would like to thank Professor Keiichi Sato, Assoc. professor Santiago Martinez, Dr. Antonio Martinez, and Dr. Ashenafi Woldergay for being my co-supervisors and for your insightful feedback and guidance in different computer science and medical research fields. Thank you.

All good things do come to an end. I want to direct a special thanks to the guys I have been sharing the office with for the last two years. Magnus Stellander, Isak Gjærum, Eric Brattli, and Morten Myrland, you all know how much I have appreciated the time with you guys. Even if it hasn't always been productive, I have enjoyed every arbitrary discussion we've had. I will miss you all.

Last but not least, I would like to thank my family and my girlfriend Anette for their continuous support and for always believing in me.

Joakim Sjøhaug - Tromsø, June 2021

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Introduction

1.1 Background

Diabetes Mellitus is a chronic disease that is characterized by higher blood glucose (or blood sugar) levels [1]. There are two main types of diabetes, type 1, a condition where the body does not produce insulin itself, and type 2, where the body is tolerant of insulin. Today over 422 million people are diagnosed with diabetes, and access to treatment is critical to their survival [1].

Managing the disease is a time-consuming task and requires the person to closely control their blood glucose levels, daily activity, and food intake. If patients do not manage their blood glucose levels properly, they could experience short- and long-term complications. Low blood glucose levels can cause hypoglycemia [2], and high blood glucose levels can cause hyperglycemia [3].

Modern technology has enabled new devices that make it easier to manage the disease. A Continuous Glucose Monitoring (CGM) device is one of the modern breakthroughs and is a small sensor that continuously measures blood glucose levels [4]. In cooperation with mobile applications, the user can get alerts when the blood glucose levels are low or high. The application can also send these alerts to family members or friends.

Even with the new technology, only 21% of young adults with diabetes meet the American Diabetes Association (ADA) recommended blood glucose levels for people with diabetes [5]. Thus, living a lifestyle that requires strict self-management is a lifestyle where motivation is a necessity.

1.2 Scope and Research Problem

This project aims to create a group-based motivational application for people with diabetes. The reasoning is that modern design and technical solutions can create a system where people with diabetes can use groups to stay motivated and achieve healthy blood glucose levels. From this, the main research problem of the project is defined.

> *How can a system that uses group-based motivation be designed for people that live in strict self-management?*

1.2.1 Sub-Problems

The primary problem is divided into sub-problems, and the first sub-problem is concerned with how people with diabetes can be motivated to reach healthy blood glucose levels each day. Therefore, it is relevant to examine which persuasive design principles can encourage people with diabetes to reach these healthy blood glucose levels each day.

> Sub-Problem 1: *Which persuasive design principles are relevant when creating a group-based motivational application for people with diabetes?*

Another critical aspect of the application is that it should be available for most people without much technical knowledge. Therefore, the second sub-research question is:

> Sub-Problem 2: *Which modern technologies can be used to obtain blood glucose data for people with diabetes?*

Today more than ever, data privacy is essential. Each day a person produces data about what they are doing, what they want to buy, and their interests. Therefore a user's privacy should be an essential factor of the application. The third sub-research problem is:

Sub-Problem 3: *How can a group-based motivational application for people with diabetes be designed with privacy in mind?*

1.3 Methods

At the start of the project, literature concerning diabetes and motivation was read. Then a review of existing applications for people with diabetes was conducted. Finally, a questionnaire was constructed and posted in an online community for people with diabetes from the observations from these two processes. To develop the application, an iterative software development process was applied. First, the requirements for the application were defined, then requirements for the application were implemented in an iterative process based on the prioritization property on the requirements. The final application was tested on people using scenarios and gathering immediate feedback from a system usability scale questionnaire.

1.4 Assumptions and Limitations

The finished application is only available and tested on iOS. In Norway, over 50% of the market share belongs to iOS [6]. A decision to only implement the application for iOS was taken because of my experience with developing applications for iOS and because of some technologies on the platform that was interesting.

A non-functional requirement specified that the application should read data from a user's CGM. Therefore, the application is tested and developed using fake generated blood glucose levels. Hence, the application is not tested on a mobile where a CGM device collects actual blood glucose levels.

Testing how the application affects motivation is a process that requires extensive use of the application over some time. In addition, since the project is working with personal health data, such a user test would need to seek permissions. The ongoing Covid-19 pandemic is another factor that made it challenging to arrange physical user tests. Because of this and the limited time frame of the project, it is only conducted a usability test of the developed system on a small user group without diabetes.

The final product shall not replace any other applications that a patient may use to manage their disorder. In addition, any advice that users share in the application shall not be treated as medical advice and must be consulted with their doctor before they try it.

1.5 Significance and Contribution

This project's main objective is to create a viable technical solution of a group-based motivational application for people with diabetes that can motivate them to obtain healthy blood glucose levels. The primary focus is people with type 1 diabetes.

The thesis outcome is threefold. First, a backend is implemented that exposes an HTTP REST API to manage groups, users, and time-in-range values. Second, a mobile application for iOS where users can sign up, discover, and create groups, and define their time-in-range goals. Lastly, an application that continuously generates mocked blood glucose level samples in the background and integrates with HealthKit on iOS.

1.6 Organization

Chapter 2: Theoretical Framework describes diabetes and the state of diabetes in Norway. Further, it describes the different types of diabetes, short- and long-term complications, and modern solutions to support self-management with diabetes. Besides, the chapter also addresses different aspects of motivation and behavior change. Lastly, the chapter presents a state-of-the-art review of mobile applications for people with diabetes.

Chapter 3: Method and Materials explains the research approach and the evaluation method of the system.

Chapter 4: Requirements Specification discusses how requirements for the system were gathered and presents all the functional and non-functional requirements of the system.

Chapter 5: Design presents a simple design system for the application and how it was utilized to create the views in the application. The chapter also outlines a system architecture for the backend of the system.

Chapter 6: Implementation goes into detail about the implementation details of the contributions of the project.

Chapter 7: Tests and Results presents the results from a questionnaire conducted during the project and the usability test of the application.

Chapter 8: Discussion talks about the evaluation of the application, strengths and weaknesses with the thesis, and future features for the application.

Chapter 9: Conclusion summarizes the project and present concluding remarks.

2

Theoretical Framework

This chapter starts by defining diabetes, its current state in Norway, different types of diabetes, hypoglycemia, hyperglycemia, and two modern technologies that help people living with the disorder. Further, the chapter explains the motivational theory and persuasive design techniques before a review of state-of-the-art diabetes applications is presented.

2.1 Diabetes Mellitus

Diabetes is a chronic disease that occurs when the body cannot produce enough insulin or if it cannot use the insulin that it makes itself. The World Health Organization (WHO) estimated in 2014 that over 422 million people were diagnoses with diabetes and that 1.5 million deaths were directly caused by diabetes in 2019 [1]. If not managed correctly by a strict self-management regime, diabetes could damage vital organs such as blood vessels or kidneys. There are three main types of diabetes, gestational diabetes (GDM), type 1 and, type 2 diabetes, where the latter is the most common [1].

2.1.1 Diabetes Mellitus in Norway

Diabetes is one of the most common chronic diseases in Norway. Norway does not have a registry of how many people are diagnosed with diabetes or have recovered from diabetes. Combining data from the Norwegian Prescription Database and health studies in Norway, The Norway Institute of Public Health (NIPH) estimates that 244,000 people have diabetes. Out of these, they estimated that 216,000 have T2DM, and 28,000 have T1DM [7].

Since 2004 the number of people living with diabetes has increased from 110,000 to 183,000 [7]. They believe that the increase has come from more new cases each year and that previously undiagnosed people have got a diagnosis. Another reason may be that people that have diabetes live longer. However, data shows that the number of new cases each year has flattened, and currently, there are approximately 15,000 - 16,000 new cases each year [7].

NIPH also states that the risk of developing T2DM is higher for some immigrant groups in Norway. For example, the data shows that people from South Asia and some African countries have a higher risk. Besides, people from these immigrant groups also develop T2DM at a younger age than ethnic Norwegians [7].

2.1.2 Type of Diabetes

As mentioned earlier, there are three main types of diabetes, gestational diabetes (GDM), type 1, and type 2 diabetes [1]. Gestational diabetes is first seen during pregnancy through screening. Patients diagnosed with gestational diabetes have a higher chance of experiencing complications throughout the pregnancy. In addition, the patient and child also have a higher chance of developing diabetes type 2 later in life [1].

Type 1 Diabetes

Type 1 Diabetes Mellitus (T1DM), also known as insulin-dependent, is a type of diabetes where the body cannot produce its needs. People diagnosed with T1DM need to manage their insulin levels daily by injecting insulin into the body. What causes and how to prevent T1DM is currently not known [1].

Type 2 Diabetes

Type 2 Diabetes Mellitus (T2DM) is the most common type of diabetes. The disease is mainly seen in adults, but lately, many children are diagnosed with T2DM. Overweight and lack of physical activity are the most likely causes of T2DM. T2DM has many of the same symptoms as T1DM, but these are less marked on the patient. Therefore, a patient with T2DB may first get the diagnosis years after the disease occurred, and complications of the illness may have arisen on the patient [1].

2.1.3 Blood Glucose Control

The overall control a patient with diabetes has with their disorder can be measured in two ways - *HbA1c* and *Time-in-Range*. The methods are very distinct in how they calculate the overall control.

HbA1c

HbA1c or A1C is a test that can be used to assess a person's risk for diabetes, diagnose diabetes, and monitor how well the person is managing their disorder over time [8]. In short, the A1C test analyzes a blood sample from a person. The result tells the percentage of red blood pigments hemoglobin that has bonded with glucose, or the average blood glucose levels the past 2 to 3 months [9]. Glucose usually stays bonded with the hemoglobin 8 to 12 weeks, and therefore, a patient with diabetes should test their HbA1c every 2 to 3 months [9]. For most people with diabetes, the target HbA1c is less than 7% but could vary between persons [10].

Time-In-Range

Time-in-range is a new way of measuring a person's control of the disorder, and opposite to HbA1c, time-in-range could tell something about the person's daily management of the disorder [11]. Time-in-range is the number of blood glucose level samples that, on a specific period, for example, a day, are inside a defined blood glucose range [9]. Ideally, time-in-range should be calculated using blood glucose levels for at least the 14 past days [11].

The target blood glucose range for people with diabetes is defined to be between 3.9-10.0 mmol/l [9]. However, as with HbA1c, the target range may differ between individuals. The time-in-range goals should be at least 70% within the mentioned range [9].

The advantage of time-in-range over HbA1c is that it captures the highs, lows, and in-range blood glucose level samples throughout a day. Therefore time-in-range can capture a hypoglycemia event and inform the patient about it [10]. In addition, time-in-range can be measured at home and does not require the person to visit the doctor to see how they are managing their disorder.

An excellent example of how time-in-range is superior to say something about people's management of their disorder is shown in Figure 2.1. It shows three people who have achieved the HbA1c goal, but only one person has achieved 100% time-in-range and has less chance for hypo- or hyperglycemia events. The two other persons have been below the range, thus having a higher chance of hypo- or hyperglycemia events.

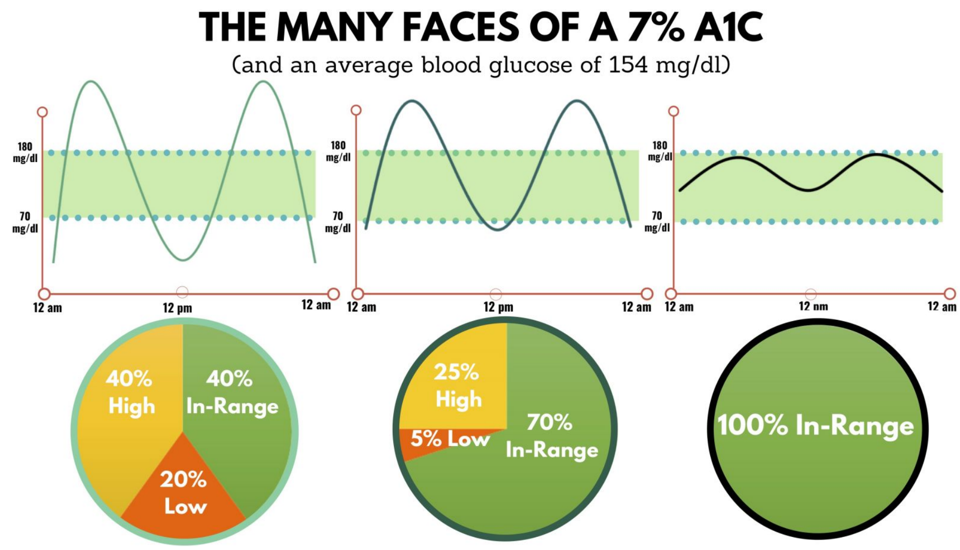

Figure 2.1: The figure shows how time-in-range can tell much better how people are managing their disorder compared to HbA1c [11]. All three persons in the figure has a HbA1c of 7% but the blood glucose levels has varied a lot between the persons.

2.1.4 Hypoglycemia

People with diabetes experience a daily threat, hypoglycemia caused by the medications used to treat diabetes. The event occurs when the blood glucose levels go below a certain threshold, which the American Diabetes Association defines as 3.9 mmol/L (70 mg/dL)[2]. Hypoglycemia can occur in different variants, severe, documented, and asymptomatic hypoglycemia. Thresholds for where the different variants of hypoglycemia occur are not defined, or at least there does not exist a consensus of the halls [12]. The disease is an inevitable side-effect of intensive insulin therapy and is a legit risk for people with diabetes. In addition to hypoglycemia's physical stress, there is also a psychological burden of always avoiding/expecting an occurrence. On average, a patient with diabetes experiences one to two episodes of hypoglycemia each week. 20% experience one episode of severe hypoglycemia in a calendar year, and 55% of the occurrences happen during sleep [13].

Asymptomatic hypoglycemia

Asymptomatic hypoglycemia is an event where the typical symptoms of hypoglycemia are not present. The blood glucose level is measured to be below, or equal to 3.9 mmol/L (70 mg/dL) [14].

Documented symptomatic hypoglycemia

An event of hypoglycemia where the typical symptoms are present. Also, here the ADA says that the blood glucose levels are measured to be below, or equal to 3.9 mmol/L (70 mg/dL) [14].

Severe hypoglycemia

A severe hypoglycemia event where the person needs assistance from another person to adjust carbohydrates, glucagon, or other actions to manage the event. In this event, it is possible to experience insufficient glucose in the brain, leading to seizures or coma [15]. Children do almost always need assistance from a parent or caregiver when they experience hypoglycemia [12].

Nocturnal Hypoglycemia

Nocturnal Hypoglycemia (NH) is an episode of hypoglycemia that happens during sleep. NH often leads to severe hypoglycemia episodes since the patient cannot recognize symptoms or do measures against the ongoing outbreak. NH is relatively common and is affecting respectively 50% of adults and 78% of children. These episodes of hypoglycemia that occur during sleep do even last for several hours [16]. NH is also one plausible theory as the cause of the "dead-in-bed" syndrome, which refers to the sudden death of people with diabetes while at sleep and accounts for 6% of the total death of diabetes patients younger than 40 years [17].

Symptoms

People with diabetes can look for different signs and symptoms to know if an episode of hypoglycemia is incoming. Typical signs are autonomic signs such as hunger, tremor, sweating, and palpitations [12]. These signs are early indicators that an event of hypoglycemia may be coming shortly. Headache and nausea are nonspecific symptoms that may also arise [12]. Deary et al. [18] found that symptoms of neuroglycopenia (shortage of glucose in the brain) are confusion, drowsiness, odd behavior, speech difficulty, and incoordination, which indicates that a hypoglycemia episode is happening.

Impaired Hypoglycemia Awareness

Impaired hypoglycemia awareness or hypoglycemia unawareness is a syndrome people with diabetes can develop. Impaired hypoglycemia awareness means that the person may be unable to detect an upcoming episode's symptoms and, therefore, start corrective actions later than required and suffer a severe hypoglycemia episode [12]. Hepburn et al. [19] estimated in a survey that approximately 25% of patients with T1DM had developed impaired hypoglycemia awareness, the portion of T2DM patients were smaller.

Measures

For severe hypoglycemia episodes, intravenous glucose infusion and glucagon are safe and reliable alternatives. The real measure against hypoglycemia is how one should manage to avoid attacks of hypoglycemia. Patients who experience mild or moderate hypoglycemia can treat themself by eating a snack, glucose drink, or tablet. For severe episodes, education about handling such situations among friends, families, or other people near the patient is crucial for the health of the patient [12]. For the long term, great glycemic controls and education to avoid poor choices that affect the blood glucose levels are the best measure to prevent hypoglycemia episodes [20].

2.1.5 Hyperglycemia

The American Diabetes Association (ADA) defines *hyperglycemia* as a technical term for a situation where the body has high blood glucose levels. This situation occurs for patients with T1DM if they have not injected enough insulin, and for patients with T2DM, the body may have enough insulin, but the insulin is not as sufficient as it should be. Other causes of high blood glucose levels are stress, too little food or too little exercise, or an unexpected dawn phenomenon. Hyperglycemia symptoms are high blood glucose levels, frequent urination, high sugar levels in the urine, and increased thirst [3].

The treatment for hyperglycemia aims to lower the patient's blood glucose levels. To reduce blood glucose levels, a patient can exercise. However, if the blood glucose level is above 240 mg/dl, the patient should check the blood for ketones. If ketones are present in the blood, exercising will make the blood glucose level go even higher. Another action against high blood glucose levels is to eat less or modify the diet. The best measure against hyperglycemia is to have good diabetes management and learn the symptoms such that an episode can be detected and treated early. Untreated hyperglycemia may course severe problems for the patient, and in the worst case, it can lead to Ketoacidosis, which is life-threatening [3].

2.1.6 Continuous Glucose Monitoring

Continuous glucose monitoring (CGM) is a modern small device that measures the glucose concentration in the blood nearly continuously. Typically, such a device performs readings every 1-5 minutes [4]. The device consists of three parts, a sensor, transmitter, and a receiving device. A CGM sensor is needle-based and inserted in the abdominal subcutis. Then a transmitter is applied over the sensor and is responsible for sending the measurements to a receiving device [4]. In addition, CGMs have made it possible to use time-in-range to control how diabetes is managed [9].

Measure

A CGM sensor does not measure the blood glucose levels, but it measures the interstitial fluid's glucose level (ISF). The sensor sends these measurements to the device to transform the glucose level measured in ISF to blood glucose values [21]. Algorithms are used on the device to convert the glucose level in ISF to blood glucose levels. The algorithms use reference measurements that the user has obtained using a self-monitoring blood glucose (SMBG) device to do the conversion. An SMBG device measures the blood glucose level by extracting a drop of blood from the finger by pricking it and then testing the extracted sample on the SMBG device. The process of obtaining reference blood glucose measurements to the CGM device is called calibration, and the user is required to re-calibrate the device every 12 hours [4].

Quality of life impact

The introduction of CGM sensors in conjunction with SMBG has demonstrated that they improve glucose control quality [4]. Besides, the data from CGMs have also introduced many new functionalities to enhance people with diabetes quality of life. These features include warnings to prevent hypo- or hyperglycemia events [22], predict the trend of the blood glucose levels [23], visualization of blood glucose levels, and even closed-loop systems that include an insulin pump with algorithms to inject insulin automatically to maintain the blood glucose levels between a safety range [24]. In addition, CGMs have made it possible to use time-in-range to control how diabetes is managed [9].

Limitations

All the new functionalities and features that CGMs have introduced relay that the devices are reliable, and that the data is accurate. For instance, it has been reported that the CGM readings do not correspond with SMBG results taken at the same time and especially not during periods of fast-changing blood glucose levels [25]. The difference occurs because of how the CGM measures blood glucose levels versus the SMBG, as mentioned earlier.

Also, the time a sensor uses to determine the change in blood glucose levels is a limitation. It has been documented that the lag time is between 4 to 27 minutes [26], which affects the CGM's accuracy accordingly. The worst-case scenario is that the lag will cause someone with diabetes to respond to a prediction from the CGM, e.g., of an incoming hypoglycemia event, and then eat something to raise the blood glucose levels to an acceptable level. However, the lag can have made the CGM not see the rise of blood glucose, making the person's action cause an over-treat of their hypoglycemia episode [27].

2.1.7 Insulin Pumps

Insulin pumps are a device that mimics the way a pancreas work. It does this by infusing small doses of acting insulin into the body. This process happens continuously, and the device will deliver a variable amount of insulin if the user has eaten. These pumps have made it possible to achieve physiological blood glucose levels or normoglycemia for people with diabetes [28]. The user wears the device, and a catheter is used to deliver insulin through a thin cannula placed into the fat, typically around the stomach area.

2.2 Motivation

Diabetes is a time-consuming disease and requires the person to use much of their time managing the disorder. For example, every day with this chronic disease, the person has to frequently check their blood glucose levels, be deliberate about what and when eating, count carbohydrates, and take all this into account when planning physical activity. These tasks are time-consuming, and Russel et al. [29] found that the recommended self-care tasks by the American Diabetes Association (ADA) will require more than two hours daily to complete. They also stated that older people, people newly diagnosed with diabetes, and people with physical limitations would use even more time than the required 2 hours.

A lifestyle that needs so much time to control the disease requires motivation to adhere to such a strict regime. Studies have found that for people with type 2 diabetes (T2DM), over 50% of the people fail to achieve the recommended glycemic values recommended by ADA [30]. For young adults with type 1 diabetes (T1DM), only 21% reached the same glycemic values [5].

Social Cognitive Theory

Social Cognitive Theory (SCT), or Social Learning Theory (SLT), named when presented by Albert Bandura in the 1960s, is a theory that a person learns by observations. The idea says that people do not learn by trying and either succeeding or failing, but observing a model act and observing if they get rewarded by the behavior.

Self-efficacy is one key concept of SCT. Self-efficacy says something about the belief people have about their capabilities to perform at such a level that it will influence events that affect their lives [31]. There are multiple ways that self-efficacy contributes to motivation [32]:

- - Shaping aspirations and goals.
- - Determining the amount of effort and perseverance one will expend in the given endeavor.
- - Shaping the outcomes from one's results.

Those who see themself as highly effective will expect good results. On the contrary, people who see themself as ineffective will expect fewer results. Thus, progressive mastery of activity will lead to satisfaction, which will be a catalyst for the ongoing motivational factor [32].

Self-Determination Theory

Self-determination theory (SDT) is a theory about human motivation. It says something about how humans are motivated through intrinsic and extrinsic motivation. Intrinsic motivation comes without a reward for action, but rather the action is the reward itself. Extrinsic motivation is a form of motivation that humans do not control but are motivated through wanting a reward or, e.g., the need to write a master thesis before the deadline. The vital difference is that intrinsic motivation is autonomous and extrinsic motivation is controlled [33] [34]. Amotivation is the last type of motivation. Actions that are amotivated people tend to not do at all or do without intent, just go through the motions of the action. Amotivation comes from not valuing an activity, not feeling competent to do it, or not expecting the action to result in an award [35].

Deci et al. [35] say that SDT is an approach to human motivation that highlights the value of self-personality development and behavioral self-regulation. Further, all humans have psychological needs that need to be satisfied for functional optimal and feeling well. These needs are:

- **Competence:** Be confident, control the outcome, and experience mastery.
- **Relatedness:** Feeling cared for and connected to other people.
- **Autonomy:** Behavior that is self-endorsed. A person entirely agrees with the behavior, and when someone is fully autonomous, the performance of the task/behavior tends to be better.

There are two types of autonomous motivation, intrinsic and integrated regulation. Integrated regulation is a form of extrinsic motivation. The individual decides the behavior if it fits the individual's values or if the individual needs it, even if the behavior is not pleasant, and integrates it to become a part of themselves [35].

2.3 Persuasive Technology

Persuasive technology is a field that covers products that use computer technology and insights from psychology to change the attitude or behavior of a user [36]. These products could be anything from a mobile phone to a digital watch. B.J Fogg defines persuasive technology as "any interactive computing system designed to change people's attitudes, behaviors or both [37]." He explains further the area of products that overlap between computers and persuasion as *Captology*. Captology is an acronym for the phrase "computers as persuasive technologies."

From his definition of persuasive technology, it is easy to argue that an average person is exposed to persuasive technology each day. Now, more than ever, technology tries to change people's behavior, and one area is mobile applications, where there are applications that try to improve people's fitness or motivate them to keep their plants alive [38].

Motivation is a fundamental necessity to change people's behavior or beliefs. Without motivation, it might be hard to help them accomplish their goals. Persuasive technologies can be used to motivate people to reach their goals without coercion or deception [36]. The Apple Watch is an example of a computing device that seeks to change people's behavior (see for an example Figure 2.2. Since its release back in 2015, it has tried to improve people's health through reminders of the progression of the daily stand, move or exercise goals and between all these reminders, it did not forget to suggest a minute of breath [39].

Figure 2.2: Example of notifications from the Apple Watch that encourages to physical activity [40].

2.3.1 Functional Triad

To make it easier to understand how computers are persuasive technologies, Fogg developed a framework called *functional triad* [37]. The framework helps to illustrate the different roles computers can play, namely tools, media, or social actors.

Computers as Tools

Computer in this role aims to make processes easier to do with the use of technology. An example can be to view the balance of a bank account.

Fogg defines seven types of persuasive technology tools [37]:

- **Reduction** - Reducing the number of steps it takes to accomplish a task.
- **Tunneling** - Using visualization or calculations to show when the user is done with something or progresses with a task.
- **Tailoring** - Making the experience more exclusive by customizing it to

the user.

- **Suggestion** - Providing suggestions at a suitable time.
- **Self-monitoring** - Use technology to track the progression to a predetermined goal.
- **Surveillance** - Using technology to see other people's progress or performance.
- **Conditioning** - Giving positive feedback when doing a task or behavior.

Each of these tools helps a product be more persuasive towards the user and when creating a product for persuasion, combining two or more of these tools to achieve the desired outcome is typical [37].

