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FACULTY OF DESIGN

MSc. Design and Technology Futures

AI-powered Preventive and Personalized Care: Empowering Diabetic Patients to Better Manage Their Health

AI-põhine ennetus- ja isikupärastatud ravi: võimaldades diabeediga patsientidel edukamalt hallata oma tervist

MASTER THESIS

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THESIS TASK

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Thesis main objectives:

1. To understand how a diabetic manages health through self-care daily.
2. To understand the pain points and opportunities in the experience of self-care management for a diabetic.
3. To design a concept to ease the process and experience for the diabetic.

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Abstract

The healthcare systems are under a burden due to the rise in the number of chronic health problems globally. Diabetes is one of them. The two alarming reasons which make diabetes important to be addressed are it's becoming more prevalent in the present population, and it leads to other health complications. Our fast-paced and undermaintained lifestyles have accelerated the possibility of one developing diabetes.

This research emphasises on understanding how patients manage diabetes on a daily basis and understanding the technical components of diabetes, patient perceptions and experiences. This study uses mixed-methodologies research about the potential and difficulties in self-care management using mobile applications by combining quantitative and qualitative methods.

The proposed solution, "Glen", is an AI-powered smartphone application which helps diabetic patients by predicting glucose level spikes and drops beforehand and recommending actions to prevent them. Glen is based on four pillars: short-term planning, preventive care, decision support system and playful engagement. These pillars drive patients to lead a better quality of life with preventive and personalised care.

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List of Definitions

- **Diabetes Mellitus:** The condition when the pancreas fails to generate adequate Insulin resulting in low or high blood glucose levels in the body.
- **Insulin:** The hormone released by the pancreas to make cells absorb glucose from the blood, maintaining the glucose level balanced.
- **Glucose:** Primarily defined as a source of energy to the body when carbohydrates are broken.
- **Glycemic Index:** The order of food based on the amounts of carbohydrates.
- **Hyperglycemia:** A condition when blood sugar levels spikes above normal levels.
- **Hypoglycemia:** A condition when blood sugar levels fall below normal levels.
- **HbA1c:** The test to measure average blood glucose levels over a period of 2-3 months.
- **Diabetic Retinopathy:** Diabetes can make the blood vessels weak and results in vision loss.
- **Diabetic Neuropathy:** A type of nerve damage due to diabetes with results in numbness in hands and feet.
- **Glucometer:** A device to measure glucose levels in the blood.
- **Continuous Glucose Monitor (CGM):** The real-time monitoring system using a sensor to detect the glucose levels in the blood.
- **Carbohydrate Counting:** A method of managing diabetes by planning meals by quantifying carbohydrates in them.
- **Pancreas:** An organ inside the human body which is responsible for regulating glucose levels in the blood by releasing Insulin.

1. Introduction

Diabetes Mellitus is a major chronic disease that has become a global health threat. The International Diabetes Federation predicts that by 2045, there will be 700 million individuals worldwide who have diabetes (IDF Diabetes Atlas, 9th ed.). Diabetes impairs the body's capacity to use and retain glucose, resulting in elevated blood sugar levels that, over time, may cause long-term harm to essential organs and tissues. A lifetime commitment to self-care management is necessary to avoid and treat the disease's consequences.

The everyday actions that people with diabetes engage in to maintain their health and avoid complications are known as self-care management, which is an essential part of diabetes management. These include controlling stress, maintaining a balanced diet, taking prescription medications as directed, and checking blood sugar levels. By controlling glycemic, life quality can be increased, and healthcare expenditures can be decreased with effective self-care management.

Self-care management can be difficult for diabetics, though, as it needs constant behavior modification and inspiration. Studies have revealed that many people with diabetes struggle to manage their condition optimally, which can have a negative impact on their health and increase their need for medical attention (ADA, Standards of Medical Care in Diabetes, 2021). In order to help people with diabetes in their everyday self-care tasks, there is a need for efficient self-care management treatments.

This thesis aims to design an AI recommendation app for diabetes self-care management, which will use real-time data on blood sugar levels, sleep, physical activity, and stress to provide personalised recommendations for food and physical activity. The app will be designed using a user-centered design methodology, incorporating user needs and preferences to ensure its usability and effectiveness.

In the remaining sections of this thesis, the literature on diabetes and self-care management will be thoroughly reviewed, along with any obstacles that may prevent someone from managing their condition well. The findings of user research, as well as the conceptual and detailed designs of the app, will be provided after the research methodology and design process for the AI recommendation app. A discussion of the consequences and potential approaches for diabetic self-care management methods will conclude the thesis.