Computers as Media

In this role, computers can be placed in two categories, *symbolic* and *sensory* [37]. A computer in the symbolic role uses technology such as images, symbols, graphs, etc., to convey information to the user [37]. Any computer in the sensory role uses audio, video, haptic-feedback, etc., to stimulate the human senses [37].

Computers as Social Actors

Computer in this role act in such a way that users think they may be a living being. A social actor can persuade through rewarding users with positive feedback, simulate an end behavior or attitude, or provide social support [37].

2.4 Gamification

Gamification describes an application that uses concepts from games to create an experience that makes it more attractive for a user to use the application/program. Gartner [41] defines it as "gamification is the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals. It is essential to distinguish gamification from video games and loyalty programs, as gamification uses techniques from behavioral science to *nudge* people into achieving their goals."

Sailer et al. [42] performed an experimental study where they looked at the effects of specific game design elements in applications in terms of psychological aspects. They found that multiple studies concluded somewhat equal but also different lists of unique characteristic design elements in games. From this, Sailer et al. [42] concluded that which design elements are characteristics of games is arbitrary and subjective.

Some typical game elements found in an application are:

- Points.
- Badges.
- Leaderboards.
- Performance graphs.
- Meaningful stories.
- Avatars.
- Teammates.

An application can use all these game elements to create engaging, sustainable, and motivational environments.

2.5 State of the Art

When starting a new project, it is advantageous to overview what already exists in the market. Doing this ensures that no one has implemented the same application. Overview of the market is also an excellent way to get inspiration for features to include and maybe not include in the application [43]. Since the project is developing the prototype for iOS, the author searched the Apple App Store for diabetes and applications. There were many results, and some of the applications were explored in detail, which is discussed below. Unfortunately, none of the diabetes-related applications were downloaded and installed since the author does not have a CGM, and therefore the applications would not work. Thus, the impressions and observations are from looking at the applications page on the app store. In addition, two applications that the author uses daily for workouts and have some great features for group motivation are reviewed.

2.5.1 Diabetes-Related Applications

Dexcom CLARITY

The application enables a person with diabetes to view their glucose patterns, trends, and statistics (see Figure 2.3). They can see how their blood glucose values are at any time. The application requires that a person with diabetes has a Dexcom account and Dexcom CGM system [44].

Pros

- Graphs.
- Time-in-range visualization.
- Export report to clinic.
- Detects patterns e.g. low blood glucose levels on mornings.
- Choice between weekly or daily notifications.

Cons

- Requires a Dexcom account.
- Only support Dexcom CGM devices.

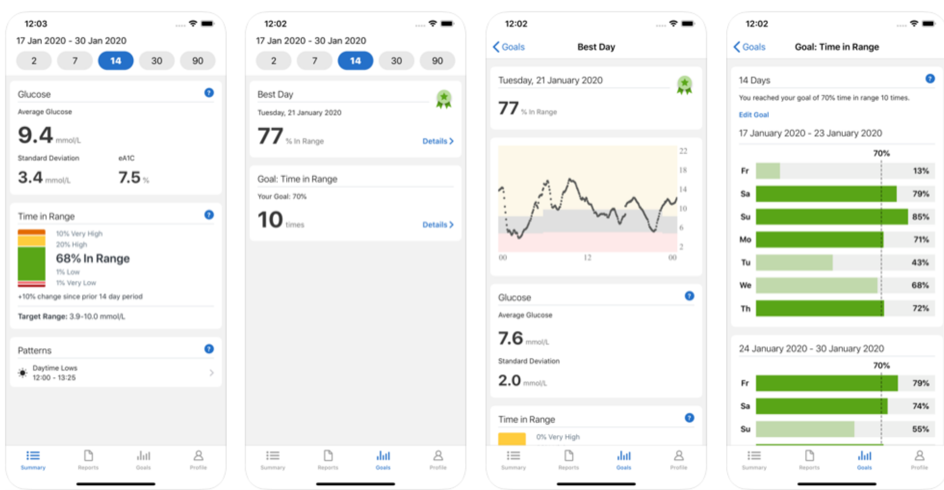

Figure 2.3: The "Dexcom Clarity" application [44]. The application show time-in-range, average blood glucose level, graphs, and history.

Dexcom Follow

The application lets a friend/family member view the blood glucose data of a person with diabetes (see Figure 2.4). The user can customize alerts for low and high blood glucose levels in the application and view graphs and trends for the blood glucose levels of their friend/family member. A person with diabetes that owns a Dexcom CGM system must invite the person through their app to allow others to see their data [45].

Pros

- Monitor other's glucose activity.
- Customized glucose alerts and push notifications.

Cons

- Only up to 10 followers.
- Works only with Dexcom devices.

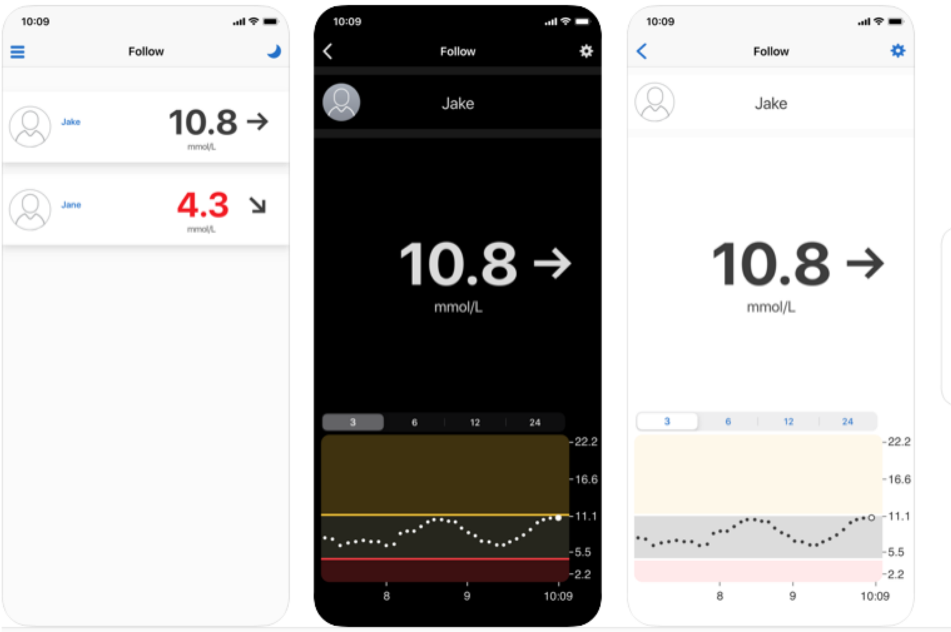

Figure 2.4: The "Dexcom Follow" application [45]. A user can follow multiple users and see their blood glucose levels and trends.

Dexcom G6

The application enables people with diabetes with a Dexcom G6 or G6 Pro system to see their blood glucose levels. The user can view their blood glucose levels on the lock screen through a widget, and if they have an Apple Watch, they can see their blood glucose levels on their wrists (see Figure 2.5). In addition, with the application, the user can invite friends/family members to see their blood glucose data through the Dexcom Follow application [46].

Pros

- Alert sounds even if phone audio is off.
- Support for the Apple Watch.
- HealthKit integration.

Cons

- Application is only made for Dexcom G6 or G6 Pro CGM systems. Many of the features are only available on Dexcom G6.
- Review mentions that graphs are hard to read.
- From a review, it seems like the Apple Watch application is slow and can display outdated data.

Figure 2.5: The "Dexcom G6" application [46]. The application show the current blood glucose level and trend. A graph is used to show the trend over time. In addition, the application has widgets.

Guardian Connect

The application lets a person with diabetes see their most recent blood glucose levels, trends over time, status about the sensor and the transmitter in the system, configure a target blood glucose range, and receive alerts when the blood glucose levels go outside the configured range (see Figure 2.6). The user can also choose to upload their blood glucose data to "CareLink™ Personal therapy management software," where they can see all the data online and share the data with friends/family members [47].

Pros

- Trend graphs.
- Custom alerts and reminders.
- Upload glucose data to CareLink™ for sharing.

Cons

- Only compatible with Guardian Connect CGMs.

Figure 2.6: The "Guardian Connect" application [47]. Features a historical graph of the blood glucose levels, current blood glucose level, customized alerts and has widget support.

Carelink™ Connect

The application lets a family member or friend of a person with diabetes see their blood glucose levels, system events, CGM system status, or insulin pump status (see Figure 2.7). In addition, users will receive notifications if the person with diabetes has blood glucose levels outside of the targeted range [48].

Pros

- View trends.
- History of events.
- Time in Range view.
- High and low glucose notifications.
- Remotely Device Status overview.

Cons

- Only compatible with MiniMed 770G and Minimed 780G insulin pump systems.
- Requires a Guardian Connect account.
- Can only view one system at a time.

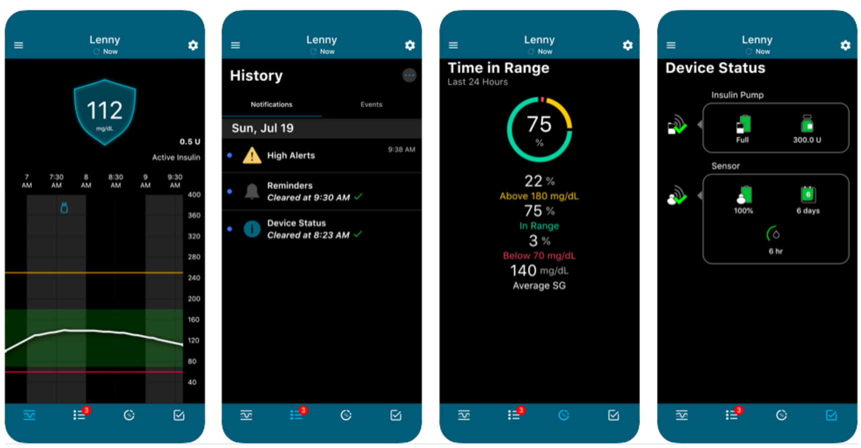

Figure 2.7: The "Carelink™ Connect" application [48]. Lets the user see the blood glucose levels over time and the time-in-range. Have a history view of events that has occurred and a overview of the system's status.

mySugr - Diabetes Tracker Log

Companion application for Accu-Check Meters that automatically import blood glucose values to the app. The application can log meals, show estimated HbA1c levels, view daily, weekly, and monthly reports about blood glucose levels that the user can share with doctors (see Figure 2.8). The application also has a subscription that enables more features like meal photos, blood glucose level reminders, insulin calculator, etc. [49].

Pros

- Apple HealthKit integration.
- Estimated HbA1c.
- Daily, weekly and monthly reports.
- Insulin calculator with precise dose recommendations.
- Glucose graphs.

Cons

- Only supports Accu-Check® systems.
- Some features are limited to a paid subscription.

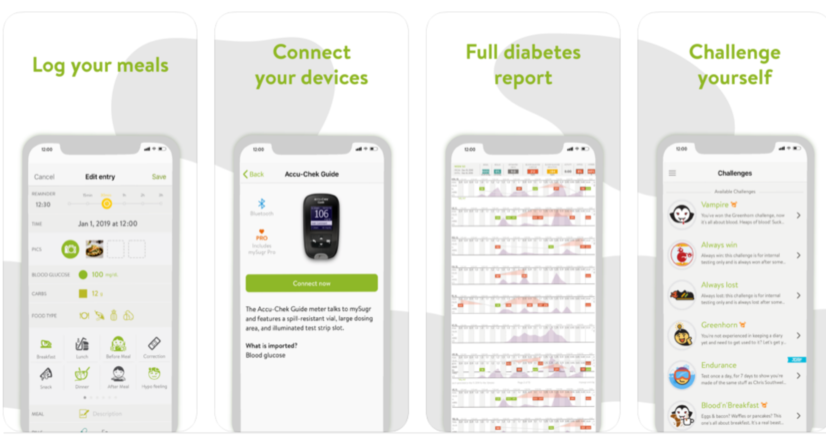

Figure 2.8: The "mySugr - Diabetes Tracker Log" application [49]. A sub-set of the features is log meals, create custom challenges, see blood glucose levels and estimated HbA1c.

2.5.2 Applications with Group Motivational Functionality

Strava

Strava is a social network application for many types of fitness, everything from swimming, running, cross-country skiing to tennis, almost every kind of workout is on the application. The application gathers data from manual entering the activity in the application or importing it from devices connected to the application. A device could be, for example, a fitness watch [50]. Figure 2.9 shows the feed in Strava.

Users can find their friends on the application, and when they are friends in the application, they can see each other's workouts. In addition, users can share their excitement about others' achievements with kudos (read like) or comment on the activity.

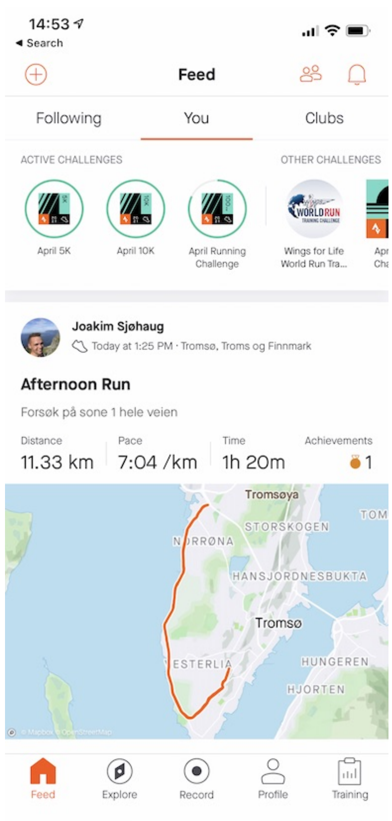

Figure 2.9: Feed in Strava [screenshot Joakim Sjøhaug].

Strava has many features that aim to motivate or engage users to be more active. One feature is called *segment*. A segment can be a ground that is known in the local area for being steep. Someone can then create a segment for this ground, and then everyone who has that ground as a part of their workout will see afterward how they performed against others on that segment. Another feature that Strava has is *challenges*. Users can sign up for challenges, and if they accomplish it, they will receive a badge for the challenge that everyone can see on their profile page. An example of a challenge can be, e.g., "Run 100km through April," and then everyone who runs 100km in April will receive a badge for that challenge (see Figure 2.10). Finally, Strava does have a group feature that is named *club*. Members in a club do not need to be friends on Strava. Therefore, clubs are excellent for, e.g., a workplace where it could be fun to see how colleagues and the workplace perform without being friends with everyone on the platform.

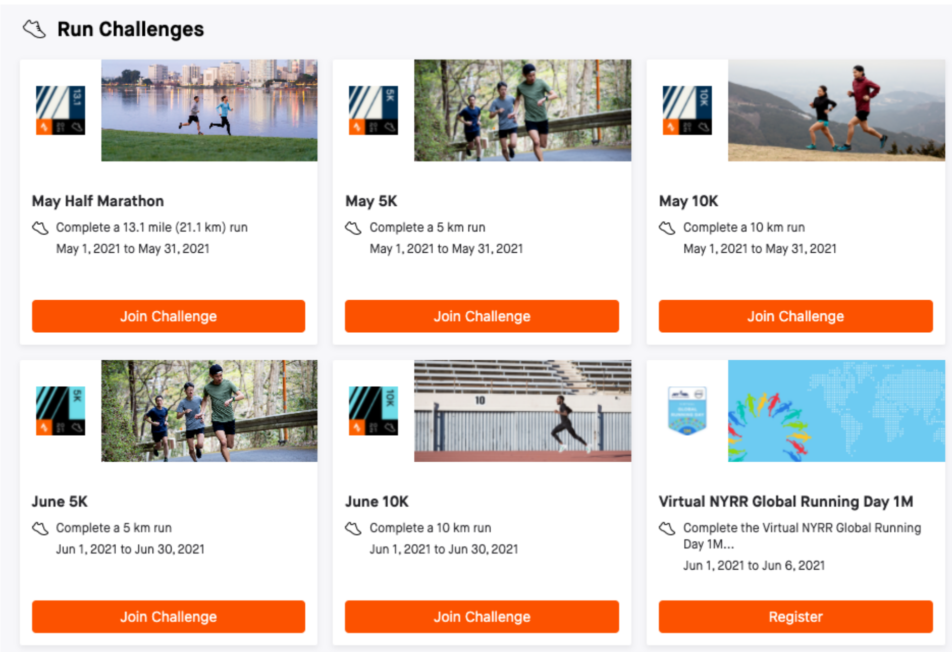

Figure 2.10: Screenshot of some running challenges in Strava [51].

Strava is not an application made for people with diabetes, but the author actively uses this application and thought it would be interesting to include it in the project. In addition, Strava does an excellent job motivating its users through extrinsic motivation from the author's perspective. Therefore, Strava may be a source of inspiration when creating the application for the project.

Pros

- Support a variety of activities.

- Variety of challenges.
- Modern design.
- The application lets the user follow their friends.
- The user can be a member of a club.
- HealthKit integration.

Cons

- Some features are only available through a paid subscription.

Apple Fitness

Apple Fitness is the primary fitness application developed by Apple for their platforms. The application enables the user to see all fitness-related data through one central hub. The user cannot enter activity data manually in the application, but instead, the application reads all activity data from the health repository, HealthKit, on iOS.

The application has a beautiful design with clear overviews of different statistics such as last activities, trends, and summaries. A user can achieve awards for achieving their move, workout, and exercise goals (see Figure 2.11).

Apple Fitness has a sharing feature that enables users to share their activity data with their friends/family members. Users that share activity data will get notifications when they have finished a workout or reached their daily goals. In addition, the application lets the user make it more meaningful to achieve the daily goals by challenging another user to achieve the most minutes of activity through a week/month.

Pros

- Beautiful design with engaging animations and colors.
- Let the user decide self whom they share their activity data to.
- Show trends about the user's activity.
- Has a functionality that lets the user challenge friends in achieving more activity minutes.

Cons

- Some users may find it confusing that one can't enter activity data in the application.

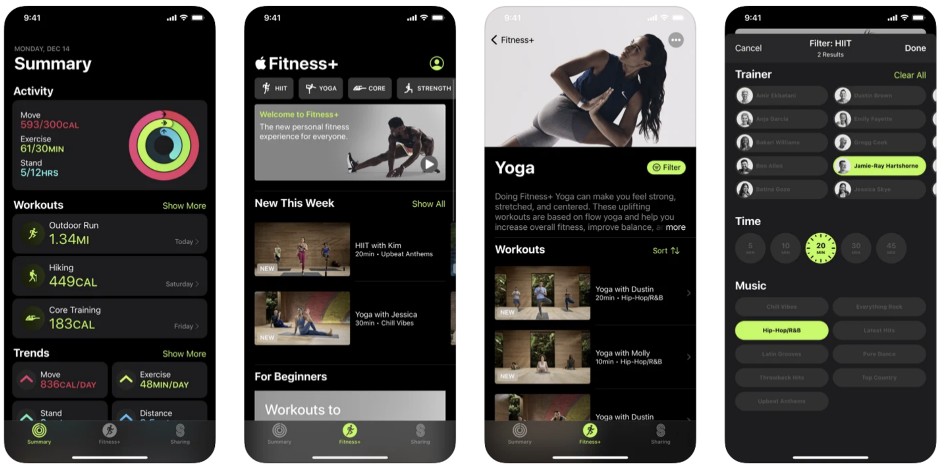

Figure 2.11: The "Apple Fitness" application [52]. Let the user get an overview of all activities with a glance, see workout sessions and challenge friends.

2.5.3 Application Summary

The diabetes-related applications enable the user to see their blood glucose levels and trends, receive notifications for low and high blood glucose levels, and share their blood glucose levels with friends/family members and clinicians. Some of them also let the user configure custom challenges, calculate insulin doses, etc. However, all of the reviewed applications require that persons with diabetes use one of their CGM systems. Dexcom G6 and the mySugr application permit the user to export the blood glucose data to HealthKit on iOS, enabling third-party applications to use the data.

Strava and Apple Fitness are two mobile applications for activity-related data. Both applications let the user see other friends' activities and compete against other users to achieve the most activity minutes. In addition, Strava's challenge and Apple Fitness's trend functionality enable users to compete with themselves to reach their activity goals.

2.6 Summary

This chapter defined what diabetes is and presented the current state of the disorder in Norway. Further, it explained the short- and long-term complications of not managing the disease properly. Aspects of motivational theory and persuasive design principles were also explained in the chapter. Lastly, a review of state-of-the-art applications for people with diabetes was presented.

3

Methods and Materials

In this chapter, the research paradigm used during the project is presented. Then a presentation of the different tools and programming languages used during the development of the application and backend. Lastly, a presentation of the system evaluation method of the application is presented before describing some shortcomings with the processes.

3.1 Research Paradigm

In "Computing as a discipline," Comer et al. [53] described three paradigms to approach engineering in computer science. The paradigms are theory, abstraction (modeling), and design, respectively. The theory paradigm is rooted in mathematics, abstraction (modeling) in the experimental scientific method, and design in engineering. Of these three paradigms, the author of this thesis has primarily taken an engineering approach to construct a system using the four steps the design paradigm consists of:

1. State requirements.

2. State specifications.

3. Design and implement the system.

4. Test the system.

An engineer using this paradigm should iterate these or even repeat some steps until the system meets all of its requirements. Iterating means that if e.g., a test unveils that a condition is not met, changed, or is not necessary anymore, the engineer should apply some of the steps again until the system meets all the specified requirements. In addition, new features needed in the application can be created during the project period leading to new conditions, requiring the engineer to repeat these steps to reach the requirement specification.

Comer et al. [53] also say that a closer examination of the three paradigms revealed that in computing, the three processes, theory, abstraction (modeling), and design, are in a complicated manner connected. Therefore, one could argue that it is wrong to say that only one of the paradigms is used during the work of this project. After closer consideration, some or all aspects of the abstraction (modeling) paradigm may be used in this project. The abstraction paradigm consists of the stages:

1. Form a hypothesis.

2. Construct a model and make a prediction.

3. Design an experiment and collect data.

4. Analyze results.

In this project, a hypothesis that group-based motivation is something people with diabetes may find helpful in staying motivated while managing their disorder was created. As a result, a questionnaire to gather data to investigate if the hypothesis is wrong was created.

For most of the project, an engineering approach has been applied to implement and design a system that accomplishes a set of requirements.

3.2 Tools

3.2.1 Mobile Application

While developing the mobile application, Xcode version 12[1] was used. Xcode is an IDE developed by Apple and designed to create and test macOS, iOS, and watchOS applications. Since the author has experience developing applications for Apple's platform, the decision to use Swift and SwiftUI, a state-of-the-art programming language and user interface framework used to write iOS, macOS, and watchOS applications, was taken.

SwiftUI is a new user interface framework released back in September 2019. Since then, SwiftUI 2.0 has been released in September 2020 and used in the project. Devices (iPhone 6s or newer[2]) running iOS 14.0 or greater supports SwiftUI 2.0, and using such state-of-the-art technologies should usually mean that the application may support a limited group of users. However, iPhone users tend to adopt the latest iOS versions early, and Apple report[3] that 86% of the devices released in the last four years use iOS 14 and that 80% of all Apple devices use iOS 14.

Limiting the application to only work on iOS reduces the potential user group. Still, since iOS's market share in Norway is 59%, it should not be a real problem for the proof-of-concept implementation [6].

3.2.2 Backend

During the backend services development, Microsoft Visual Studio Code[4], a lightweight code editor was used. The package tool Pipenv[5] is used to ensure that all packages used in Python services are present on any computer the service is running on.

1. Xcode 12, *Apple* [website], `https://developer.apple.com/xcode/` (accessed 14 April 2021)
2. New features available with iOS 14, *Apple* [website], `https://www.apple.com/ios/ios-14/features/` (accessed 1 April 2021)
3. App Store, *Apple* [website], `https://developer.apple.com/support/app-store/` (accessed 14 April 2021)
4. Visual Studio Code, *Microsoft* [website], `https://code.visualstudio.com` (accessed 14 April 2021)
5. Pipenv [website], `https://github.com/pypa/pipenv` (accessed 14 April 2021)

3.2.3 Prototype

While prototyping the application, Figma[6], a widely used application, to create prototypes and designs was used. One of the reasons to use such a tool to create prototypes is because of experience from an earlier project that prototyping early makes it easier to visualize where the project is going and may reveal early that some features may not work or are missing. Besides, while meetings with the research group during the Covid-19 pandemic are online, it is easier for the group to understand what the author thought and get concrete feedback when graphical prototypes were available.

3.3 Research and Experiment Methods

3.3.1 Consulting with Experts in the Field

Every week during the project, there have been online meetings with the research group and everyone interested in or connected with the project. The participants have all broad knowledge of specific fields in health informatics, and the diversity has been of great help in the project. At the start of the project, these meetings were actively used to help set the direction of what to create as the author felt it was hard to identify something that would be unique and innovative.

3.3.2 Data Collection

When a vision about how the application should approach the problem was settled, the author designed a questionnaire published in an online community for people with diabetes. The anonymity of the participants of the questionnaire was of the highest priority. Before posting the questionnaire, it was reviewed by the research group multiple times to ensure that the questions were relevant.

Questionnaire Design

The questionnaire design is based on thoughts that the author had after reading up on motivational theory and reviewing existing applications in the market. Below a short description of some question's existence is given. All questions in the questionnaire is listed in Table 3.1 and is only available on Norwegian.

6. Figma [website], `https://www.figma.com/` (accessed 14 April 2021)

4. Was asked to discover how established time-in-range is as a relatively new way of measuring the average blood glucose levels.

5. Asked to see if the participant means that they achieve healthy blood glucose levels. In addition, what participants answer here may influence the answer to the other questions.

6. Thought as a control statement to question 5. It felt natural that someone who claimed they are achieving healthy blood glucose levels is also satisfied with their blood glucose levels.

7. Blood glucose levels are sensitive health data, and the participant's view of having them public is important.

8. Asked to examine if it was more accepted to share blood sugar levels with family members.

9. Asked to get the participant's view on group-based motivation.

10. Motivational theory states that people tend to be motivated by other people's successes. Therefore, this question was included to see what people with diabetes mean about it.

11. Motivational theory also states that people are easier motivated when they define a goal. Therefore, it was interesting to examine if the participants usually achieve goals that they set for themself.

12. Notifications will be necessary to inform the users of their progressions or other events in the application. Therefore, a question about what they think about the number of notifications their device delivers was asked.

13. Not all people with diabetes use a Continuous Glucose Monitoring device, so asking if the participant used a CGM was natural.

14. Many CGM devices exist with different features. To get an overview of the CGM used by the participants, this question asked which CGM device they use.

15. Included in the questionnaire since one of the research group members meant that it was interesting to see how often people measure their blood glucose levels manually through a day.

16. Same as with question 15, the research group member also meant that it would be interesting to see how often people look at their blood glucose

levels through a day.

17. This question was asked to see what the participant think is the thing that motivates them most in a group. The question was optional.

18. Group-based motivation is not something that would be something for anyone. Therefore, this question asked what motivates the participants the most. The question was also optional.

Questionnaire Review

A few groups on Facebook were considered before deciding on a group to post the questionnaire. The third research sub-problem, defined in section 1.2.1, made groups that looked like targeting people with not much technical knowledge more appealing. Therefore, the decision was made to publish the questionnaire in a group called "For oss med Diabetes" which has at the time of writing over 10k members.

Before posting the questionnaire in the group, the author applied for membership. When an administrator accepted the membership, a message was sent to one of the administration to ensure that it was okay to post the questionnaire in the group[7]. The administrator also reviewed the questionnaire[8] and came with valuable input to change some of the questions.

The questionnaire's main goal was to reveal if the target group thought motivational groups could work for people with diabetes. In addition, one of the questionnaire sub-goals was to get an overview of which continuous glucose monitoring device people use.

Table 3.1: All questions in the questionnaire. A formatted version of the questionnaire is available in appendix A.3.

1	Hva er din alder?
2	Har du selv diabetes eller svarer du på denne undersøkelsen som pårørende?
3	Kjønn
4	Jeg måler hvor godt blodsukkernivået er kontrollert over tid ved hjelp av
5	Jeg oppnår sunne blodsukkernivå
6	Jeg er fornøyd med mitt blodsukkernivå

7. The message to the administrator is available in appendix A.1
8. The questionnaire is found in appendix A.3

7	Jeg synes det er greit at andre ser blodsukkernivået mitt
8	Jeg synes det er viktig at andre familiemedlemmer kan se mitt blodsukkernivå
9	Jeg kunne tenkt meg å delta i en motivasjonsgruppe for å oppnå og holde sunne blodsukkernivå
10	Jeg blir selv motivert av å se andre sin fremgang
11	Når jeg har satt meg et mål, pleier jeg å nå det
12	Jeg synes applikasjonene på telefonen min gir for mange varsler
13	Jeg bruker kontinuerlig blodsukkermåler CGM
14	Hvis ja på forrige spørsmål - Hvilken kontinuerlig blodsukkermåler CGM har du?
15	Hvor ofte måler du blodsukkeret manuelt?
16	Hvor ofte ser du på blodsukkernivået ditt?
17	Hva skal til for at du blir motivert i en gruppe?
18	Hva motiverer deg mest?

3.3.3 Testing Methodology

The application was tested by performing a system usability test on six people. The test was constructed such that the participants first had to complete five different scenarios in the application (the application and the scenario handout is shown in Figure 3.1). Then, after they had completed all the scenarios, they were presented with a System Usability Scale questionnaire. Since the application's core feature depends on data and events generated after extensive use, populating the system with mocked data before testing was necessary to get valuable feedback.

Before each test session, the user was introduced to the Thinking Aloud Method. The thinking aloud method is a simple technique commonly used in user testing that encourages the users to talk while performing the tasks/scenarios [54]. The tester should not give the user any clues or instructions during testing but be supportive [55]. While speaking, the tester notes any feedback and encourages them to continue talking while doing the chores.

3.4 Critiques of Methods

The most prominent area of critique is user testing. During the development, users should have been more involved when developing ideas and prototypes. However, the Covid-19 pandemic and all the regulations that have been in

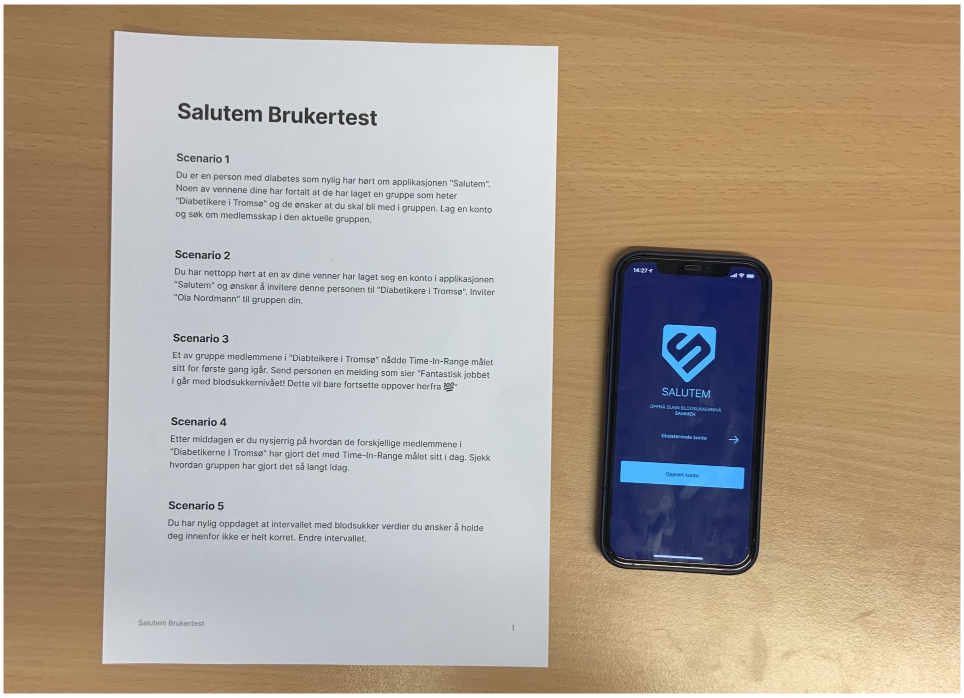

Figure 3.1: Handout with scenarios along with the mobile phone with the application used during user testing.

place and constantly changing, extensive user testing has been difficult to arrange. Therefore, testing the application and feedback has come chiefly from the weekly online meetings with the research group and fellow students at the office.

Not validating how the system had performed with actual people with diabetes is also a shortcoming. However, since the application does not depend on devices that people with diabetes have but instead the data the device produces, it could be demonstrated that our system worked by mocking the blood glucose levels these devices made. In addition, the trial users could also give valuable input on the application after performing the scenarios.

The lack of an extensive literature search is also under critique, and such a search could have revealed more features or other directions the project could have taken. However, consulting with an expert in the field helped navigate the area and unveil a new state-of-the-art way, time-in-range, that could be used to measure how healthy blood glucose levels a user achieved.

3.5 Summary

This chapter described the research approach to this project. Further, a short description of relevant tools and programming languages used when developing the mobile application and the backend services were given. The chapter also described how weekly meetings with the research group guided the author in the right direction when everything was unclear about the project's direction. Then a description of how data from people with diabetes was collected by conducting a questionnaire on an online community. Lastly, a description of the usability testing of the system was explained before a critical view was pointed at the research method.

4

Requirements Specification

This chapter explains the sources and presents the requirements defined for the system. It shows how personas and scenarios were used to identify requirements for the system. Lastly, the chapter presents the non-functional requirements of the system.

4.1 Source of Requirements

The requirements for the application are gathered from multiple sources. The author has used his knowledge as a software developer, personas, scenarios, and the results from the questionnaire mentioned in section 3.3.2 to gather most application requirements. Besides, requirements have also been created after discussions with the research group (Gunnar Hartvigsen, Professor, Eirik Årsand, Professor, Antonio Martinez Millana, Ph.D., Ashenafi Woldaregay, Ph.D., Santiago Gil Martinez, Associate Professor, Keiichi Sato, Professor). The review of competitive (read similar) applications in chapter section 2.5 also brought some requirements.

4.1.1 Personas

A persona is an "imaginary" user of the system. The author uses personas to get an understanding of which types of users could use the product. Personas have different intentions for the application, which is defined by their background and needs [43]. Therefore, the description of a persona should include why they may want to use the product, their technical skills, and their education. In addition, various personas may help identify if a feature in the application is valuable and likely to be used by people with diverse backgrounds and technical abilities [56].

For this project, three personas were created, Ola, Gaute, and Kari, and each persona is described below.

Ola

Ola, age 28, is a web developer in Tromsø, one of the largest cities in Norway. He was born in Stokmarknes, a small town in Nordland. Ola is a healthy man and weighs just above 70-kilos. One of his favorite interests is exercise, and he loves being outdoors in the mountains with his friends. Ola moved to Tromsø to study Computer Science when he was 20 years. After he finished his degree, he immediately got a job as a web developer in a local firm.

When Ola was 16 years old, he was diagnosed with type 1 Diabetes. In the start, he found it hard to adapt to the new lifestyle. Primarily because of the unhealthy lifestyle he had in his teenage years. However, with support and help from his family, especially his mother, he managed to get used to the new lifestyle. He found it frustrating and unfair during high school that the disease could influence a whole school day.

When Ola was 22 years old, his doctor approved his wish to get a Continuous Glucose Monitoring (CGM) system, and since then, it has been easier to control his blood glucose levels. With the CGM, Ola has found it easier to calculate how much insulin he needs to inject, and he does not have frequent episodes where the blood glucose level is too low or high. He uses time-in-range to measure how good his blood glucose levels are throughout a day, and he manages to stay above 80% time-in-range on average.

Even though Ola is happy with his life now and copes with diabetes, he is missing to speak with people in the same situation and interests. What motivates him with exercise is sharing his hikes with friends on a social platform and seeing their hikes. Therefore he is excited about the new application *Salutem*[1], where he can join a group for people with diabetes and with the same interest in mountain hikes. He hopes that seeing other people with diabetes achieve their

1. The name is *safety* in Latin and the idea is that people should feel safe by participating in motivational groups.

blood glucose goals will motivate him to continue achieving healthy blood glucose levels also in the future.

Gaute

Gaute, age 25, is a salesman in his hometown Ås. His bodyweight is above 85 kilos, and he tries to have a healthy diet. After finishing high school, he started his career as a salesman in one local electronic store. He has worked here for the last five years, and his employee highly values him for his skills. In addition, his colleagues appreciate him for his humbleness, passion, skills, and mood. Gaute's favorite hobby is flowers, and he uses most of his spare time to grow and take care of his plants.

Gaute got diagnosed with type 1 diabetes recently and is currently adapting to the new lifestyle. Now, he struggles to achieve healthy blood glucose levels, which makes him unable to reach his standards at work, and after work, he is so tired that he struggles to take care of his plants. One of Gaute's biggest struggles with the disorder is finding it hard to calculate how much insulin he needs to inject after meals, workouts, and after walking to work. Therefore, he ends up using too much insulin than necessary.

He is excited to try *Salutem* and become a member of a local group for people with diabetes in Ås. As a member of the online community "flower power," he believes that a group with other people with diabetes can help him learn about the disease and achieve healthy blood glucose levels soon. He looks forward to being his usual self again.

Kari

Kari, age 52 and weighs 65 kilos, is a teacher from Oslo. She has three children who are adults now and do not live together with Kari and their dad. Kari started working as a teacher imminently when she finished her education over 20 years ago.

Kari was diagnosed with diabetes type 1 over 30 years ago, and she lives a healthy life, where she manages to live with the disease. She regularly goes to control, where they check her HbA1c. On average, she has normal values for people with diabetes, which lays around 53 mmol/mol[2]. Kari does not use a CGM to measure blood glucose values but uses a finger-prick device. After

2. HbA1c, langtidsblodsukker, *NHI* [website], `https://nhi.no/sykdommer/hormoner-og-naring/diabetes-generelt/hba1c/` (accessed 10 April 2021)

each prick, the device syncs the reading with her phone and saves it.

Now Kari wants to share her experience with others who struggle with diabetes, as she knows how hard it can be to live with the disease. She is excited to use *Salutem* to create a group to invite people who have newly gotten the disease. Her vision is to create a group where she can see people's progress, motivate them to reach their goals, and talk and encourage those who did not achieve their goals.

4.1.2 Scenario

Scenarios is a technique that product developers can use to discover features that will enrich the application [56]. Product developers have used the method in Software Engineering since the 1980s. The author can best describe scenarios as a narrative about a situation where a user is using the application. In this situation, the user uses some of the application's features to accomplish something they want to do. Thus, a good scenario gives the user some context around the problem they want to solve using the application. Still, scenarios should not be too detailed as it is not an exact system specification [56].

A scenario for the system implemented in this project is shown below, and from this scenario, one can see that it helps identify requirements for the application. For example, a requirement for the application can be to support creating an account or searching for groups. Thus, scenarios were found advantageous when gathering requirements for the system.

> Ola is a young adult living in Tromsø. When Ola was 16 years old, he was diagnosed with type 1 diabetes. Ola has found a new lifestyle that requires strict self-management hard and wants to find people in the same situation to seek advice and an inclusive environment.
>
> From friends, he became aware of the application *Salutem*, which is an application where people with diabetes can create groups, monitor each other's progress, and discuss how they can regulate their blood glucose levels.
>
> He locates the application in the App Store and installs it on his phone. After launching the application, he immediately creates an account, customizes his targeted blood glucose range, and adjusts his daily time-in-tange goal. Then he located the "Groups" feature and searched for groups named "Tromsø" and found the group "Personer med diabetes i Tromsø." He sent a request to join the group.
>
> When Ola become a member of the group, he got access to the group overview. There he could see the members and how their time-in-range trend had been the past week.

4.2 Functional Requirements

Functional requirements are a description of a service/feature the application/system must offer. A functional requirement can describe some part of the system, e.g., a component or the system as a whole. The structure of a functional requirement is typically a part/actor in the system (e.g., a user) and some action performed on the system and the intended output from this behavior. As far as possible, functional requirements should not mention technologies that the developer should use to implement them [57].

> The application shall gather blood glucose levels.

All requirements for the application are listed in Table 4.1. Requirements are specified using a subset of the properties of the "Volere Requirements Specification Template" [57, p. 397]. Each of the requirements has the following properties:

- **Requirement #** A unique ID for the requirement

- **Description** A short description of the intent of the requirement.
- **Rationale** Justification of the existence of the requirement.
- **Source** Who proposed the requirement.
- **Fit Criteria** A way of measuring if the requirement is met. It can be interpreted as an acceptance criterion.
- **Priority** This is not a property in the Volere Requirements template. The author chose to use prioritization instead of customer satisfaction and dissatisfaction since stakeholders are not actively involved in the project. Scale from 1, not important, to 5, very important.
- **Dependencies** Identifies if the requirement does depend on some other requirements to be implemented.

Table 4.1: Functional requirements for the system.

ID	Description	Rationale	Source	Fit Criteria	Priority	Deps.
#1	It shall be possible to create a group in the application.	Gathering users in groups make it possible to see each other progress, find friends and give advice.	Author	A signed-in user should be able to create a group from the group section of the application	5	None
#2	The application shall import blood glucose data from an external data source.	The import of blood glucose data makes it possible to display in the system how someone is doing with their time-in-range goal.	Author	Opening the application reads the latest blood glucose values from an external data source.	5	None

#3	The application shall ask the user for their permission to read blood glucose data.	Asking for permission before reading data will show that the system gives the user the transparency they deserve and make it possible to earn the user's trust.	Author	Before reading blood glucose data, the application displays a dialog asking about permissions to read the data.	5	2
#4	It shall be possible to create an account in the application.	Users will use accounts to log in, join groups, view progress, etc.	Author	A button shall prompt "create account" and display a form asking for the different inputs from the start.	5	None
#5	It shall be possible to log in to an existing account.	Users reinstalling the application or given credentials to an account will log in and access the related data.	Author	A button should prompt "existing account" and, upon tap, display a form asking for the credentials and having a "sign-in" button to log in.	5	4
#6	It shall be possible to sign out.	It will make it possible for someone to sign out of the account and log in to another account.	Author	When a user is signed in, a button shall prompt "sign out" and sign the user out of the application upon tap.	3	4, 5

#7	The application shall have a feature that allows users to invite members to a group.	It will make it possible for an organizer to invite friends or other people to their group.	Author, Research group	When viewing a detailed overview of a group, a button shall prompt "Invite members" and allow the user to invite other members.	3	1
#8	The application shall ask for permissions to send notifications to the users.	Asking for permissions will make it possible to send notifications for events in the application and acquire attention to the application. Also, this will strengthen the transparency of the application.	Author	When starting the application, the application shall ask for permissions for notifications.	4	None
#9	The system shall be able to accept/decline invitations to a group.	The system will achieve security of sensitive data if invitations to a group can be approved or declined before sensitive data is available for a group.	Author	When an invite is sent, the user receives a notification saying that someone invited them to a group. The user can then decide if they want to join the group.	3	7
#10	It shall be possible to change the time-in-range goal.	Changing the time-in-range goal makes it possible to aim higher or lower if someone struggles or finds it too easy to reach their goal.	Author	When signed in, the system can change the time-in-range goal.	4	5

#11	It shall be possible to change the blood glucose target range in the system.	The system will be available for more users if it is possible to change the blood glucose range.	Author	When signed in, users can change their blood glucose range to a preferred range.	4	5
#12	A group member shall be able to see the progress of other members in the group.	Seeing the progress of other members in the group can have a motivational aspect. Besides, seeing the progress of other group members may engage in sending a message to the member.	Author	At a group overview, the time-in-range for each member at the current date is present.	3	1
#13	It shall be possible to send direct messages to other group members.	Messages are a great way to send motivational tips or praises.	Author	When signed in, a user can view a user profile and tap a button to send a DM to the user.	3	5, 4
#14	Group members shall see each other's time-in-range history.	The questionnaire enlightened that many are motivated by seeing other's achievements/progress.	Survey	When viewing a group member's profile, it shall show the time-in-range history, e.g., the latest week.	3	1,4
#15	It shall be possible to join a group.	It makes it possible for a user that discovers a group to become a group member.	Author	When a user discovers a new group, a button shall propose "join the group."	4	1

#16	It shall be evident in the application that any health advice is not given from an expert.	A disclaimer about health advice given in the application may avoid a worst-case scenario that could have catastrophic consequences for a user. Diabetes is a highly individual disease, and what works for someone may not work for others.	Author, Research group	An information view shows the disclaimer when singing in for the first time and viewing any user suggestions.	2	4, 5, 13
#17	The application shall have a feature for creating challenges.	Diabetes is a highly individual disease, and some find it motivating to sign up for a challenge instead of groups.	Survey	A user can create a custom challenge in the application and sign up for the challenge itself.	2	4
#18	An organizer of a group shall have the possibility to accept or decline join requests to the group.	Some people wish to create a group for their friends and not let anyone join the group and see their blood glucose values.	Author, Survey	An organizer will get a notification when someone wants to join a group they created. From the notification, the organizer can decline or accept the request.	2	1, 15

4.3 Non-Functional Requirements

Non-Functional Requirement describes the abilities of the system/application. System designers use these requirements to impose constraints or restrictions on the design of the application. A non-functional requirement can describe the system/application capabilities, such as scalability, reliability, environmental aspects, usability, etc [57].

> New users must customize their blood glucose level range and time-in-range goal after the first successful login.

The four non-functional requirements defined for the application are described below.

Usability

The application targets a varying age group and should therefore have a straightforward user interface that is easy to understand. Besides, the appearance should have a modern look that fits well into the iOS system that users are already using.

Security

The system shall send time-in-range data and other types of data over secure channels. Sensitive data such as blood glucose levels should not leave a user's device.

Supported Continuous Glucose Monitors

The system shall support multiple types of CGMs. Supporting multiple types of CGMs will make the application attractive for a wide group of people with diabetes.

Portability and compatibility

The application must run on iPhones with at least iOS version 14.5. In addition, the application must have a dynamic user interface that scales between the different screen sizes[3].

3. iOS Device Display Summary, *Apple* [website], `https://developer.apple.com/library/archive/documentation/DeviceInformation/Reference/iOSDeviceCompatibility/Displays/Displays.html#//apple_ref/doc/uid/TP40013599-CH108-SW2` (accessed 15 May 2021)

4.4 Summary

This chapter described how personas, scenarios, questionnaire results, and discussions with the research group were used to help identify the functional and non-functional requirements for the system. Each requirement is defined using the Volere template, and a description was given why prioritization was used as a property instead of customer satisfaction and dissatisfaction.

5

Design

This chapter describes how a simple design system was created for the mobile application and how components of the design system were composed to create views that fulfilled the requirements specified in chapter 4. Functional requirements that a view meets are referred to in parentheses. For example, (#1) means that the described view meet requirement number 1 in Table 4.1. Further, the chapter proposes an outline of the backend service architecture and motivational methods for the application.

5.1 Mobile Application

Design System

A design system can best be described as a set of LEGO bricks that can be composed to create scenes. As Stephen Hay says, "*We are not designing pages, we are designing systems of components [58].*"

Before making the prototype scenes of the mobile application, a small design system was created. The design system includes only a subset of what Brad Frost defines as a design system [59].

Color Palette

The first part of the design system is the color palette. Colors in the application's color palette are shown in Figure 5.1 and consist of four colors.

- **Primary** - The most prominent color in the application.
- **Secondary Background** - Used to create contrast against the primary color and in scenes where the primary color does not fit.
- **White** - The white color used in the application.
- **Gray** - A gray color that is used as the background color in the application.

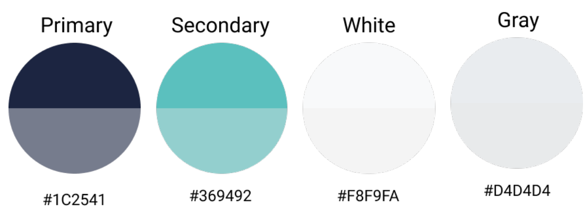

Figure 5.1: Color palette.

Components

The component library consists of commonly used components in the application. These are buttons, sliders, text input fields, progress circles, sliding graphs, cards. Figma makes it easy to organize components, thus making it easy to compose them together to prototype scenes for the application. Below a subset of the elements in the component library is described. Figure 5.2 present the components.

Sliders

A slider is a component that lets the user choose a numeric value by dragging a knob on a fixed interval. The design system has two kinds of sliders: selecting a range and selecting a numeric value on a set range.

Button

The component library consists of three different button variants primary, secondary, and ghost. All these buttons also support having an icon to indicate further what the button does.

Progress Circle

Circles are a common element used to show progress. The progress circle of the component library displays the value and title inside a circle that is not closed. The circle comes in three different sizes, large, small, medium, and two variants, primary and secondary.

Sliding Graph

Sliding Graph is a component that displays values on a closed range by drawing vertical bars on a line. The horizontal stripe has labels on the tips to show the minimum and maximum value of the range. One could also draw a second range on the line to indicate a range of interest.

History card

The history card is a component that can be used to display historical values, e.g., blood glucose values, the past week. Bars with a fixed height based on the average blood glucose values on a given day are drawn beside each other on the card. By drawing them beside each other, it can be easier to get a sense of how the average blood glucose level was each day or to compare days. The component can also draw a horizontal line for a specific value in the range that will overlay each bar.

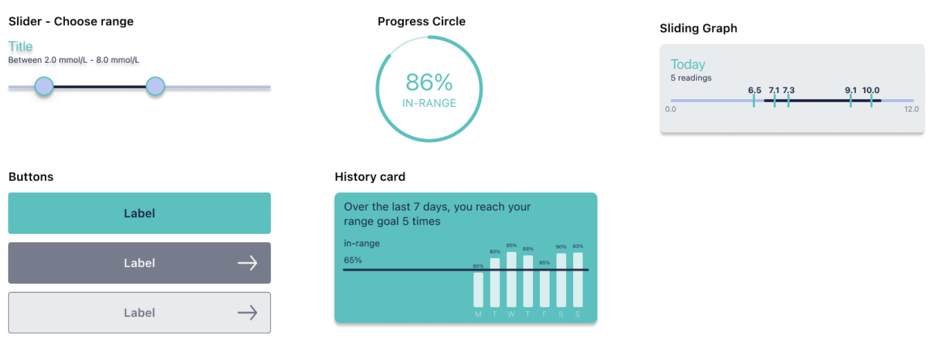

Figure 5.2: Subset of the Components Library. From top left, slider to define a range, a circle indicating process, a sliding graph with value annotations, buttons and a history card.

Scenes

From the requirements specified in chapter 4 different scenes are made to meet these. A screen is made by composing the components in the design system. The most important scenes in the application are described.

Home

The user can see how many blood glucose samples the application has read on a current day from the home screen. A large progress circle is used to indicated the time-in-range value on the current day.

A favorite group can also be shown on the home screen. A simple card showing the current time-in-range, name, and a short description will be displayed for each member in the group.

The user can also see its target blood glucose range and tap the card to change the target range (#11). A bell icon that can be filled or stroke indicates that the user has new notifications. Figure 5.3 show the home screen and Figure 5.4 show the home screens with a favorite group and available notifications.

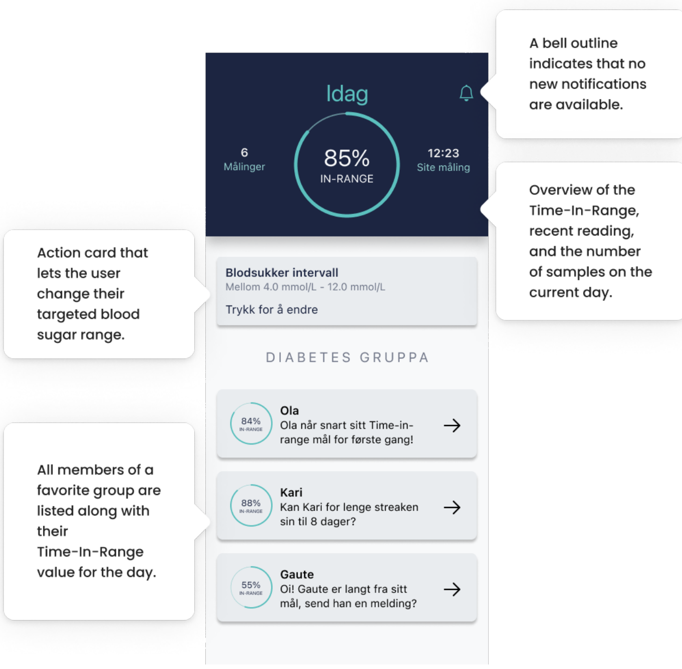

Figure 5.3: Application home screen with annotations.

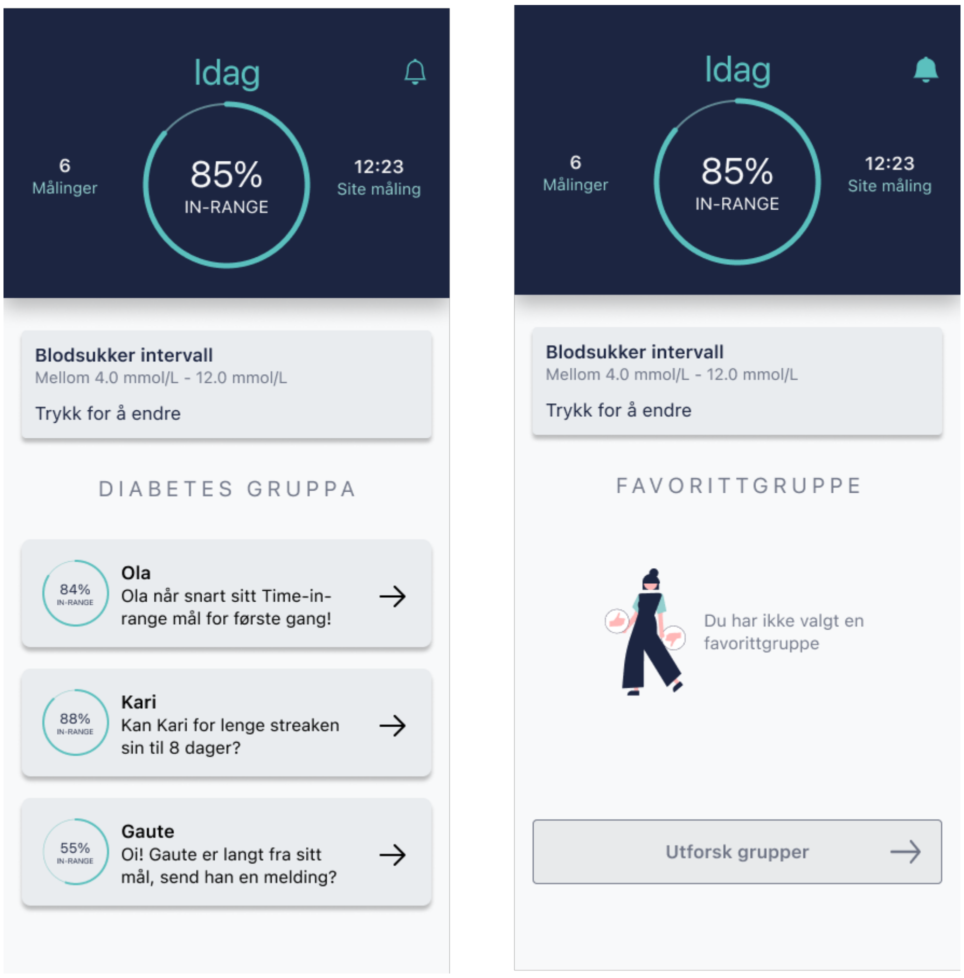

Figure 5.4: Application home screens. The right illustration show how the view looks when no favorite group is selected and when notifications are available. Illustration from unDraw [60].

Profile

On the profile page, the user is presented with a today and overview section (see Figure 5.6). Today's section gives the user an overview of today's blood glucose samples and their value and the average blood glucose value. In the overview section, the user can see their time-in-range values for the past week in addition to the average blood glucose value. From the profile page, the user can update the personal information and change the time-in-range goal (#10).

When a user views a group member's profile (see Figure 5.5), the only information shown is the past week's time-in-range values (#14), the current streak, bio, age, CGM device, groups, and a button to send the user a message (#13).

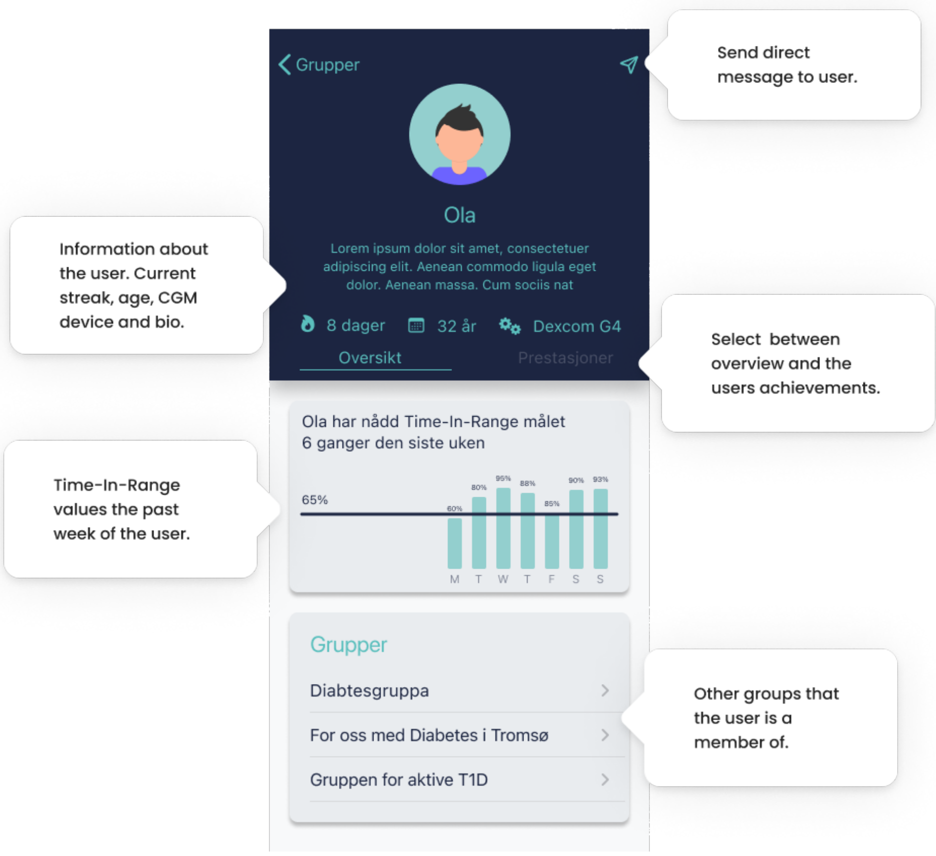

Figure 5.5: Profile view of a group member with annotations. Illustrations from unDraw [60].

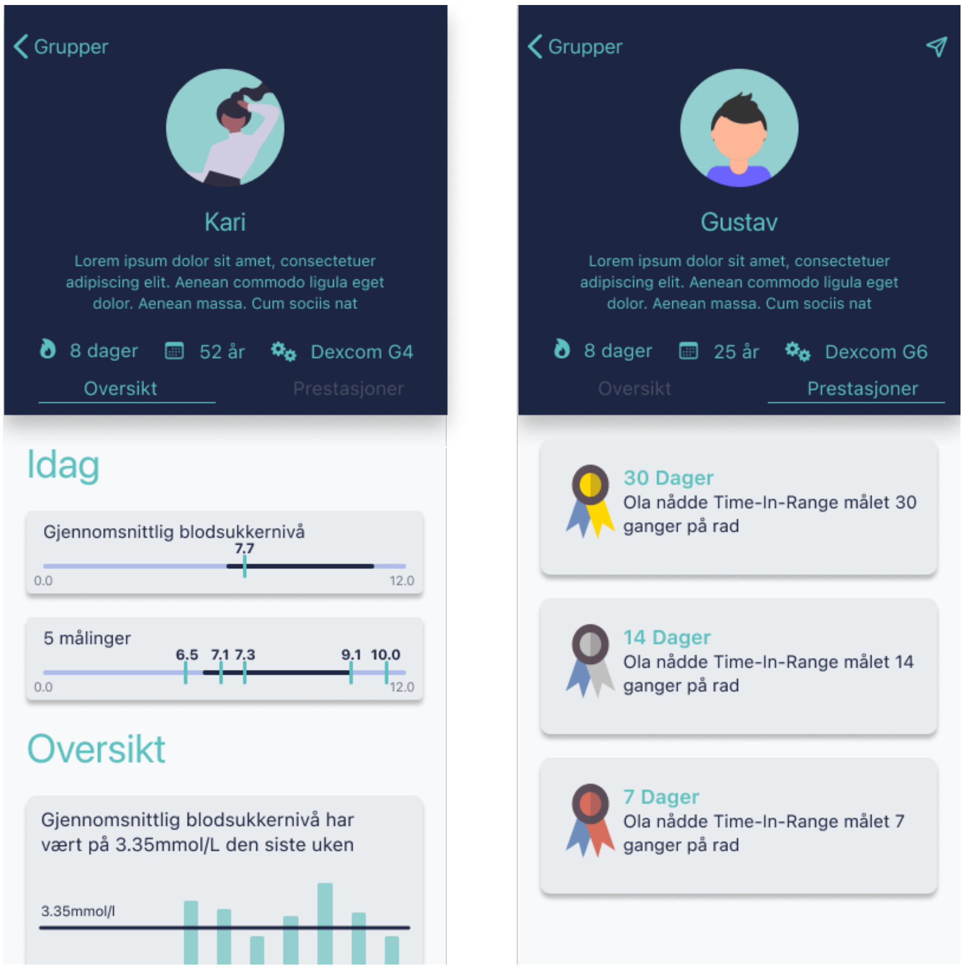

Figure 5.6: Viewing the profile as a user and group member. The user can see the average blood glucose levels on the profile page, all samples of the current day, and average blood glucose levels of the past week. The right illustration shows how achievements could be illustrated in future iterations of the application. Illustrations from unDraw [60].

Group

The group section consists of three main scenes. These scenes are *discover/overview*, *create* and *group view*.

Discover/overview
All the groups the user is a member of are shown in a list with their names. A search bar lets the user discover new groups, and when tapping a search result, the user is navigated to a detailed view of the group.

Create
A user can create a new group by pressing a plus sign on the navigation bar (#1). The user must then give the new group a name and a short description. Figure 5.7 show the discover overview.

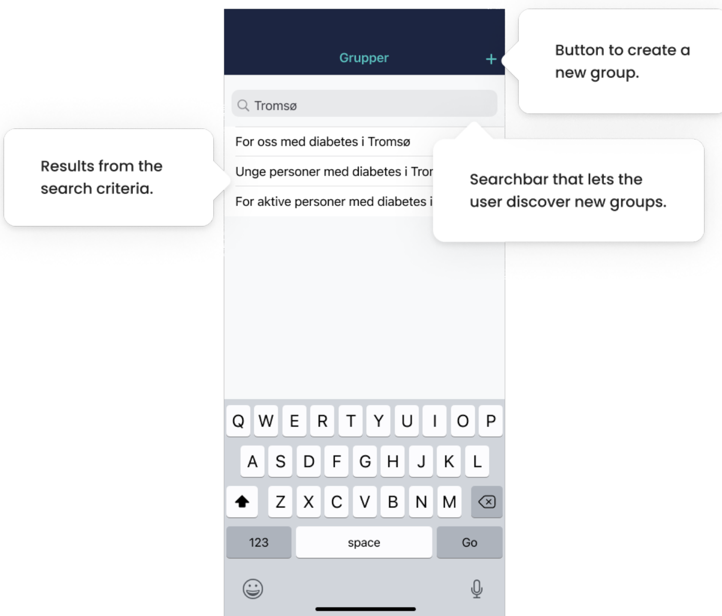

Figure 5.7: Groups view with annotations.

Group View
The group view (see Figure 5.9) shows the name and the description of the group. If a user is not a group member, a button to join the group is available (#15). When the user is a group member, the scene consists of two sections, overview and members. In the overview section, a card for each member is shown. The card shows the member's name and how their time-in-range value is for the given day (#12). Each summary card is tappable and will navigate to the profile page of the given user. In the second section, all the members of the

group are listed. From this section, the user can also invite other members to the group (#7).

Notifications

Notifications are an essential part of the application. These are used to acquire a user's attention to perform some activity in the application. Mainly notifications are used to inform the user if they are about to or reached their targeted time-in-range value. Besides, they also get notified if they did not achieve their targeted time-in-range.

Group members receive notifications when a group member reaches or does not reach their time-in-range goal. For example, suppose a member has two blood glucose level readings above or below the targeted range. In that case, a notification will prompt other members to start a conversation about the consecutive readings outside of the interval. Figure 5.8 show some example notifications.

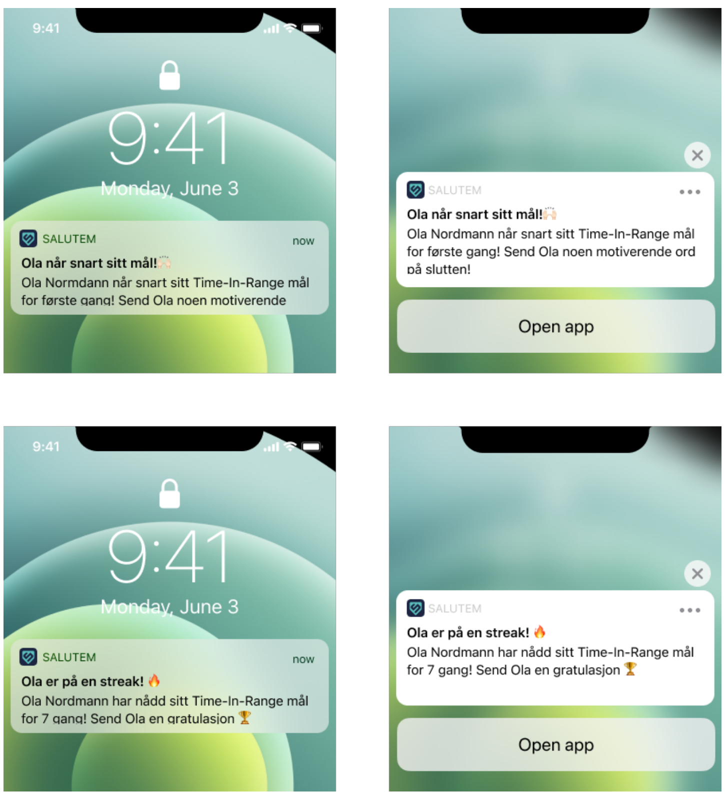

Figure 5.8: Top: Notification that a user is about to reach their time-in-range goal. **Bottom:** Notification that a user reached their time-in-range goal for the 7th day in a row.

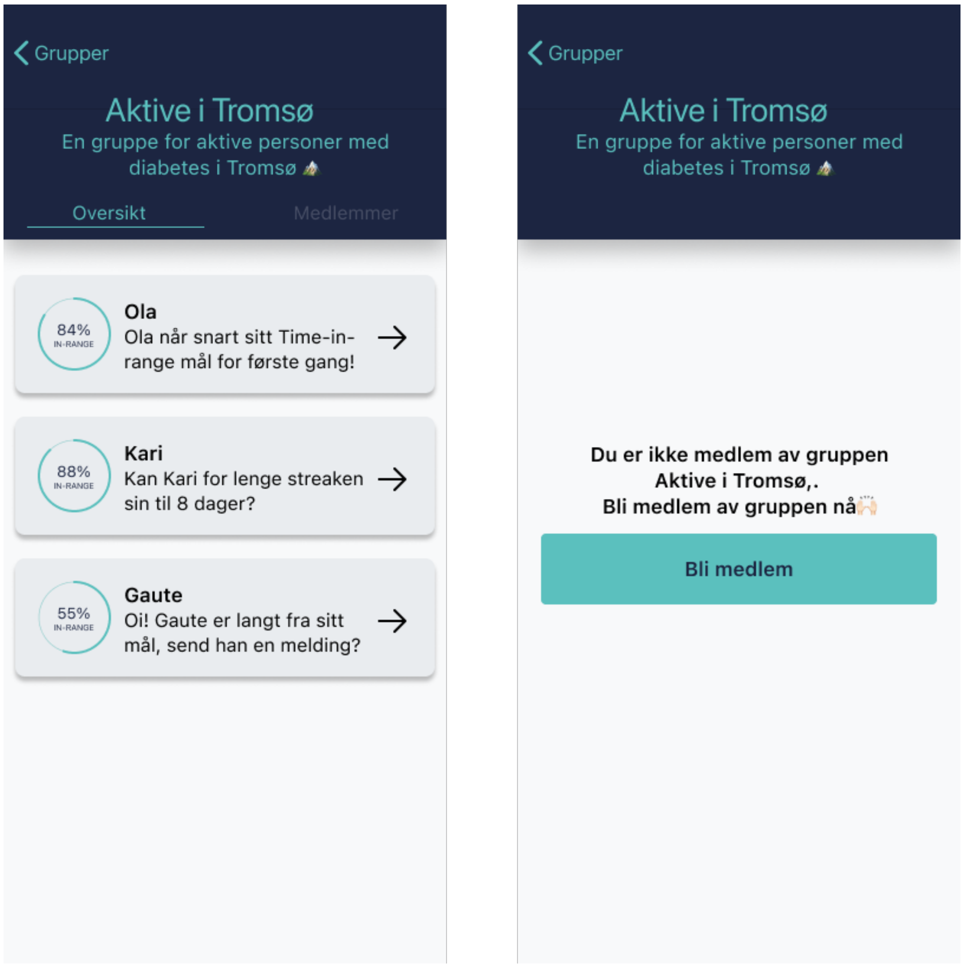

Figure 5.9: Detailed group views. The left illustration shows how a detailed group view is for group members. On the right is the view when a user is not a group member.

Onboarding

When starting the application for the first time, the user has to be onboarded to the application. The onboarding process has at most five scenes if the user needs to create a new account.

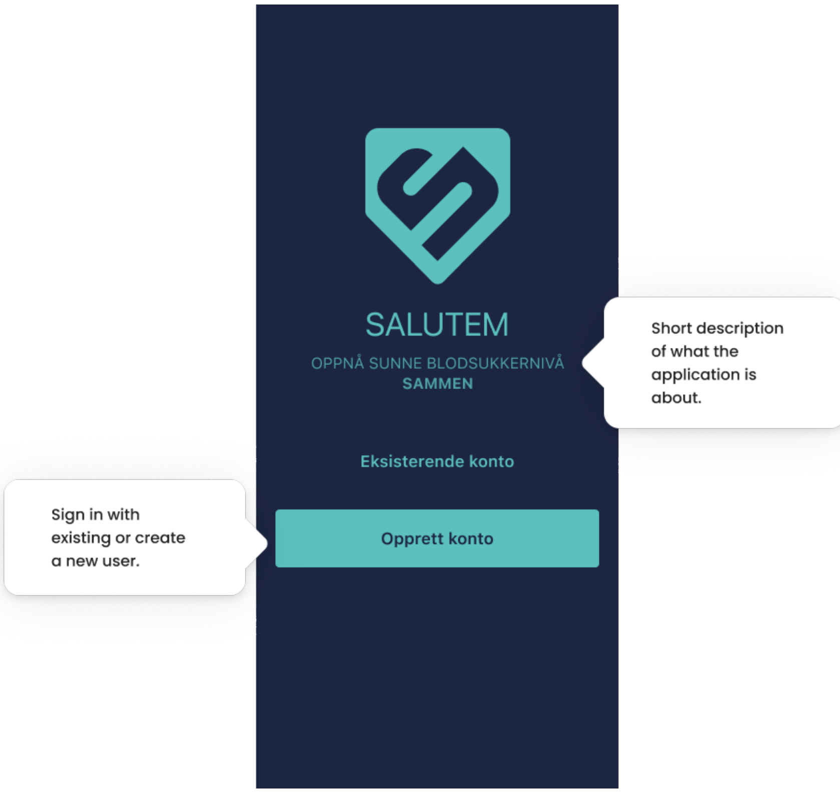

Figure 5.10: Onboarding launch screen.

First, the user is welcomed by the application and given a short description of what the application is. A user can then choose to either log in with an existing account or create a new account (#4, #5). Figure 5.10 show the launch screen.

If the user has an account, they can log in with their credentials by filling out the form. On the other hand, if the user needs to create a new account, they are presented with a form that asks for the necessary details to create a new account.

Upon the first login, the user is shown a form to modify their profile and define their targeted blood glucose range and time-in-range. A short description is given for each target to help the user understand the goals. The last step in the onboarding process is to ask for permissions and clarify why the application

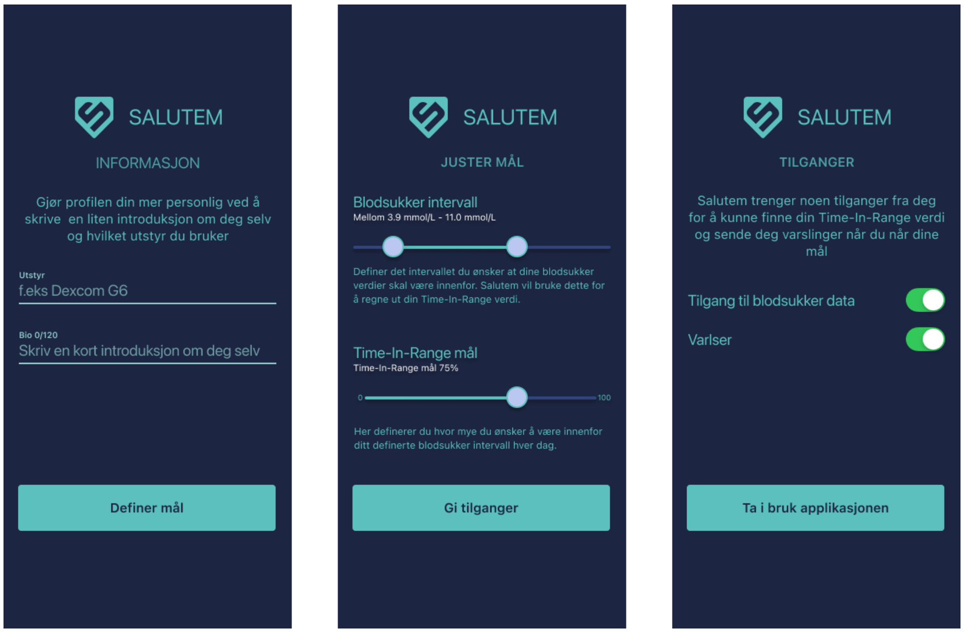

Figure 5.11: Onboarding scenes. From left, add a personal description and which CGM the user is using, define the target blood glucose range and time-in-range goal and lastly give the application permissions to read blood glucose data and send notifications.

requests these permissions (#3,#8). Figure 5.11 show the different onboarding scenes.

5.2 Backend

The backend service provides the application with the necessary services to create and read users, groups, time-in-range readings, and group memberships. Before the backend services are implemented, the author created an outline of a database scheme and architectural design of the services.

Database Schema

Using the functional requirements outlined in chapter 4, the database tables to support the application were identified. The tables are User, Group, Time-In-Range reading, Memberships, Challenges, and Participants. A description and reasoning of each table's existence are provided below, and Figure 5.12 gives an overview of the tables and their relationship between them.

User

In the user table, all users in the system will be contained. A user can have many memberships, participate in many challenges, and have many time-in-range readings.

Group

The group table held all available groups in the system. A group can identify many rows in the membership table.

Time-In-Range

To enable the system to have many features around time-in-range readings, the author decided to separate the time-in-range reading from a row in the user table to a separate table.

Membership

The membership table exists to contain an overview of which users that are a member of a group. A membership can identify exactly one user and one group.

Challenge

The challenge table is used to hold all challenges. A row in the challenge table can be used to identify many rows in the participant table.

Participant

The participant table contains rows that are used to identify which users have participated in challenges. A row can identify exactly one user and challenge. Further, a row in the table also includes the progress of the user in the given challenge.

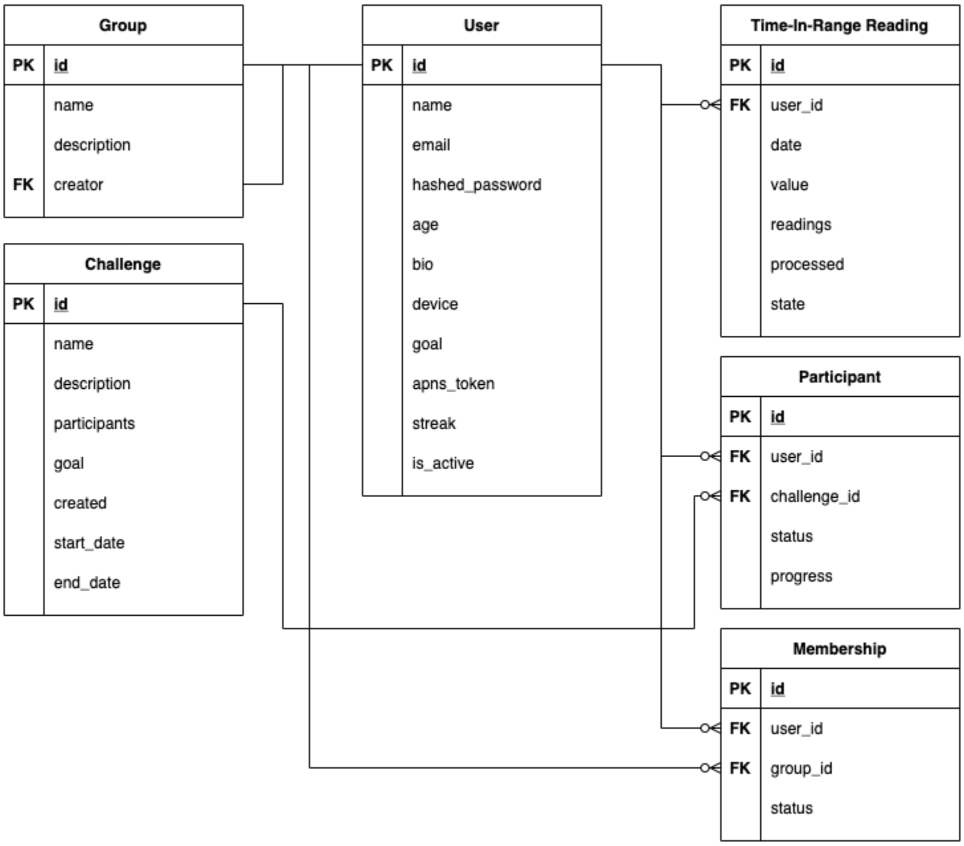

Figure 5.12: Database schemes and their relationship to each other.

System Architectural design

An outline of an architectural design of the backend services was created using the functional requirements and non-functional requirements listed in chapter 4. The goal was to design a microservice architecture such that the different parts of the system can be deployed independently.

Three services to support the application were identified:

1. The application required a database. The application will use the database to hold the schema described in the last section.
2. A way of interacting with the database is necessary.
3. A service to perform tasks such as verify that users reach their goal and send notifications to groups.

Figure 5.13 shows an outline of our architectural design. In the figure, a message broker is added to the outline responsible for sending messages from the API service to the processing services in the system.

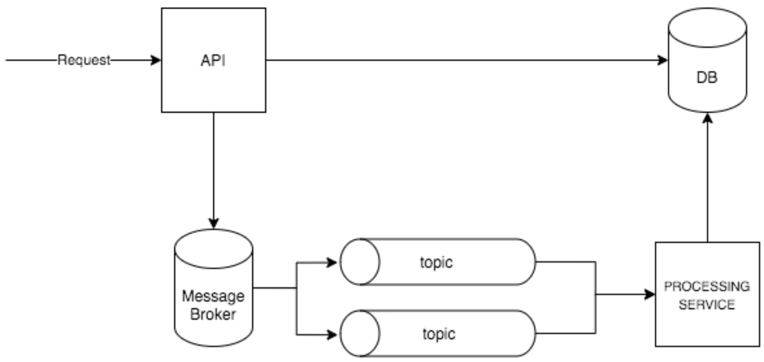

Figure 5.13: An outline of the system architecture. The HTTP REST API is listening for requests. The API can schedule tasks on the processing service through the message broker and access data in the database.

5.3 Motivational Methods

Time-in-range will be the property used to measure how well a user manages the disorder and as a method to motivate the user. The motivational perspective of time-in-range will be that the user can configure a time-in-range goal and a custom blood glucose range. Finally, all members in a group can see each other's time-in-range value and see how they have managed their disorder compared to others.

Notifications are planned to be used to encourage users to motivate each other by sending motivational text messages to other group members that either achieve or not achieve their time-in-range goals. In addition, the system will send notifications with motivational texts to the user based on the progress on their time-in-range goal.

5.4 Summary

In this chapter the application and system architecture design based on the functional and non-functional requirements defined in chapter 4 is presented. Lastly, the motivational methods planned to be used between the users were presented.

6
Implementation

This chapter explains how the backend and a mobile application of a group-based motivational system were implemented. First, a description of the backend architecture and how the different services are implemented is given. Then, a description of the mobile application's architecture and implementation is presented. Lastly, a description of an application that generates mocked blood glucose samples is described.

6.1 Backend

The backend is responsible for supporting the mobile application with authentication services, creating groups, users, and memberships, uploading blood glucose data, and sending notifications. The design chapter presented an outline of the architecture, and the following segment will explain the implementation of the services.

6.1.1 REST API

The API service is a web server that exposes a REST API with endpoints for a client to utilize. The endpoints are grouped into nouns that describe what entity can be retrieved or manipulated through the endpoint. E.g., the endpoint to retrieve a specific user looks like */users/2*. The groups of nouns are:

- **Users** - All endpoints that retrieves or manipulate users.
- **Groups** - All endpoints that retrieve or manipulate groups.
- **Auth** - A group of endpoints that authenticate a user with the system.
- **Challenges** - A group of endpoints to retrieve or manipulate challenges in the system.
- **TIR-readings** - All endpoints that retrieve or manipulate time-in-range readings.

The REST API is implemented by using the Python library FastAPI[1]. FastAPI is a modern library for building APIs in Python, and one of its strengths is its integration with types in Python.

Posting Time-In-Range data

The time-in-range readings table has only one row for each day for a user. Therefore, a request to upload time-in-range data to the backend must include the user's id, the time-in-range value, and metadata about if the most recent reading on the device was outside the user's target blood glucose range. When new samples are available on the device and uploaded to the backend, the system updates the current day's row in the time-in-range readings table. In addition, the metadata about the most recent reading's position in the range is also appended to the given row. Figure 6.1 show the upload flow.

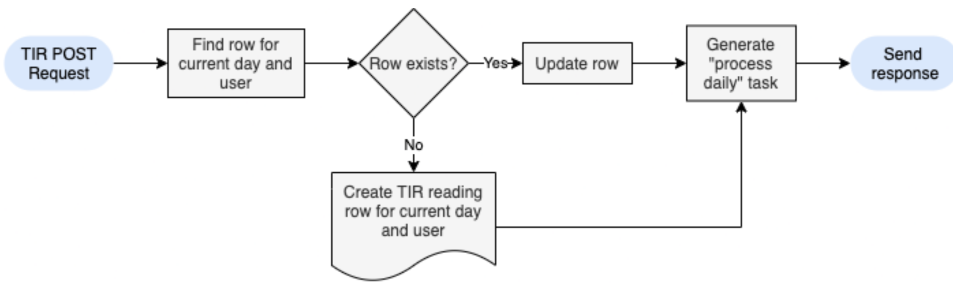

Figure 6.1: Flow upon a time-in-range POST request.

1. FastAPI [website], `https://fastapi.tiangolo.com/` (accessed 7 May 2021)

6.1.2 Authentication

All endpoints except the routes for creating a user and authentication are limited to a signed-in user. JSON Web Tokens (JWT)[2] is used to prove that a user is signed in. Protected routes read a JWT from the request's authorization header, and if the JWT is valid, the request is granted access to the endpoint. Some endpoints are limited further. E.g., to retrieve all members in a group, the user must also be a member of the group itself. Otherwise, the system returns a 403 Forbidden response. The authorization flow is shown in Figure 6.2.

JWT provided from the system is limited to a configured lifetime. A JWT that has exceeded the lifetime is not valid anymore, and a user must then authorize itself again to gain access to the system's protected resources. The system provides a client with two tokens upon a successful authorization, a *access token* and *refresh token*. A client uses the access token to access resources and the refresh token to create a new access token without signing in again. It is essential to notice that a refresh token can only generate a new access token and can not access resources in the system.

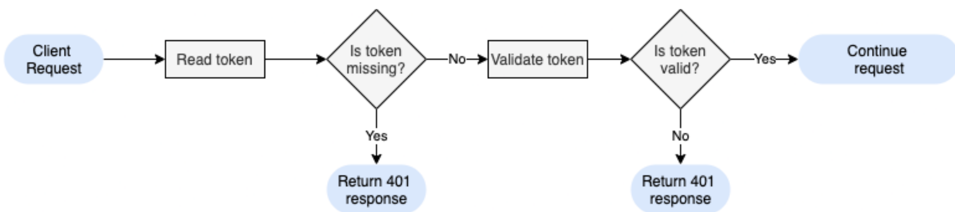

Figure 6.2: Verifying a request to a protected route.

6.1.3 Database

The implemented system uses a Postgres[3] database to hold all the tables outlined in the design chapter. Postgres is a relational database that lets a client use SQL queries to retrieve and manipulate data.

Data Access

Interacting with the database from the backend services is done through a repository architecture. A repository architecture is a system where independent components, often named data access objects (DAOs), interact with a

2. JSON Web Tokens [website], `https://jwt.io` (accessed 7 May 2021)
3. PostgreSQL [webiste], `https://www.postgresql.org` (accessed 7 May 2021)

central data store, which is the database. The system has one data accessor object for each noun discussed in the previous section that the webserver can use to perform Create, Update, Read and Delete (CRUD) operations on the entities stored in the database. Figure 6.3 show the different DAOs.

As mentioned, DAOs let the client perform CRUD operations on entities stored in the database. The interaction between the DAOs and the database is achieved by using the Python library SQLAlchemy[4], specifically their object-relational mapper (ORM) component. The ORM makes it easy to create a decoupled implementation between the DAOs and the database. Decoupled in this context means that the DAOs do not depend on a specific type of database engine. Thus, at any time, the database engined of the system can be changed without modifying the implementation of the DAOs.

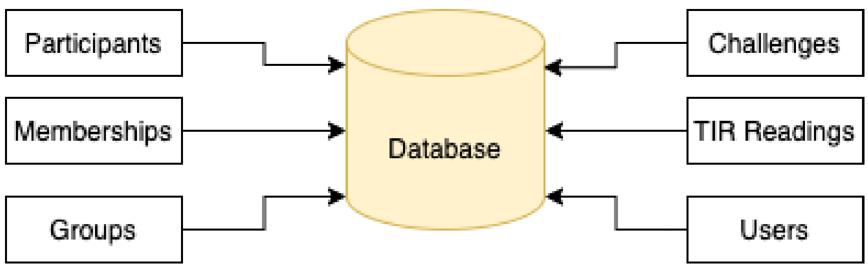

Figure 6.3: Overview of DAOs in the backend.

6.1.4 Notifications

An essential requirement for the system is that it should be able to send notifications to the user. As mentioned in chapter 3, the mobile application is only implemented for iOS, and thereby, the system only supports sending notifications to iOS devices. iOS uses push notifications to present notifications to the user. A web server can send notifications to an iOS device using remote notifications. There are two requirements for sending remote notifications to an iOS device. First, the developer must issue a certificate that the server can use to authenticate with the Apple Push Notification service (APNs). Secondly, the system must obtain a token that acts as an address for the notification destination.

The system has a service that is responsible for sending notifications to a user or a group. To interact with the APNs the Python library PyAPNs2[5] was used, which implements the APNs protocol[6].

4. SQLAlchemy [website], `https://www.sqlalchemy.org/` (accessed 7 May 2021)
5. PyAPNs2 [website], `https://github.com/Pr0Ger/PyAPNs2` (accessed 7 May 2021)
6. Communicating with APNs, *Apple* [website], `https://developer.apple.com/`

Types of Remote Notifications

APNs can categorize notifications, making it possible for the mobile application to behave differently based on the category. The system has four different types of notifications that the backend system can deliver. These are action, message, tip, and invitation. An action notification is a type that will ask the user to take action. e.g., to send a message. Message and tip are types that will notify the user that a new message is available. Lastly, an invitation type tells a user that someone has invited them to a group.

6.1.5 Processing Service

The processing service is a worker process responsible for completing tasks that the system produces. Using Celery[7], a distributed task queue, the processing service is a worker in the system that listens for tasks on a specific topic on the message broker. The process listens for four types of tasks.

Process Daily

Process daily is a task that is executed every time a user uploads time-in-range data. The task checks if the user is about to reach its goal for the first time or lose its streak. If one of the scenarios is true, the system will send notifications to all the user groups. Another scenario where the system will send a notification to a user's groups is to have multiple consecutive blood glucose readings outside their targeted range.

Process Past Day

Process past day is a task that runs one time each day. The job fetches all of the users in the system and then examines one by one if they reached their time-in-range goal the previous day. Depending on if the user reached their time-in-range goal or not, a notification is sent to all the user groups to encourage users to motivate each other to keep it going or try again.

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library/archive/documentation/NetworkingInternet/Conceptual/RemoteNotificationsPG/CommunicatingwithAPNs.html (accessed 7 May 2021)

7. Celery [website], https://docs.celeryproject.org/en/stable/ (accessed 7 May 2021)

Send Message

Send message is a task that the system uses to deliver messages between users. When a client posts a new message through the REST API, the service issues a new message task on the queue. The worker process then reads the job and delivers it to the destination user using remote notifications.

Group Invitation

The system uses the *group invitation* task to send notifications to users invited to join a group. As with the send message task, the system schedules this job when a client posts an invitation request to the REST API service. The worker process will then deliver the invitation notification to the target user.

6.1.6 Scheduler

A scheduler does ensure that the system executes the task to check if the users reached their time-in-range goal the preceding day every day. The scheduler is another component from Celery, namely the Beat[8] service. This service is used to schedule the *process past day* task each day at 9 AM.

6.1.7 System Deployment

The system can be deployed using Docker[9]. Each component in the backend, REST API, Processing Service, RabbitMQ, Scheduler, and database, is configured to be deploy in distinct containers using their custom docker image, except the database[10] and RabbitMQ[11] which uses public docker images. Docker-Compose[12] is a tool that is useed to organize these containers together and define which ports are exposed. The only port that is exposed from the system is the port used to reach the REST API service of the backend service.

8. Periodic Tasks, *Celery* [website], `https://docs.celeryproject.org/en/stable/userguide/periodic-tasks.html` (accessed 7 May 2021)
9. Docker [website], `https://www.docker.com` (accessed 7 May 2021)
10. Postgres, *Docker* [website], `https://hub.docker.com/_/postgres` (accessed 7 May 2021)
11. rabbitmq, *Docker* [website], `https://hub.docker.com/_/rabbitmq` (accessed 7 May 2021)
12. Overview of Docker Compose, *Docker* [website], `https://docs.docker.com/compose/` (accessed 7 May 2021)

6.2 Mobile Application

The mobile application is a gateway to the system. From the application, a user can sign up and sign in, create groups, discover groups, and view the progress of their groups. As mentioned in chapter 3, the application is written in Swift and is only available for iOS. This section describes how the author implemented the different screens, how the system gathers blood glucose data and how notifications are implemented. In addition, an overall description is given of the application's business layer.

6.2.1 Scenes

All scenes in the application are written using the declarative user interface library SwiftUI. The declarative way of writing user interfaces can best be described as "the system is given a recipe of how the scene should be structured, and then the system will construct it based on the application's current state."

The user interface implementation follows the same structure as the design system presented in chapter 5, which means that many small components are implemented. These components are then composed together to create the scenes in the application.

User Interface Design Pattern

When writing an application with a graphical user interface, different patterns are used to separate the business logic (e.g., interacting with the backend) from the view. The implemented application uses the design pattern Model-View-ViewModel (MVVM) to separate the user interface (UI) logic from the business logic. In MVVM, the *view* represents the current state of the view model, which held the UI state. The *view model* has all the methods that can alter the UI state, e.g., when pressing a button or fetching data from the internet. Thus, a *model* is the actual business logic of the application. Figure 6.4 show an example of a MVVM view in the application.

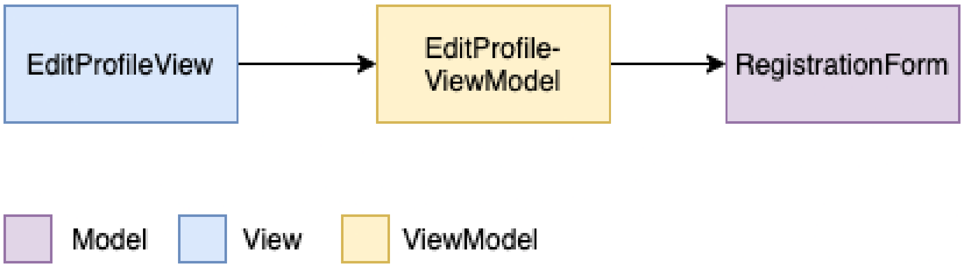

Figure 6.4: Example of a view using MVVM in the application.

6.2.2 Reading Blood Glucose Data

iOS has an API named HealthKit[13], an API for reading health-related data from a central repository on the mobile phone. All applications which have asked and received permissions can read and write data from this repository. The application relies on HealthKit to gather the blood glucose levels of the user.

Apple requires that an application asks for permission before reading or writing data to HealthKit[14]. A request about permissions to health-related data is presented in a modal to the user (see Figure 6.5). In the modal, the user can decide to grant an application some or none of its requests. A developer must also give an understandable description of what the application will do with the user's data.

When the user has signed in for the first time, the application asks the user to read blood glucose data from HealthKit. In addition, a short disclaimer, seen in Figure 6.5, informs the user that the application will only use the blood glucose data to calculate the time-in-range value and that no data will at any time leave the application.

Calculating Time-In-Range

Time-in-range is measured using all blood glucose values for a given day and determining how many readings are inside a given range. In addition, the application has a service that is responsible for interacting with HealthKit. From this service, the application can calculate the time-in-range value and upload it to the backend service.

13. HealthKit, *Apple* [website], `https://developer.apple.com/health-fitness/` (accessed 7 May 2021)
14. Setting up HealthKit, *Apple* [website], `https://developer.apple.com/documentation/healthkit/setting_up_healthkit` (accessed 7 May 2021)

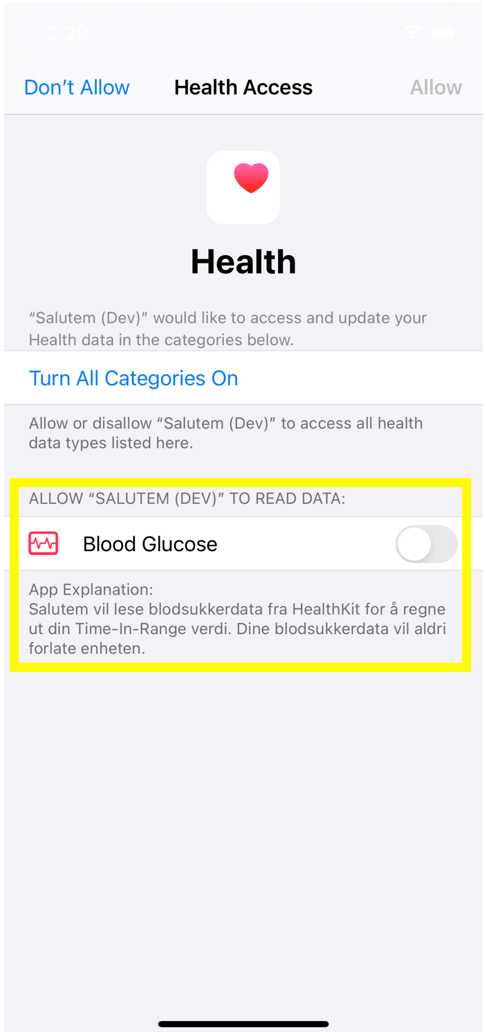

Figure 6.5: Modal shown when asking for permissions to read data from HealthKit.

The service gathers all readings for a day by constructing an HKSampleQuery that returns a snapshot of all blood glucose samples. First, samples that are above or below the user's targeted range are removed. Then the time-in-range value is calculated by dividing the number of readings inside the range by the total number of samples, and the result is uploaded to the backend.

Uploading Time-In-Range Data

As mentioned in the previous section, the system uploads the time-in-range value for a user when new samples are available through HealthKit.

Whenever uploading a time-in-range value to the backend, the application also appends metadata on the request. For example, a number is appended to indicate if the most recent reading was below, inside, or above the target range. As explained in 6.1.5, the backend uses this metadata to send notifications to a user's groups if the user has multiple readings outside of the target blood glucose range.

To avoid uploading a time-in-range reading when there have not been any new samples, the application stores a timestamp of the most recent reading and does not upload data again if the same timestamp occurs. Figure 6.6 show the upload flow.

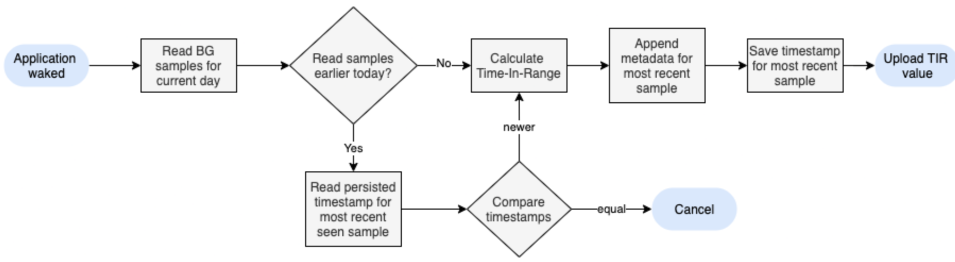

Figure 6.6: Time-in-range upload flow in the mobile application.

6.2.3 Notifications

The design chapter stated that notifications were vital for the application. As with reading health data, Apple requires that a user give the application permission to send notifications[15]. When launching the application for the first time, the application will ask the user for permission. If granted, iOS will give the application a token, which acts as an address to the user's phone. The application uploads this token to the backend, which will store the token in the user table for later notifications.

Notifications that the application receives from iOS is not persisted by default. Therefore, a Notification Service app extension[16] is implemented. The extension will intercept notifications before the system presents them to the user, enabling the application to persist notifications. When users open the application after receiving a notification, they can navigate to a screen to see all their latest notifications.

15. Asking Permissions to Use Notifications, *Apple* [website], `https://developer.apple.com/documentation/usernotifications/asking_permission_to_use_notifications` (accessed 7 May 2021)
16. UNNotificationServiceExtension, *Apple* [website], `https://developer.apple.com/documentation/usernotifications/unnotificationserviceextension` (accessed 7 May 20201)

Direct Messages

The mobile application has a feature that enables users to interact with each other by sending direct messages. The feature is implemented by utilizing the notification service. When sending a message, the backend will send a remote notification to the receiver of the message. To achieve this, the notification service appends the message and the sender's user id in a custom payload field in an APNs payload[17].

On the receiver's device, the extension mentioned in the latter section will persist the message notification before the system presents the notification to the user. When the user wakes the application again, the application will check if it received any message notification when idle and ensure that all chats are updated.

6.2.4 Business Layer

The components to create, read and update data in the system are located in the business layer. View models described in section 6.2.1 use these components when acting with data in the application. This group of services is divided into two categories *stores* and *services*.

Stores

The store category can be interpreted as a repository architecture. Each component in this category exposes methods that read data from persisted storage on the mobile device. The mobile application's business layer has four store objects, and a short description of each follows.

- **HKStore** - This is a store object is used to create HKSampleQueires to the HealthKit repository on the application. The object also asks for permission upon the first query after the application is started. If the permissions are not granted, the store cannot read blood glucose data from the device.

- **BGDataStore** - An object that can calculate statistics such as the time-in-range and average blood glucose levels for the current or past seven

17. Creating the Remote Notification Payload, *Apple* [website], {`https://developer.apple.com/library/archive/documentation/NetworkingInternet/Conceptual/RemoteNotificationsPG/CreatingtheNotificationPayload.html` (accessed 7 May 2021)

days. This object utilizes the HKStore object to execute the queries to fetch the samples.

- **AppUserDefaults** - An object that held cached values to enhance the experience of the application. An example of a value that is stored here is the timestamp of the most recent blood glucose reading as mentioned in 6.2.2.

- **UserStore** - This is an object that held cached information about a signed-in user. It held information such as user information (age, name, email), if a user is signed in or not, a user's favorite groups, and the authorization token for the current user.

- **ChatStore** - An object that caches all direct messages to persistent storage on the device. From this object, the application can read and persist messages sent or received from other users.

Services

The objects that interact with the backend through HTTP calls and local iOS API on the device are located in the service category.

- **AuthenticationService** - This service is used to authenticate a user by username and password. The service can also renew the access token by using the refresh token if the access token is outdated.

- **APIService** - A service that is used to make any HTTP requests that require a token to the backend. The service is implemented by using the library Moya[18], a third-party library in Swift, to make HTTP calls.

- **NotificationService** - This service can ask for permission regarding displaying notifications to the user from the application. In addition, this service is responsible for ensuring that notifications are received when the application is active. Which is not the default behavior on iOS.

6.3 Blood Glucose Generator

As described, the implemented application integrates with HealthKit to read a user's blood glucose data. Since the data would be available in HealthKit

18. Moya [website], `https://moya.github.io` (accessed 7 May 2021)

through another application's integration with HealthKit, e.g., as Dexcom G6 described section 2.5.1, a custom application that acted as an application gathering blood glucose data was created (see a screenshot of the application in Figure 6.7).

The application supports generating blood glucose readings in the background and exporting them to HealthKit. There are several configurations on how to generate blood glucose readings:

- A closed interval where the values of the generated readings will reside.
- The chance that a generated reading could be outside of the configured range.
- A range of days to generated readings for.
- The number of readings to generated for each day.

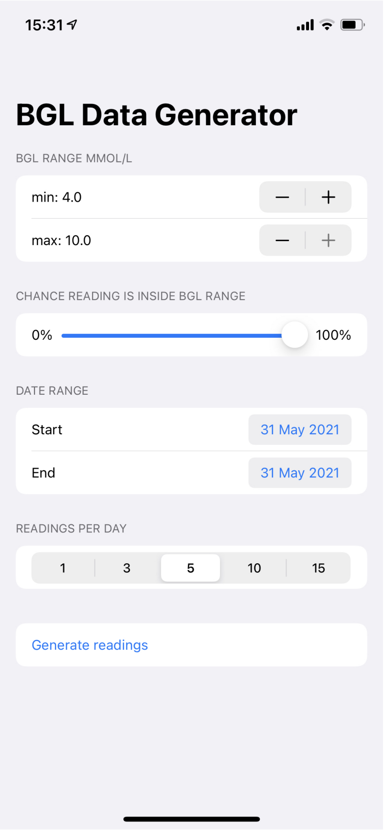

Figure 6.7: A screenshot of the blood glucose generator. There are several configurations to how blood glucose readings are generated.

6.4 Summary

This chapter described how the backend and a mobile application of a group-based motivational system are implemented. First, a description of how the backend services were implemented was given (see the authorization flow and the view hierarchy of the application in Figure 6.8 and Figure 6.9). Then a description of the mobile application's implementation and architecture was given. It also detailed how blood glucose data is gathered from the integration with HealthKit on iOS and used to calculate the time-in-range value. Lastly, a description of an application integrated with HealthKit and acted as it was connected to a continuous glucose monitoring device by continuously writing blood glucose data to HealthKit was described.

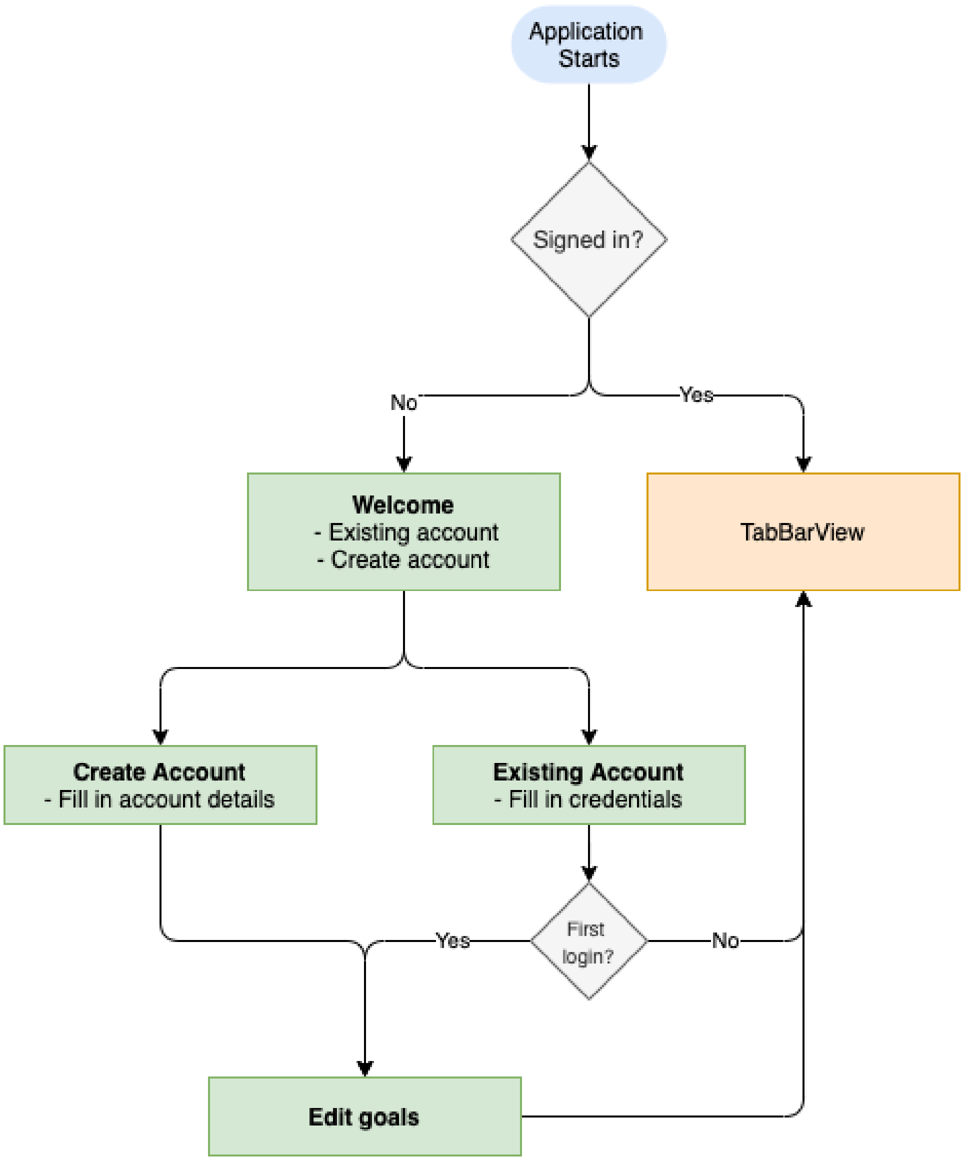

Figure 6.8: Application Authorization Flow.

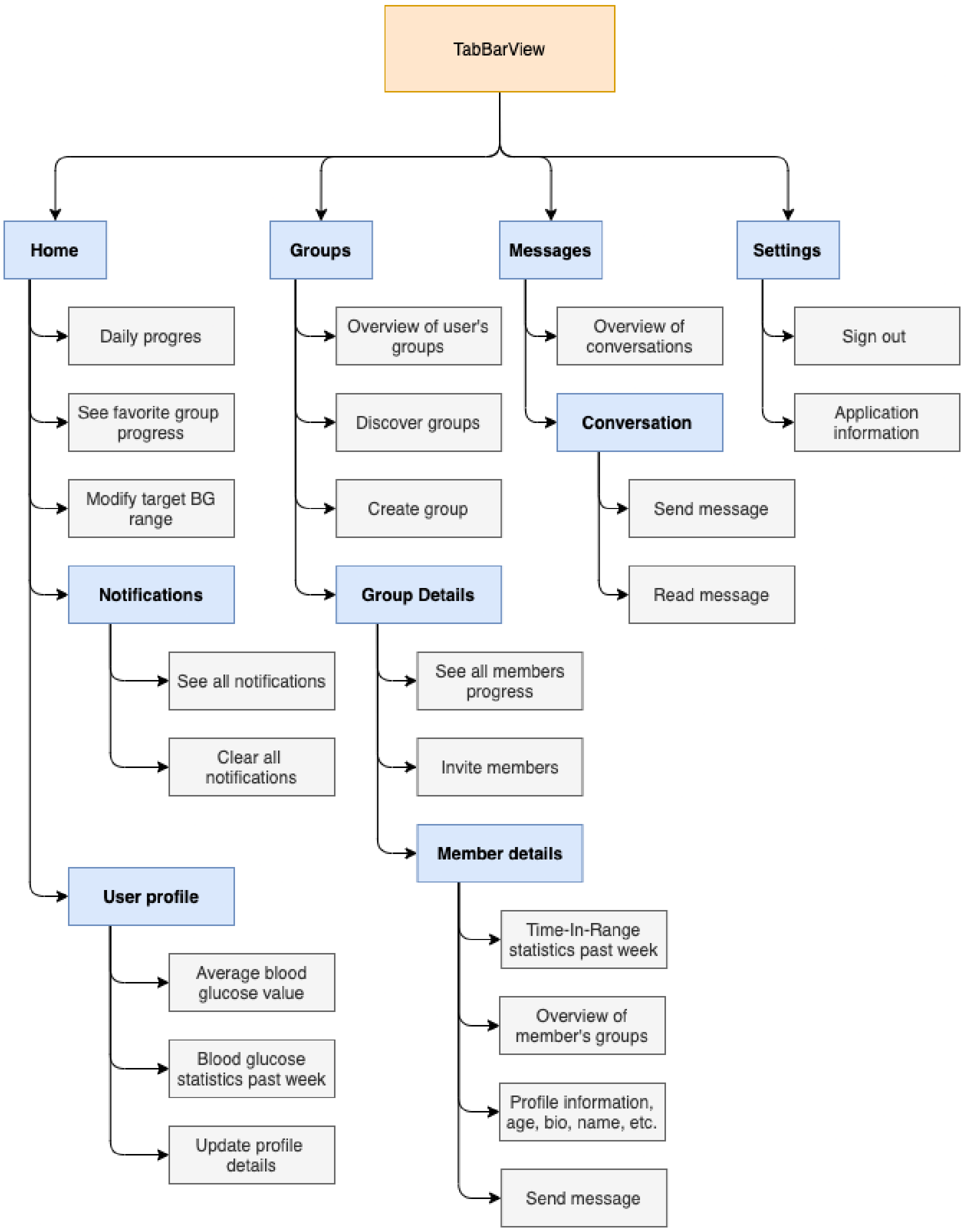

Figure 6.9: Application view hierarchy when authenticated.

7

Tests and Results

This chapter presents the results from the questionnaire and the evaluation method described in section 3.3.3. Then the results from a System Usability Scale (SUS) questionnaire and feedback from the users that conducted the usability test are presented.

7.1 Questionnaire

In the early stages of the project, the author created a questionnaire published in an online group on Facebook. The questionnaire's questions were questions based on the author's experience with technology and mobile applications, a market review (see section 2.5), and feedback from the research group. As mentioned in section 3.3.2, the questionnaire was iterated on after input from the research group and administrators of the online group.

The questionnaire consists of 18 questions and is found in appendix A.3 and is only available in Norwegian. The majority of the questions present alternatives to the participant, and the rest of the questions addresses an allegation. A question that shows an allegation lets the participant select a value between 1 and 7, where one ultimately disagrees and seven completely agrees with the allegation. The following sections summarize the answers to the questions.

7.1.1 Participants

The three first questions asked about the participant's age (Figure 7.1), if they had diabetes themself (Figure 7.2) or if they answered on behalf of someone with diabetes and their gender (Figure 7.3). Over 50% of the participants were between 35-60 years, and 33% were between 20-35 years. In addition, 96% of the participators had diabetes themself and 84% of the participants were women.

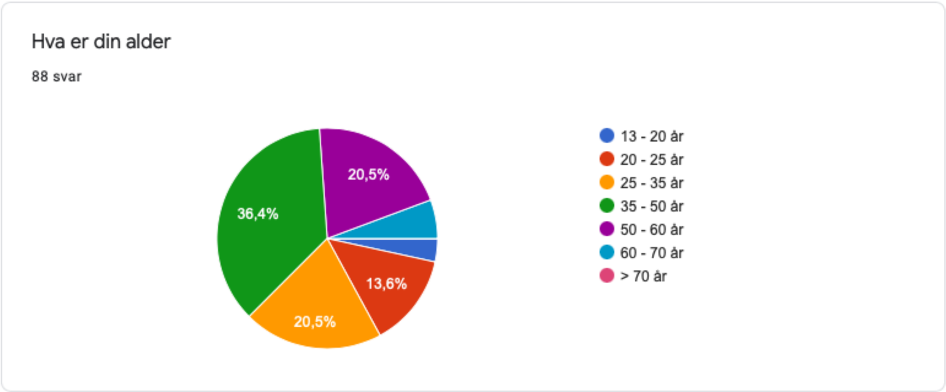

Figure 7.1: The majority of the participants were between 35 and 50 years. Only about 15% was younger than 25 years.

Figure 7.2: A comment from one of the group administrators was that some group members were parents of children with diabetes. In the questionnaire, 4.5% of the participants answered on behalf of someone else.

7.1.2 Blood Glucose Levels

Question 4-6 was about the participant's blood glucose levels. The first of these questions was about how they control their average blood glucose levels

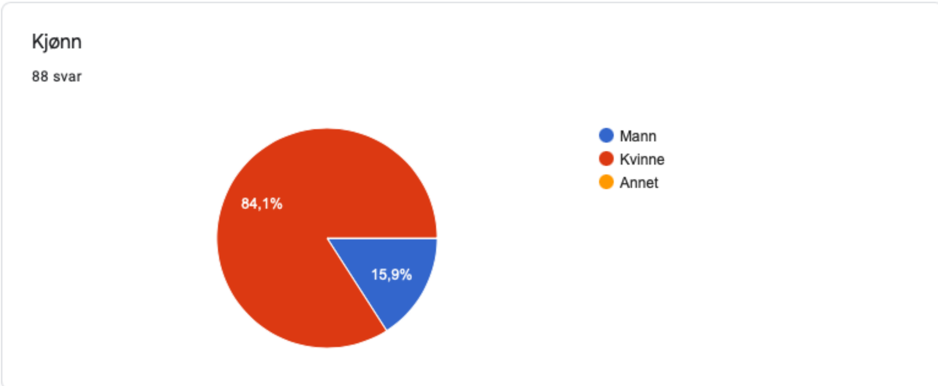

Figure 7.3: Most of the participants were women.

over time (Figure 7.4). Here the participants were given three multiple-choice alternatives HbA1C, Time-In-Range, and if they were unsure, they could enter an answer in free text. 84% measured their long-time average blood glucose levels using HbA1C, and 53% used Time-In-Range. The two following questions asked if they reached healthy blood glucose levels (Figure 7.5) and were satisfied with their blood glucose levels (Figure 7.6). Over 60% of the participants claimed that they achieved healthy blood glucose levels and were satisfied with their blood glucose levels.

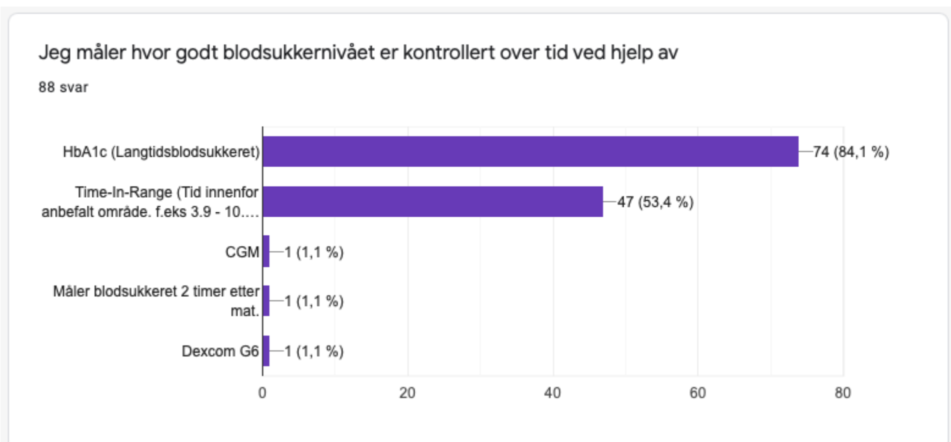

Figure 7.4: Participants could select multiple alternatives regarding how they measured average blood glucose levels over time. HbA1c and Time-In-Range were known and used by the majority of the participants. Some of the participants may have misunderstood the question and answered how they measure their blood glucose levels.

The two following questions were regarding the participant's view of sharing their blood glucose levels. Question 7 claimed that the participant thought it

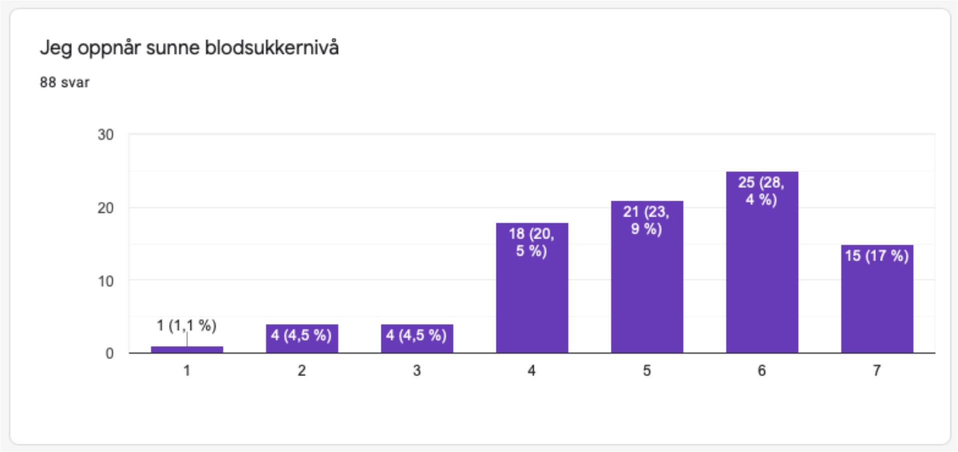

Figure 7.5: A vast majority of the participants agreed that they achieve healthy blood glucose levels.

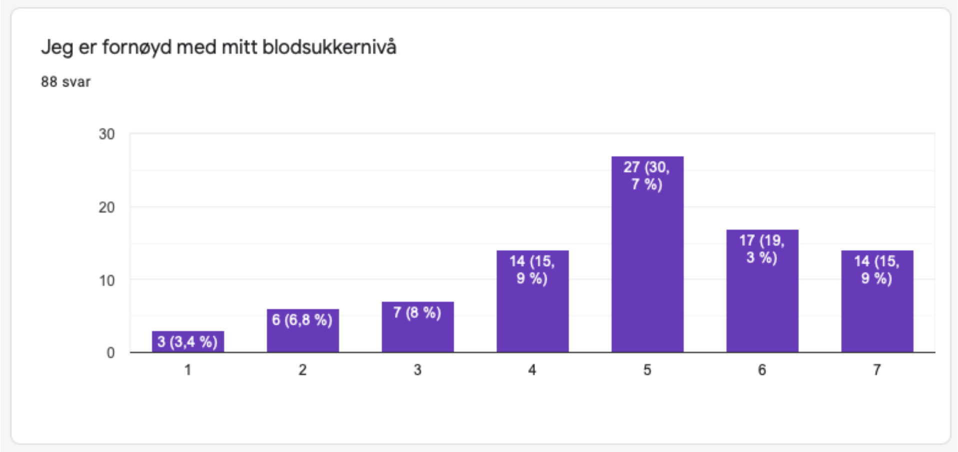

Figure 7.6: Most of the participants were happy with their blood glucose levels. Around 20% was not pleased with their blood glucose levels.

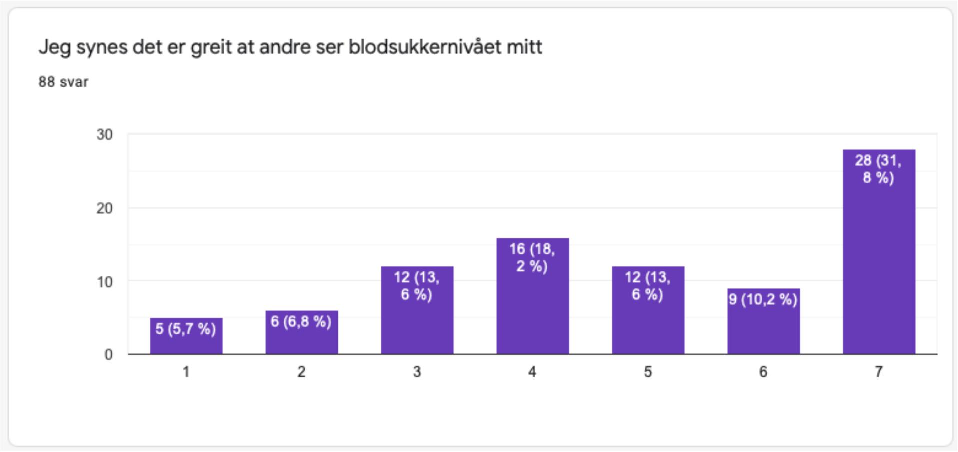

Figure 7.7: Over half of the participants agreed that it was no problem to let others see their blood glucose levels.

is okay for others to see their blood glucose levels (Figure 7.7), and question 8 claimed that family members should at least see their blood glucose levels (Figure 7.8). 55% of the answers agreed, and 45% of the responses were unsure or did not agree with the claims.

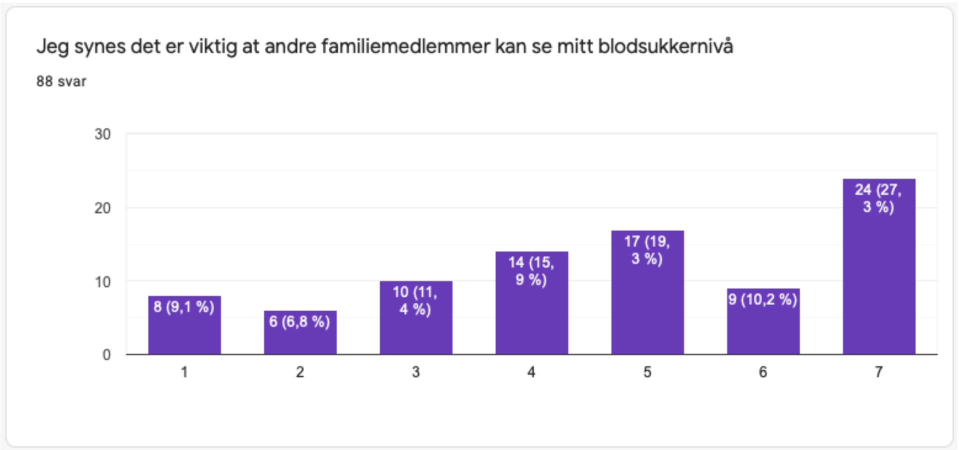

Figure 7.8: Over half of the participants also thought it was important that family members see their blood glucose levels.

7.1.3 Motivation

Question 9-11 was about their thoughts on motivation. The first question asked if they could see themself participating in a motivational group to reach healthy blood glucose values (Figure 7.9). The second question was a claim that the participant is motivated by other's accomplishments (Figure 7.10) and the last question in this section was a claim that when the participant has set a goal, they tend to reach it (Figure 7.11). 53% of the participants could think to be part of a motivational group. 43% of the answers agreed or strongly agreed that they were motivated by other's progress and 25% neither disagreed nor agreed with the claim. Over 66% agreed or strongly agreed that they reach goals that they set themself.

7.1.4 Notifications

Question 12 presented the claim that a participant's mobile phone displays too many notifications throughout the day (Figure 7.12). 2 out of 3 disagreed or completely disagreed with this claim.

Figure 7.9: Almost half of the participants could be interested in participating in motivational groups to obtain healthy blood glucose levels.

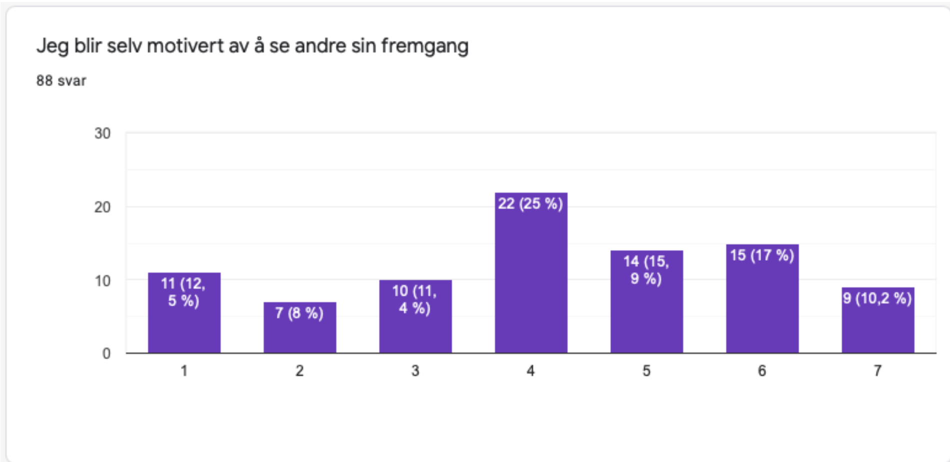

Figure 7.10: The participant's motivational effect by other people's progress was evenly divided into groups that did not agree, neither agreed nor disagreed, or agreed with the claim.

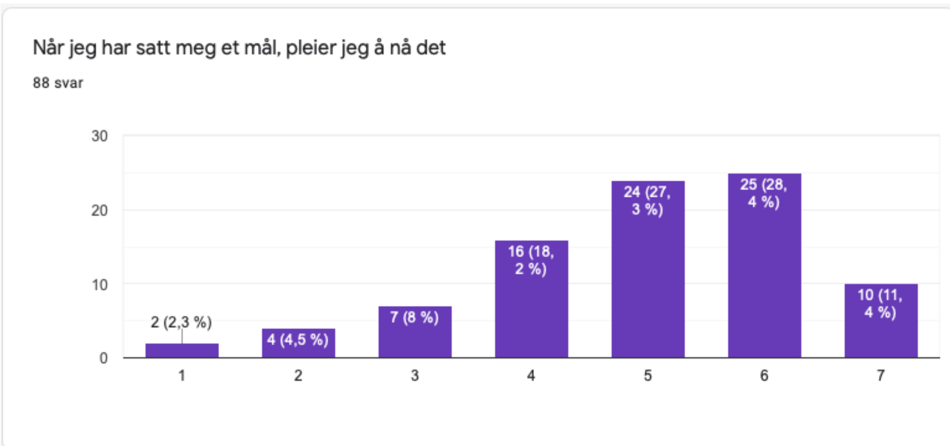

Figure 7.11: Most of the participants agreed that they tend to reach their self-defined goals.

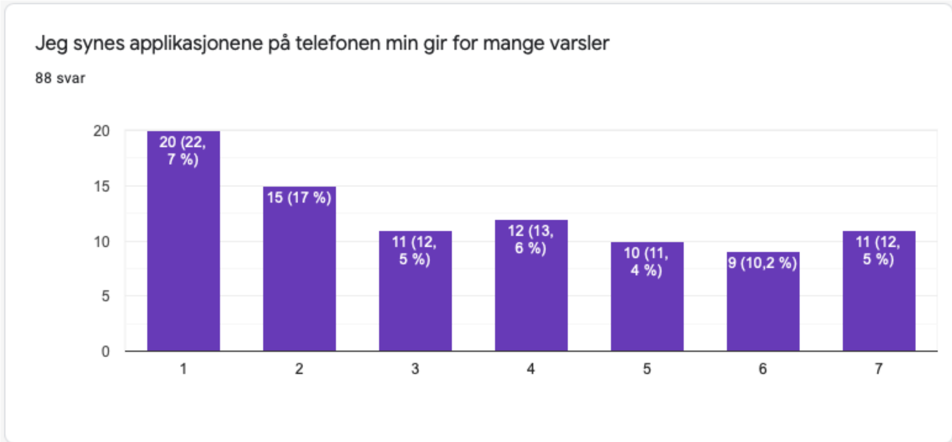

Figure 7.12: Almost one-third of the participants meant that their application did produce too many notifications.

7.1.5 Measuring Blood Glucose Levels

The four following questions were about how the participants measure their blood glucose levels. The first question asked if the participant used a Continuous Glucose Monitoring (CGM) device (Figure 7.13), and the following question, if they answered "yes," asked which type of CGM they used (Figure 7.14). The third question asked how many times they measured their blood glucose levels manually (Figure 7.15), and the last question asked how many times a day they look at their blood glucose levels (Figure 7.16).

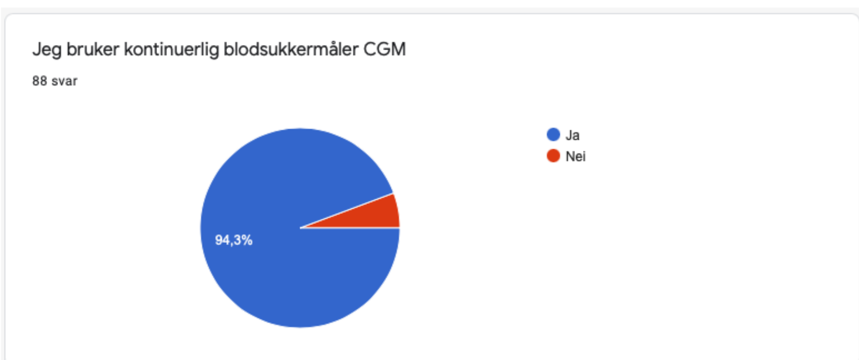

Figure 7.13: Over 94% of the groups used a Continuous Glucose Monitoring device.

94% of the participants have a CGM device, and the three most popular CGM devices were Dexcom G6[1] (40.7%) Freestyle Libre 2[2] (37%), and Guardian

1. Dexcom G6, *Dexcom* [website], `https://www.dexcom.com/nb-NO` (accessed 18 May 2021)
2. Freestyle Libre 2, *FreeStyle* [website], `https://www.freestyle.abbott/no-no/`

Connect[3] (16%). Over 86% of the participants measured their blood glucose levels manually 1-5 times a day, and over 73% of the participants looked at their blood glucose levels more than ten times a day.

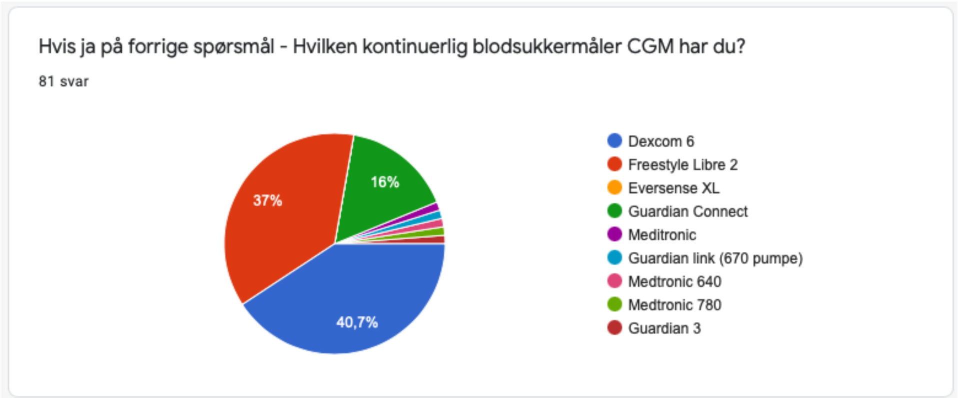

Figure 7.14: The Dexcom 6 and Freestyle Libre 2 were the two most common Continuous Glucose Monitoring devices that the participants used.

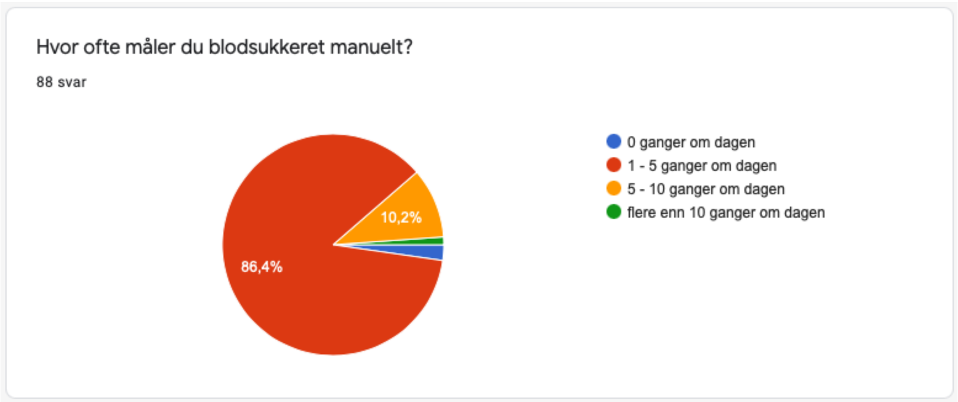

Figure 7.15: The majority of the participants manually measured their blood glucose levels 1-5 times a day.

7.1.6 Motivation in Group

Question 17 and 18 were optional questions where the participants could enter their answers as free text. The questions questioned what motivates them in a group and what motivates them most. Many participants had the same suggestions. What motivates them in a group is that the group shares information, is homogeneous (same interests, same age group), engagement

`freestyle-libre-system/freestyle-libre-2.html` (accessed 18 May 2021)

3. Guardian Connect, *Medtronic* [website], `https://guardianconnect.medtronic-diabetes.co.uk` (accessed 18 May 2021)

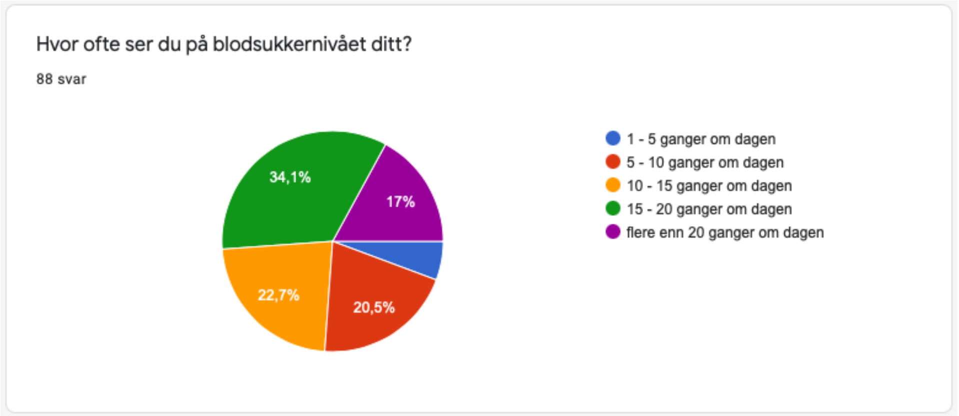

Figure 7.16: How many times the participants looked at their blood glucose level throughout a day was spread between all the alternatives.

and results. Some people pointed out that diabetes is a highly individual disease, and what may work for others may not work for themself. The most common answer was that a defined goal was the factor of motivation about what motivates them.

7.1.7 Satisfaction and Participating

A diagram showing what people answered on "I am satisfied with my blood glucose levels" and "I could imagine participating in motivational groups" was created from the results from the questionnaire.

The diagram, Figure 7.17, shows that more people who are satisfied with their blood glucose levels do not want to participate in motivational groups. On the contrary, those who are not satisfied with their blood glucose levels do want to participate in motivational groups. This result is somewhat expected, but it is positive that some of those satisfied with their blood glucose levels do want to participate in motivational groups. These people may have helpful tips or experiences that could help other people to manage their disorder better.

7.2 User Testing

The implemented mobile application and its backend system were tested on actual users through a usability test. Each user conducted a test as described in section 3.3.3. All the testers have experience with mobile applications, and the author considers them heavy users in the field. They were all in the age

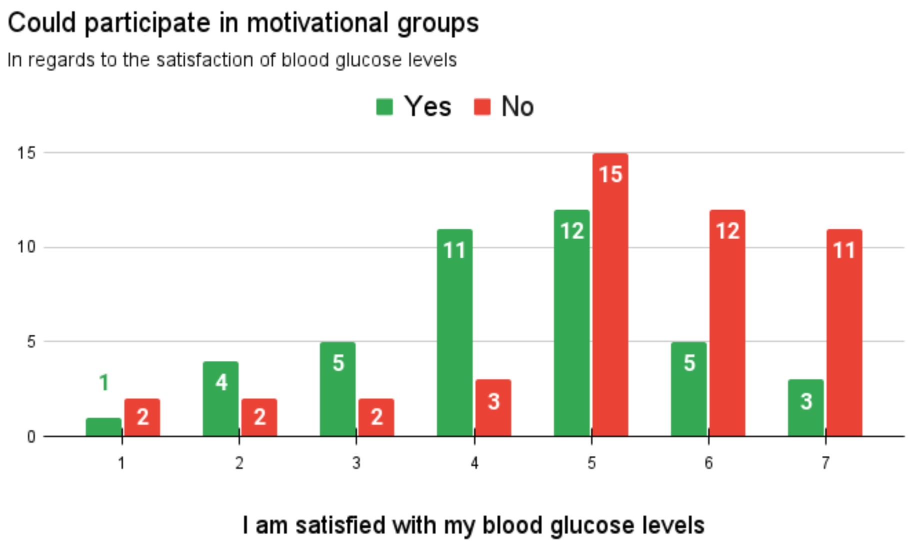

Figure 7.17: The figure shows that the majority of people who are satisfied with their blood glucose levels do not want to participate in motivational groups. However, those who are not satisfied are more interested in motivational groups.

range 20-35 years, and three of the testers use iOS daily, the other half use Android.

7.2.1 Before Testing

Before each test, the tester was introduced to the application and how they should behave during the session. The introduction covered a short presentation of the five scenarios, the mobile application, and the thinking aloud method described in section 3.3.3. All testers received a handout that explained the five scenarios[4].

7.2.2 During Testing

During each test, the author sat beside the tester to help if any fault occurred during the session. I also noted any feedback from the tester "thinking out loud" and observations made when the tester conducted a scenario.

4. The handout is available in appendix B.

7.2.3 Results

Each tester's answer on the SUS questionnaire is presented in Table 7.1. The score for each question alone cannot say anything meaningful. Still, if the score is summarized for each question and multiplied by 2.5, a single number is obtained, which represents the system's overall usability [61].

Table 7.1: Each user's value on the question in the SUS questionnaire on a scale from 1-5.

Question	P1	P2	P3	P4	P5	P6	M	SD
1	4	5	4	3	5	5	4.3	0.81
2	1	1	1	1	1	1	1	0
3	4	4	5	5	5	5	4.6	0.51
4	2	1	1	1	1	1	1.1	0.41
5	4	5	5	5	5	5	4.8	0.41
6	2	1	1	1	1	1	1.1	0.41
7	3	5	4	4	5	5	4.3	0.82
8	2	1	1	1	1	1	1.1	0.41
9	5	5	4	5	5	5	4.8	0.41
10	3	1	2	1	1	1	1.5	0.84
	Pi = user i; M = mean; SD = Standard Deviation							
	Positive response: The user agrees or strongly agrees for odd numbered questions and disagrees or strongly disagrees for even numbered questions.							
	Neutral response: Neither agree nor disagree.							
	Negative response: The user disagrees or strongly disagrees for odd numbered questions and agrees or strongly agrees for even numbered questions.							

Calculating the SUS score from a tester is done by subtracting one from the odd number questions. Then five is subtracted from the scale score on even-numbered questions [61]. The summarized value from each question is then multiplied by 2.5. Figure 7.18 show the score for each question in the questionnaire. The average SUS score of the system can then be calculated:

$$\frac{221 \cdot 2.5}{6} = 92.08$$

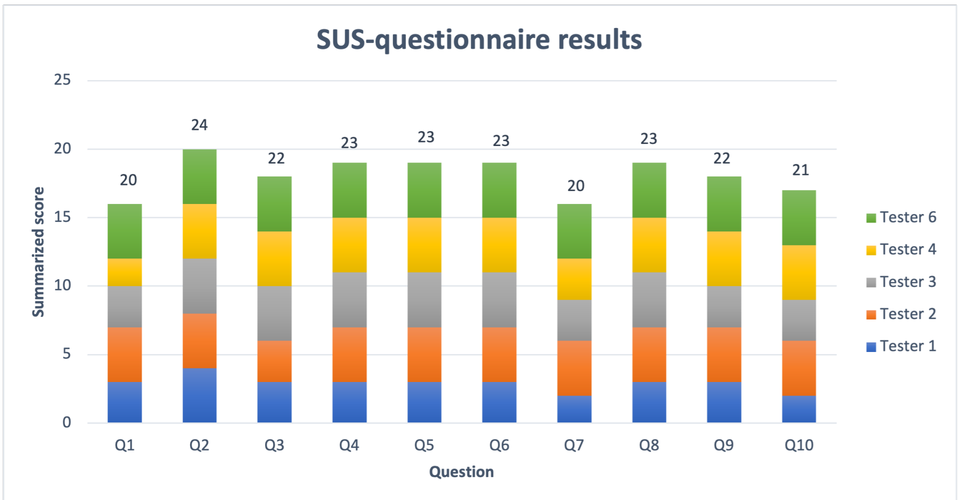

Figure 7.18: The total System Usability Score per question. Each tester's score is marked as a proportion of the bars.

7.2.4 Feedback

During and after each test, the tester had feedback that was noted. All of the testers commented that the application had an appealing user interface and was easy to use. In all test sessions, the only negative comment was that the feature to edit the target blood glucose range should have been in the same scene where one edit the time-in-range goal.

One of the testers expressed that the application should have a feature that allowed a group member to "like" or give "kudos" similar to Strava section 2.5.2, as an alternative to sending a message when a group member reached their time-in-range goal.

Another suggestion from some of the testers was that the current time-in-range value for a day should have been visible on the detailed scene of a group member.

All testers stated that the application was very clear of the permissions needed from the users to read health data and send notifications and thought that it was displayed clearly. They also regarded that the application clearly described what the time-in-range goal and blood glucose range terms meant.

7.3 Summary

This chapter presented and summarized the questions and results from the questionnaire. Besides, it also explained the usability test that classmates conducted and evaluated the system using the System Usability Scale. On the system usability scale, the system got a score of 92. Feedback from the usability test was also presented in this chapter.

8

Discussion

This chapter starts by discussing the limitations and strengths of the project. Following is a discussion of whether the project has answered the research questions outlined for the project. It then explains how guidelines affected design choices and the reasoning behind the phrasing of some of the notifications from the application to the user. Lastly, a presentation of future features for the application is presented.

8.1 Limitations and Strengths

8.1.1 User Based

The questionnaire described in section 3.3.2 got a total of 88 answers. Creating a system where one could decide on features and limitations with so much data is nothing that should be taken for granted, considering the limited time frame of a master thesis. User-based features are one of the strengths of this project's work. The data from the questionnaire has proven that there is interest in a group-based motivational application. In addition, it made it possible to decide to gather blood glucose data from HealthKit. Lastly, the questionnaire proved that time-in-range could be used as a property to base a user's progress on.

8.1.2 Central Data Store

An advantage of using a central data store such as HealthKit on iOS is that the application does not have any requirements to which Continuous Glucose Monitor (CGM) device a user has. Therefore, to use the system, a user must only have a CGM where the companion application support writing blood glucose data to HealthKit on iOS. The integration with HealthKit would also embrace other users who may use another application to record their blood glucose data. Again, the only requirement is that the application is integrated with HealthKit. Another benefit of not having a close integration between the implemented system and a specific CGM device is that it is easier to maintain the codebase since it is only affected by HealthKit API changes.

8.1.3 Implementation

Creating an application that only supports iOS devices means that almost half of the user group [6] is excluded. As described earlier, the decision to only create the application for iOS was taken because of the author's experience with the platform. This choice has not made any significant limitations to back-end services considering the potential of implementing a native application for Android. However, the notification service is the only service that is only compatible with iOS. Therefore, another service for Android must be implemented or a service that supports both systems to make the backend compatible with Android.

8.1.4 Evaluation

User Study

Any people with diabetes did not conduct the system usability study. The main reason for this was the limited time remaining when the system was ready for a user study. Another reason was the covid-19 pandemic which made it challenging to arrange physical sessions. Therefore, it was considered to have an online system usability study. However, due to the circumstances around sensitive data such as health data, it was not enough time to seek permission to perform such a test.

The decision was then to perform the usability study of the application and the system on fellow students[1]. During the usability test, many testers commented that they thought it was difficult to understand what a person with diabetes

1. This was legal in regards to the local rules at the time of the pandemic.

would like or dislike with the application. The group was found suitable to perform the usability study because they have much experience with and expectations of a mobile application. Although, a usability test on people with diabetes would have been preferred.

SUS-Questionnaire

The user study presented the users with a System-Usability-Scale (SUS) questionnaire that was not modified for people with diabetes. One could debate that the questionnaire should have been modified such that the testers were presented with claims about the usability of the system from the perspective of a user with diabetes.

For example, the first question, "I think that I would like to use this system frequently," could have been adjusted to "I think that people with diabetes would use such a system frequently." Rephrasing the question would also make the user aware that the system is intended for people with diabetes. However, as mentioned in section 3.3.3, the testers were presented with five scenarios that they executed before they were given the questionnaire. In these scenarios, it was clear that the user had diabetes and that the application is intended for people with diabetes.

8.1.5 Measuring Effectiveness

The project's primary goal is to motivate people with diabetes to achieve and continue to obtain healthy blood glucose levels through a group-based motivational application. Unfortunately, measuring the application's effectiveness regarding that goal is a time-consuming task, and it was not done experiments that could conclude with this.

A user study measuring the effectiveness of the application would have taken many weeks and require permission to conduct such a study since it uses sensitive health data. Even if such a study were achieved, it would be hard to conclude that the application was the primary factor in their blood glucose level changes.

The application is not by any means a tool for people with diabetes to manage their disease, but rather a social community where they can meet, share tips, and see other people's progress. Measuring the effectiveness of this would have been not easy. The author would have enjoyed gathering feedback from users with diabetes who had used the application over a period to get their perspective on my thoughts and design choices.

8.2 Research Problems

In section 1.2, the main research problem and sub-problems derived from the primary research problem was listed. This section discusses and answers the research problems using the experience and findings obtained from the project.

8.2.1 Sub-Problem 1

> Sub-Problem 1: *Which persuasive design principles are relevant when creating a group-based motivational application for people with diabetes?*

To create a group motivational application for people with diabetes, four of the persuasive tools described in section 2.3.1 has been applied to the application.

- *Tunneling* appears when the user opens the application during a day. As shown in section 5.1, a circle is used to show how the user progresses with their daily time-in-range goal.
- *Self-Monitoring* is used such that the user can configure a targeted range for their blood glucose values and a target goal for the percentage of readings on a day they would like to have inside the range.
- *Surveillance* appears when a user is a member of a group. All members of a group can see the progress of each other.
- *Conditioning* appears when the user achieves the goals defined. The application will give the user positive feedback, and the system will encourage members of the same group to send positive feedback when a member achieves their goals.

These four persuasive tools were applied to the application based on the results from the questionnaire described in section 3.3.2. The questionnaire unveiled that most participants were motivated by goals, other people's progress, and reaching their own goals.

The combination of these persuasive design principles can help people living under strict self-management to stay motivated. However, as mentioned in section 3.3.3, the application is not tested extensively by people with diabetes.

8.2.2 Sub-Problem 2

> Sub-Problem 2: *Which modern technologies can be used to obtain blood glucose data for people with diabetes?*

The second research sub-problem was concerned with collecting blood glucose data without requiring that the user has too much technical knowledge. The reasoning behind this was that during the early stages of research, it became clear that most companies do not make it easy for the user to share their blood glucose data with other services.

As a result of the companies making personal data unavailable, parents of children with diabetes developed Nightscout[2]. This open-source project aims to allow remote monitoring of glucose levels using existing CGM devices. The system "hacks" the blood glucose data transmitted from a CGM sensor and uses a mobile application to upload the data to a personalized webserver. The server lets any device with access to the internet view the data. Even though this solution does not require programming skills, technical knowledge is required to configure such a system, and in the process, the user can break something, void warranties, etc. [62].

During the market review in section 2.5 it became apparent that Dexcom was compatible with HealthKit on iOS. Further, as Figure 7.14 shows, the questionnaire unveiled that many participants used a Dexcom CGM. Reading up on Dexcom's integration with HealthKit unveiled that the application would write blood glucose data to the health application on iOS continuously every three hours, hence not in real-time. This dealy is unfortunate, but since the application does not aim to give real-time alerts based on group member's blood glucose levels, this delay was tolerable.

The application uses HealthKit, a modern API on iOS that enables applications to read and share health data through a central repository on the device. User's do not need technical knowledge to enable this. They only give the application permissions to read data from HealthKit. Figure 6.5 show the prompt for permissions to read blood glucose data.

2. Nightscout [website], `https://nightscout.github.io/` (accessed 21 May 2021)

8.2.3 Sub-Problem 3

> Sub-Problem 3: *How can a group-based motivational application for people with diabetes be designed with privacy in mind?*

Creating a social application that let people interact with each other need to an extent some personal information. The designed system uses personal information such as a user's name, email, and age. These properties are stored on the user's device and in the database tables. Other users can only see another user's personal information if they are authenticated. Authenticated users can see all member's names since they can invite people to join groups. A user's age and bio are only limited to members of the same group.

The blood glucose levels that the mobile application reads from HealthKit are never stored in the application or sent to the backend services. The time-in-range value computed from these samples is the only product from a user's health data that leaves the device.

The General Data Protection Regulation (GDPR) defines, among other things, people's privacy rights. A user has the right to be informed, access, rectification, erasure, restrict process, data portability, object, and rights related to automated decision making, and profiling [63]. However, the current state of the application does only fully the rights to have access, erasure, and restrict processing. Currently, a user can request access to all data about the user and request that all the stored in the system about the user is deleted. In addition, a user can restrict the processing that the backend does by leaving all groups or restricting the application's access to health data. Future iterations of the application shall include more information about how the data is used in the application. For example, make it explicit that the personal information is only available to authenticated users and is limited to name, age, and bio.

8.2.4 Main Research Problem

> *How can a system that uses group-based motivation be designed for people that live in strict self-management?*

This project started with the goal of creating a motivational application for people who live under strict self-management. The approach was to examine how groups could be used as the primary factor to motivate users to continue to or achieve healthy blood glucose levels. By reading relevant literature, exploring existing systems, and having a questionnaire, a group-based motivational application that can accomplish this was created. It is built upon the idea that other applications that collect blood glucose data use modern APIs such as HealthKit to share the user's data between applications on their device.

The final application uses persuasive design tools commonly used to motivate people to reach their goals. Self-Efficacy, a fundamental concept of Self-Cognitive Theory, describes how people's beliefs impact if they succeed in a situation. One method that enriches people's self-efficacy is seeing other social models accomplish their goals, especially people who are comparable to themself. Homogeneous groups where people see each other's progress, accomplishments, and feedback are ways to improve people's self-efficacy concerning achieving healthy blood glucose levels.

Determining if the developed application and design choices have created an application that can motivate people living in strict-self management cannot be concluded. Because of a limited time frame for this thesis, there was not enough time to conduct an extensive user study where people used the developed application regularly and gave their feedback. Therefore, the effect on people's motivation after using the application must be examined in the future.

8.3 Design

8.3.1 Human Interface Guidelines

Designing a user interface is a process were achieving the right design for the first time is unlikely. The scenes shown in this thesis are based on guidelines from Apple[3]. These guidelines involve everything from colors, typography, controls, and welcoming new users to the application.

For example, the button discussed in section 5.1 is created after the dimensions of icons in Apple's design templates for iOS[4]. These design templates have also been used to base the padding between the components in the design. Basing the design on Apple's design principles did make the application fit well into the iOS platform, as the usability test revealed.

3. iOS Design Themes, *Apple* [website], `https://developer.apple.com/design/human-interface-guidelines/ios/overview/themes/` (accessed 20 May 2021)
4. Apple Design Resources, *Apple* [website], `https://developer.apple.com/design/resources/` (accessed 20 May 2021)

8.3.2 Notification Phrasing

An aspect discussed with the research group was the phrasing of the notification produced from the system when a user accomplished or did not accomplish their time-in-range goal. The focus was primarily on framing the notification that the user did not reach their TIR goal.

It was important that the notification to a user about not reaching their time-in-range goal did not make them feel bad about it. If the system made the user feel sad, it could have the opposite effect and making the user continue not to reach their time-in-range goal.

When not achieving a time-in-range goal, the system does not frame the notification as "You did not reach your goal yesterday. That is not good!". Instead, it tries to communicate it in a more supportive manner "It seems like you did not reach your goal yesterday. Today is a new chance to reach your goal!". This way, the user is made aware that they did not reach their time-in-range goal yesterday without using negative words, and they are reminded that today is a new chance to accomplish their goal.

The notification that a user achieved their time-in-range goal is framed such that they should feel proud. For example, if a user reaches their time-in-range goal for the first time, the notification is framed as "Fantastic! You achieved your Time-In-Range goal for the first time. Keep up the excellent work!". Moreover, when the user starts to achieve the time-in-range goal multiple times in a row, the notification includes the current number of times in the message. Such a message looks like, "You are crushing it! Yesterday, you achieved your Time-In-Range goal for the 7th day in a row. Fantastic work!".

The idea behind including the streak in the message is that it could help make it a habit to reach the time-in-range goal continuously. This idea to use streaks is inspired by Snapchat[5] since it has shown that at least adolescents strive to keep streaks alive [64].

8.4 Requirements Prioritization

Section 4.2 mentioned that the Volere Template except user satisfaction and dissatisfaction is used to structure the functional requirements for the system. Instead, prioritization is used to determine which requirements were most

5. Snapchat, *Apple* [website], `https://apps.apple.com/no/app/snapchat/id447188370` (accessed 22 May 2021)

important.

The results from the questionnaire, personas, feedback from the research group, and the market review presented in section 2.5 were used to set the priority for each requirement. The finished product meets all requirements with a priority of three or higher. A threshold of three priority was set because of the limited timeframe that was available for the project.

8.5 Security and Privacy

Security was one of the non-functional requirements listed in section 4.3 for the application. In addition, the requirement stated that the privacy of a user in the system was crucial. These two subjects were major factors while designing and implementing the application, and both are discussed below.

8.5.1 Security

Each user in the application must protect their account with a password. Passwords are stored in the database by constructing a hash using the hash algorithm BCrypt[6]. The application never keeps a user's password, and the communication between the application and the system is over HTTPS.

When successfully authenticating with the system, the system provides the user with a refresh and access token. These tokens are persisted in the application and used when communicating with the application. As mentioned in section 6.1.2, an access token has a limited lifetime. When expired, the user must re-authenticate with the password or the refresh token. The thinking behind this is that if someone were to obtain the access token, they would have a limited time to harm the system. However, in the unlikely scenario where someone gets the refresh token, the system can be vulnerable. The refresh token would be useless for them, except if they know that they can use the token to generate new tokens on a specific endpoint in the system.

8.5.2 Privacy

The system stores information such as a user's name, email address, bio, age, CGM device, time-in-range values, and time-in-range goal. Of this information,

6. BCrypt, *PassLib* [website], `https://passlib.readthedocs.io/en/stable/lib/passlib.hash.bcrypt.html?highlight=bcrypt` (accessed 21 May 2021)

only the user's name, bio, age, CGM device, and the time-in-range goal is available for other authenticated users. The Bio, CGM device and age are only viewable for members of the same group. As described in section 6.1.2, some endpoints require that an authenticated user also is a group member to access various endpoints in the system.

Persisting Time-In-Range

Calculating the time-in-range for a user needs all the blood glucose level samples for a given day. Blood glucose level samples are sensitive health data, and the author wanted to avoid transferring these between the application and the backend. Hence the time-in-range value is calculated on the device before passed to the backend.

The database table for time-in-range readings has a metadata field used to realize a feature that can notify a group that a member has had multiple blood glucose readings outside their targeted range without knowing the actual value of the samples. As mentioned in section 6.2.2, the application appends a number to a time-in-range update to tell if the last blood glucose reading was below, inside, or above the user's target range. The system appends this number to the metadata field for each time-in-range update during a day. This way, the system can notify a group that a member has had readings outside of the range without persisting the sensitive data hence preserving a member's privacy.

8.6 Future Work

8.6.1 Include More Health Data

HealthKit, which is used to import blood glucose data, also has various other types of health data. Other types of activity data could be imported in a future version of the application to let the user see how physical activity affects blood glucose levels. Another possibility is to import nutrition data which could have unveiled other insights into the blood glucose levels based on what a person consumes.

8.6.2 Alternative Interaction between Users

During the usability tests, a comment from one of the users was "*Really intuitive and organized. However, it would be nice if one could have a 'thumbs up' option* *as an alternative to comments when a member achieves their time-in-range goal.*". The idea is that the application could have a faster alternative to congratulating someone who achieved their goal by sending a thumbs up instead of sending a comment.

8.6.3 Context-Aware Suggestions

The current iteration of the application notifies the user if two or more blood glucose samples are outside of their configured interval. In addition to the notification, the application could provide the user with context-aware information and suggestions on improving their blood glucose management. Context-aware means that the application can use other health data such as physical activity and nutrition. Combining physical activity data with the blood glucose data, the application could identify if physical activity was a possible reason for an "unexpected" drop in blood glucose levels. The application could present the user with information and suggestions about managing the blood glucose values better when working out.

8.6.4 Challenges

A feature that lets the user sign up for challenges is currently not implemented in the application. The reasoning behind the challenges feature was that the questionnaire mentioned in section 3.3.2 unveiled that some users did not believe in motivational groups. A portion of these users (19%) did not agree that they obtained healthy blood glucose levels. These users also answered that they were unsure or did not agree that they were motivated by other's progress. Thereby, the idea is that if users could sign up for challenges to, for example, reach their time-in-range goal seven days in a row, it could attract the people that were not interested in motivational groups.

Challenges can also be available for those who also participated in motivational groups. User's who accomplished a challenge could be awarded badges (see an example of a profile page with badges of achievements in Figure 5.6), which could be displayed on the profile page.

8.6.5 Statistics

Statistics for a group is another feature that can encourage users to motivate each other by improving the statistics for the group. For example, statistics could be and are not limited to the total number of times group members have reached their time-in-range goal, the average time-in-range value of the group, the number of days in a row all group members achieved their time-in-range goal, etc.

8.6.6 Additional Roles

Motivational groups should not be limited to people with diabetes. An additional role in the system could have been an "observer/spectator." The observer role can make it possible to have groups where family members or friends of a person with diabetes are members of the same group. These can then observe how the person manages the disease and encourage the person to continue achieving or achieve healthy blood glucose levels.

8.6.7 Data Sources

The application does only collects blood glucose data from HealthKit. In the future, the application could have a feature that lets the user manually enter blood glucose values or add the possibility to integrate a NightScout server with the application. Nightscout[7] is an open-source project for people with diabetes that lets them visualize their data from the continuous glucose monitoring sensors in the cloud.

8.7 Summary

From the discussion, I have argued that I have created a group motivational application for people with diabetes to help them stay motivated under their strict self-management lifestyle. In addition, using blood glucose data from a HealthKit, I have demonstrated how applications can arise from that other applications integrates with technologies such as HealthKit.

The limited time frame of the thesis and the circumstances around the covid-19 pandemic made it challenging to conduct an extensive user test. Therefore, the user study of the system was only conducted on fellow students. The limited time frame also affected which requirements of the system that was implemented in the application.

This chapter also discussed how the market review, questionnaire, and literature were the foundation to develop the application that answers the research problem for the project.

7. Nightscout [website], `https://nightscout.github.io/` (accessed 21 May 2021)

Lastly, new features were presented, such as how reading other types of health data can give a user even more information about how other activities or nutrition affect their blood glucose levels.

9 Conclusion

Throughout this thesis, I have described how I have implemented a group motivational application for people with diabetes. During the project, I have become aware of how much impact the disease has on people with diabetes lives and why motivation is a crucial aspect of managing the disease properly. Managing the disease is enough motivation for many, but as literature revealed, some tend to lose their motivation when they feel that they fail to manage their condition. Persuasive design and social cognitive theory described tools and methods that can influence people's motivation. The final application has incorporated some of these tools and techniques to motivate people to achieve healthy blood glucose levels using group-based motivation.

Ideas and functional requirements for the application were gathered through conversations with experts in the field, the research group, a questionnaire posted in an online community for people with diabetes, reading relevant literature, and examining existing applications targeted for people with diabetes. These were the fundamentals of an application that meets most of the functionality requirements, and future features for the application are presented. Unfortunately, a user study was not conducted on people with diabetes but a group of classmates due to the ongoing pandemic while writing the thesis. However, they gave valuable feedback which could further improve the application and addressed that the application met the non-functional requirements for the application.

A final thought is that group-based motivational applications may not be limited to only people with diabetes. It may exist other groups of people that live or temporarily live with a health condition that requires strict self-management, where motivation may be a crucial factor in recovering properly. These groups could also incorporate a similar group-based motivational application described in this project. They only have to find an activity or action that could be used as a motivational aspect between group members.

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A

Questionnaire

A.1 Administrator Message

When the membership of the online community for people was accepted, the author sent a message to the administration about permission to post the questionnaire in the group. The message gave a short description of the project and who the author was.

Hei
Ser du er administrator for gruppen "For oss med Diabetes" så derfor sender jeg deg denne meldingen.

Jeg er master student ved Universitetet i Tromsø og i min masteroppgave undersøker jeg hvordan teknologi og motivasjonsgrupper kan brukes til å hjelpe personer med diabetes til å oppnå og holde sunne blodsukkernivå. Har laget en spørreundersøkelse som jeg gjerne skulle ha postet i gruppen, men tenkte det kunne være greit å spørre om tillatelse først. Selve undersøkelsen stiller spørsmål relatert til blodsukkernivå, målinger, hvordan personer måler og motivasjon. Spørreundersøkelsen er anonym.

Du kan ta en titt på undersøkelsen her: `https://forms.gle/nikp3NuGNScHEiMH7`
Med vennlig hilsen
Joakim Sjøhaug

A.2 Introduction Message

Below is the message that was posted in the online community for people with diabetes. The post gave a short description of the project and who the author was. In addition, the message had an estimate of how long it takes to finish the questionnaire such that people could know how much time it would take. It was also specified that the questionnaire was anonymous.

Hei!

Mitt navn er Joakim Sjøhaug og jeg studerer Informatikk ved Universitetet i Tromsø. For tiden jobber jeg med masteroppgaven som undersøker hvordan teknologi kan motivere personer med type 1 diabetes til å oppnå og holde sunne blodsukkernivå.

I forbindelse med dette har jeg laget en spørreundersøkelse som jeg håper så mange som mulig av dere kunne tenkt dere å svare på. Den stiller spørsmål relatert til blodsukkernivå, målinger og motivasjon. Den tar ca. 5 minutter, og er anonym.

På forhånd - Tusen takk for hjelpen!

A.3 Schema

Motivasjonsgrupper for personer med diabetes

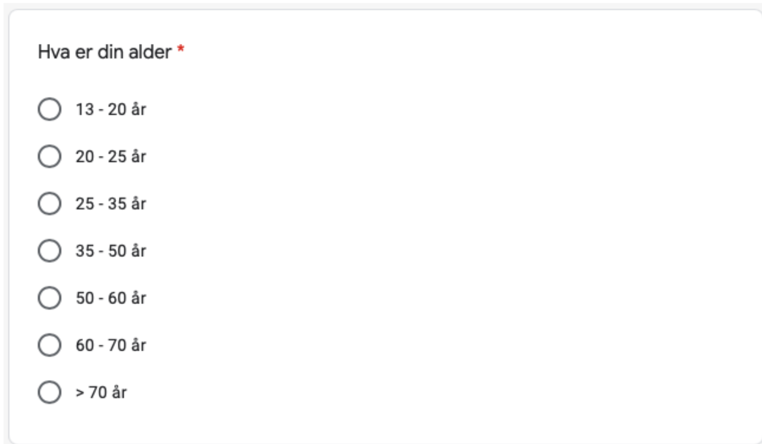
Mitt navn er Joakim Sjøhaug(www.sjoha.ug) og jeg studerer informatikk ved Universitetet i Tromsø. I min masteroppgave undersøker jeg hvordan teknologi kan motivere personer med diabetes type 1 til å opparbeide gode vaner til å oppnå og holde sunne blodsukkernivå. Jeg ser konkret på hvordan man kan oppnå dette ved å motivere hverandre i grupper.

Graden av hvor sunne blodsukkernivå du har kan måles ved hjelp av Time-In-Range (Tid i intervall). "Time-In-Range" sier noe om hvor lenge du med diabetes er innenfor et intervall med sunne blodsukkernivå (3,9 – 10 mmol/l) over et gitt tidsrom. Eksempelvis kan Ola Nordmann ha 83% "Time-In-Range" det siste døgnet.

Dette er en anonym spørreundersøkelse og ingen av svarene kan direkte knyttes opp mot deg.

*Må fylles ut

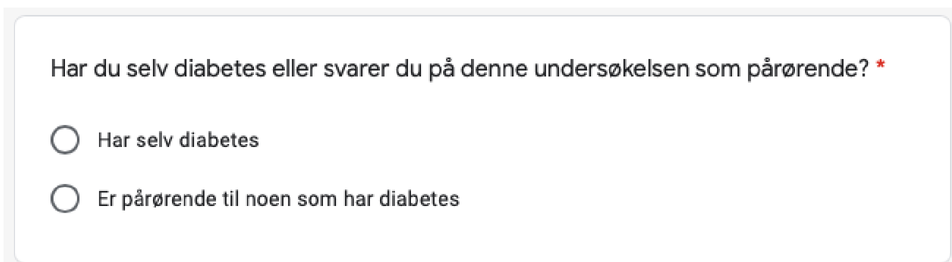
Figure A.1: Questionnaire introduction



Hva er din alder *

- 13 - 20 år
- 20 - 25 år
- 25 - 35 år
- 35 - 50 år
- 50 - 60 år
- 60 - 70 år
- > 70 år

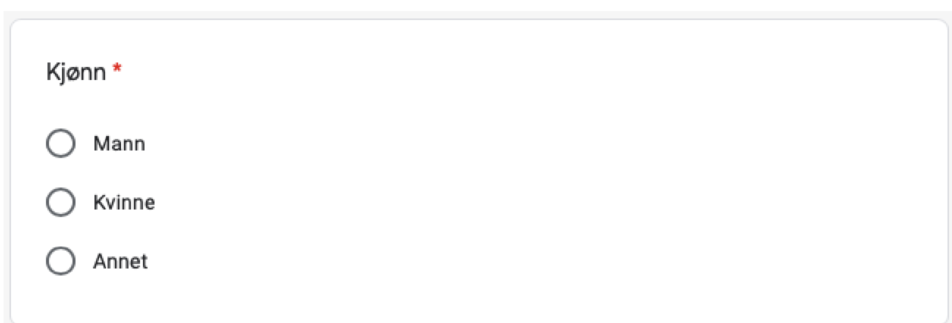
Figure A.2: Question 1



Har du selv diabetes eller svarer du på denne undersøkelsen som pårørende? *

- Har selv diabetes
- Er pårørende til noen som har diabetes

Figure A.3: Question 2



Kjønn *

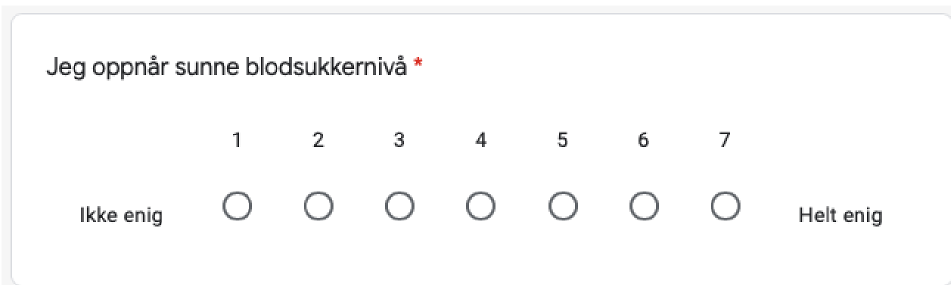
- Mann
- Kvinne
- Annet

Figure A.4: Question 3


Jeg måler hvor godt blodsukkernivået er kontrollert over tid ved hjelp av *

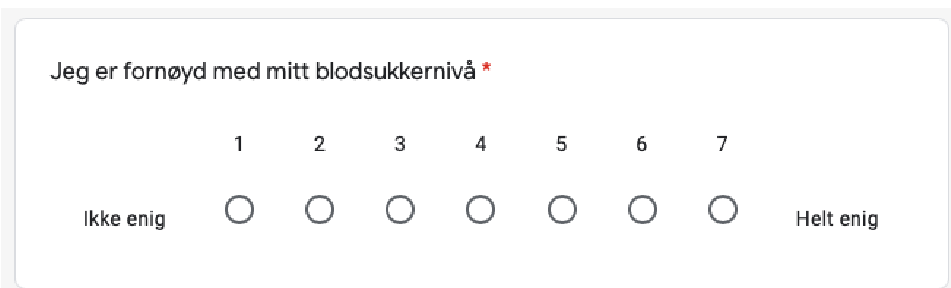
- [ ] HbA1c (Langtidsblodsukkeret)
- [ ] Time-In-Range (Tid innenfor anbefalt område. f.eks 3.9 - 10.0 mmol/L)
- [ ] Andre:

Figure A.5: Question 4


Jeg oppnår sunne blodsukkernivå *

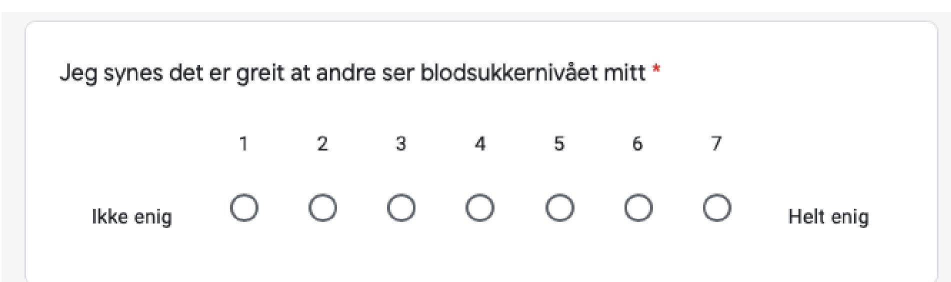
	1	2	3	4	5	6	7	
Ikke enig	○	○	○	○	○	○	○	Helt enig

Figure A.6: Question 5


Jeg er fornøyd med mitt blodsukkernivå *

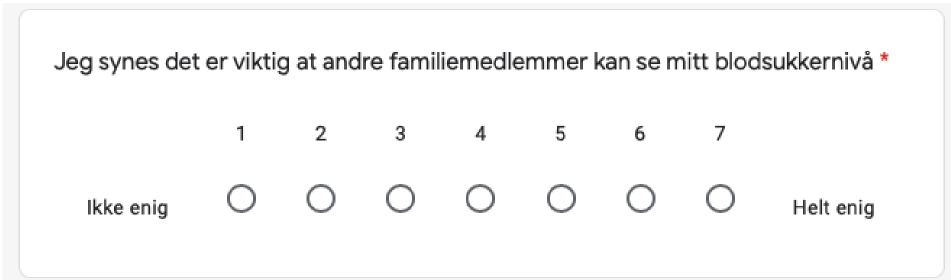
	1	2	3	4	5	6	7	
Ikke enig	○	○	○	○	○	○	○	Helt enig

Figure A.7: Question 6


Jeg synes det er greit at andre ser blodsukkernivået mitt *

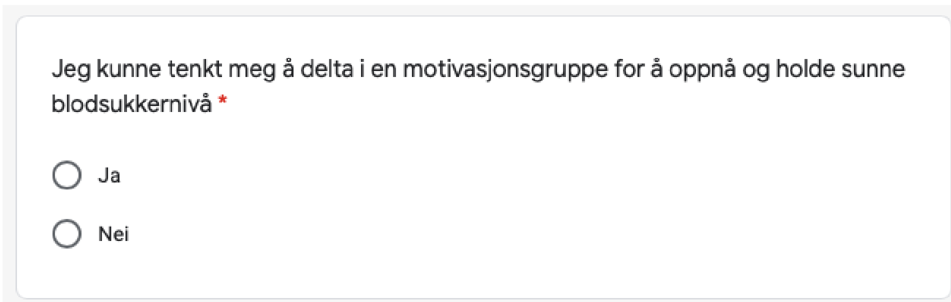
	1	2	3	4	5	6	7	
Ikke enig	○	○	○	○	○	○	○	Helt enig

Figure A.8: Question 7


Jeg synes det er viktig at andre familiemedlemmer kan se mitt blodsukkernivå *

	1	2	3	4	5	6	7	
Ikke enig	◯	◯	◯	◯	◯	◯	◯	Helt enig

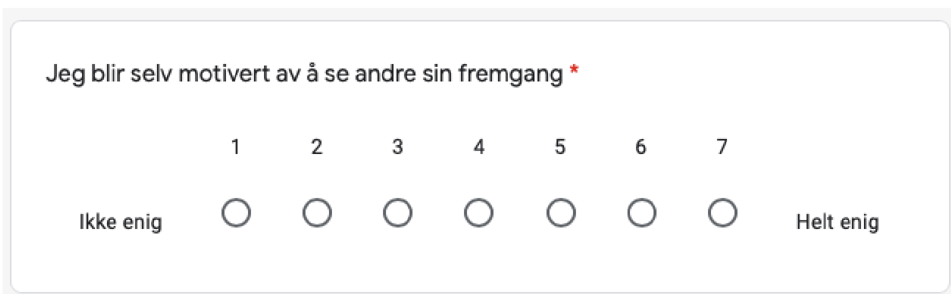
Figure A.9: Question 8


Jeg kunne tenkt meg å delta i en motivasjonsgruppe for å oppnå og holde sunne blodsukkernivå *

◯ Ja

◯ Nei

Figure A.10: Question 9


Jeg blir selv motivert av å se andre sin fremgang *

	1	2	3	4	5	6	7	
Ikke enig	◯	◯	◯	◯	◯	◯	◯	Helt enig

Figure A.11: Question 10


Når jeg har satt meg et mål, pleier jeg å nå det *

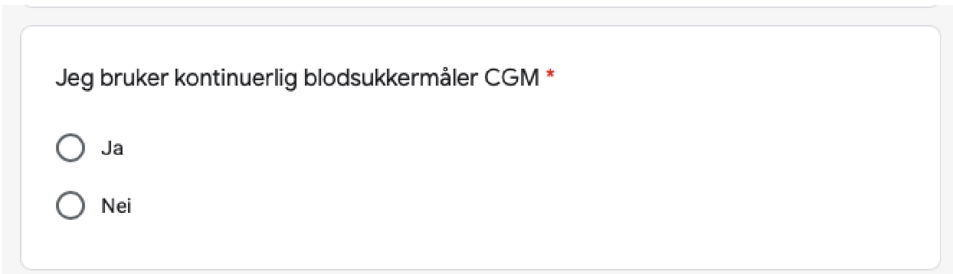
	1	2	3	4	5	6	7	
Ikke enig	◯	◯	◯	◯	◯	◯	◯	Helt enig

Figure A.12: Question 11

Jeg synes applikasjonene på telefonen min gir for mange varsler *

	1	2	3	4	5	6	7	
Ikke enig	○	○	○	○	○	○	○	Helt enig

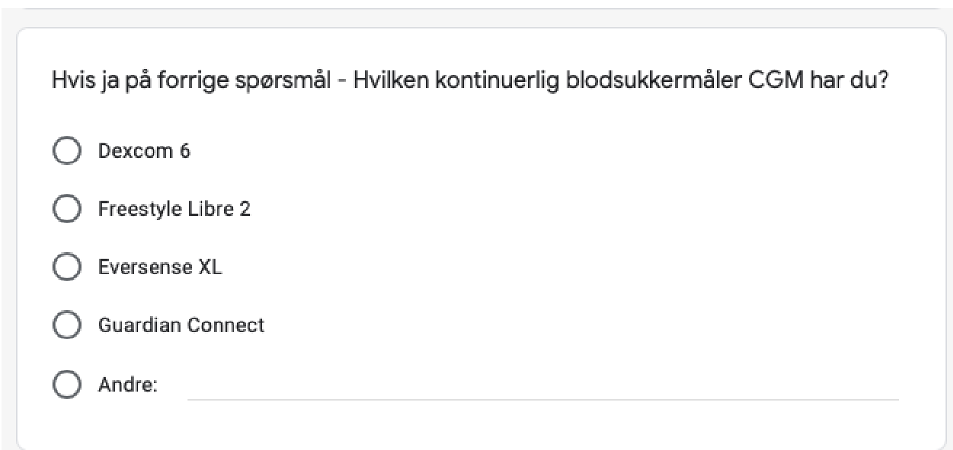
Figure A.13: Question 12



Jeg bruker kontinuerlig blodsukkermåler CGM *

- ○ Ja
- ○ Nei

Figure A.14: Question 13



Hvis ja på forrige spørsmål - Hvilken kontinuerlig blodsukkermåler CGM har du?

- ○ Dexcom 6
- ○ Freestyle Libre 2
- ○ Eversense XL
- ○ Guardian Connect
- ○ Andre:

Figure A.15: Question 14

Hvor ofte måler du blodsukkeret manuelt? *

- ◯ 0 ganger om dagen
- ◯ 1 - 5 ganger om dagen
- ◯ 5 - 10 ganger om dagen
- ◯ flere enn 10 ganger om dagen

Figure A.16: Question 15

Hvor ofte ser du på blodsukkernivået ditt? *

- ◯ 1 - 5 ganger om dagen
- ◯ 5 - 10 ganger om dagen
- ◯ 10 - 15 ganger om dagen
- ◯ 15 - 20 ganger om dagen
- ◯ flere enn 20 ganger om dagen

Figure A.17: Question 16

Hva skal til for at du blir motivert i en gruppe?

Svaret ditt

Figure A.18: Question 17

Hva motiverer deg mest?

Svaret ditt

Figure A.19: Question 18

B

User Test Handout

A user testing the application was given a handout attached in this section. The flyer gave the user a brief introduction to the application and which tasks they should accomplish by using the application. Following the user was presented a system usability scale.

Salutem Brukertest

Scenario 1

Du er en person med diabetes som nylig har hørt om applikasjonen "Salutem". Noen av vennene dine har fortalt at de har laget en gruppe som heter "Aktive i Tromsø" og de ønsker at du skal bli med i gruppen. Lag en konto og søk om medlemsskap i den aktuelle gruppen.

Scenario 2

Du har nettopp hørt at en av dine venner har laget seg en konto i applikasjonen "Salutem" og ønsker å invitere denne personen til "Aktive i Tromsø". Inviter "Ola Nordmann" til gruppen din.

Scenario 3

Et av gruppe medlemmene i "Aktive i Tromsø" nådde Time-In-Range målet sitt for første gang igår. Send personen en melding som sier "Fantastisk jobbet i går med blodsukkernivået! Dette vil bare fortsette oppover herfra 💯"

Scenario 4

Etter middagen er du nysjerrig på hvordan de forskjellige medlemmene i "Aktive i Tromsø" har gjort det med Time-In-Range målet sitt i dag. Sjekk hvordan gruppen har gjort det så langt idag.

Scenario 5

Du har nylig oppdaget at intervallet med blodsukker verdier du ønsker å holde deg innenfor ikke er helt korret. Endre intervallet.

Spørsmålene er basert på System Usability Scale og brukes for å måle tilfredshet med et system.

Vennligst fyll ut det alternativ som passer best til din opplevelse etter å ha brukt systemet.

1. Jeg kunne tenke meg å bruke dette systemet ofte.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

2. Jeg synes systemet var unødvendig komplisert.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

3. Jeg synes systemet var lett å bruke.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

4. Jeg tror jeg vil måtte trenge hjelp fra person med teknisk kunnskap for å kunne bruke dette systemet.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

5. Jeg syntes at de forskjellige delene av systemet hang godt sammen.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

6. Jeg syntes at det var for mye inkonsistens i systemet. Det virket ulogisk.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

7. Jeg vil anta at folk flest kan lære seg dette systemet veldig raskt.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

8. Jeg synes systemet var veldig vanskelig å bruke.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

9. Jeg følte meg sikker da jeg brukte systemet.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

10. Jeg trenger å lære meg mye før jeg kan komme i gang med å bruke dette systemet.

Sterkt uenig **Sterkt enig**

1	2	3	4	5
◯	◯	◯	◯	◯

Kommentarer:

Oversatt til norsk av Dag Svanæs, NTNU.