1.1 Problem Statement and Motivation

Diabetes must be managed regularly to keep blood glucose levels at their ideal range and avoid problems. Monitoring blood sugar levels, taking medications as directed, maintaining a nutritious diet, doing regular exercise, and controlling stress are all examples of self-management activities. Although there are several self-management methods available, many people with diabetes still have poor glucose control.

The need for continuing behaviour modification and motivation is one of the major obstacles to diabetes self-management. According to studies, people with diabetes may find it difficult to manage their condition because of a lack of support, information, and motivation. Poor self-efficacy, a lack of information and comprehension of diabetes, and a lack of social support were identified to be significant obstacles to successful self-management in a review of research looking at diabetes self-management (Powers, Bardsley & Cypress, 2017).

Self-management duties can sometimes be demanding and time-consuming, which can result in poor adherence and inadequate glycemic control. Only 36% of participants in a study of people with type 2 diabetes said they adhered to every portion of their self-management plan (Oser, Blalock & Ziemer, 2011). According to Fisher, Hessler, Polonsky, and Mullan (2012), people who suffer diabetes-related sadness or depression may also be less likely to engage in self-management activities and maintain optimal glycemic control.

The absence of individualized help and feedback presents another difficulty in managing diabetes on one's own. Traditional self-management treatments frequently offer broad counsel and suggestions that might not be suited to a person's particular requirements and preferences. It's possible that a lack of personalisation will result in low interest and self-management task adherence. According to a comprehensive analysis of diabetes self-management programs, those that offered individualized feedback and support were superior to those that did not in terms of increasing glucose control.

Effective interventions are also required to help people with diabetes manage their comorbidities and other medical issues. Many people with diabetes also have other chronic diseases, such as hypertension or cardiovascular disease, which call for extra self-management activities and treatments.

To improve glycemic control, avoid complications from diabetes, and improve the overall quality of life for people with diabetes, it is important to find solutions to the problems connected with self-management. Additionally, my personal encounter with a diabetic patient who is my grandfather taught me a major lesson on how life changes after diagnosis with diabetes.

1.2 Research Questions and Objectives

The genesis of the research started with the direction towards data integration between patient-generated outcomes and the hospital system to enhance the quality of care for diabetic patients. Over further research, the scope is focused on diabetic patients and self-care management.

Reframing the problem statement, which was earlier penned as "To explore the opportunities for data integration using patient health records to enhance care quality for diabetic patients", changed to "**What are the challenges diabetic patients face in their day-to-day self-care management and how could it be made simple?**"

The main objectives of this research are:

- To understand how a diabetic manage health through self-care daily.
- To understand the pain points and opportunities in the experience of self-care management for a diabetic.
- To design a concept to ease the process and experience for the diabetic.

1.3 Chapter Overview

Chapter One introduces the theos topic and gives an overview of the problem space and research questions towards the self-care management of diabetes.

Chapter Two explains the methodology and design research process carried out in this thesis. It gives details about the problem's background.

Chapter Three presents the overview of the literature review conducted and defines different biological phenomena involved in diabetes.

Chapter Four explains the synthesis of design research done through interviews and survey.

Chapter Five is about the proposed design concept, where the author explains how it works and what value it brings to the life of a diabetic person.

2. Methodology

In this chapter, details about the problem background, theoretical framework and different methodologies are discussed. Also, an overview of the design process and literature sources are presented.

2.1 Problem Background

Millions of individuals throughout the world suffer from the chronic condition of diabetes. The World Health Organization (WHO) estimates that 422 million individuals had diabetes in 2014, and by 2045, 629 million persons are expected to have the disease. Diabetes is a major factor in kidney failure, amputation, heart disease, and blindness. The International Diabetes Association predicted that 83,900 individuals in Estonia (or 8.7% of the population) will have diabetes by 2022. An estimated 23125 persons are living with undiagnosed diabetes. 6.1% of Estonian adults (64681 individuals) lived in Estonia in 2017, a rise of 2.6% from 2017 to 2022. More than 61 million individuals are in the EU Region, and this number will increase to 69 million. These numbers serve as a reminder to develop more efficient diabetes management and control strategies.

For those with a chronic illness, self-care refers to various techniques and pursuits that advance their physical, emotional, and mental wellness. It entails managing medications and taking them as directed, adapting movement and exercise routines to the condition, establishing good sleep hygiene, engaging in stress-reduction exercises like deep breathing and mindfulness, getting emotional support from family members creating a support system and making lifestyle changes (Kennedy, 2007). These self-care techniques assist people with chronic diseases in controlling their symptoms, improving the quality of their lives, and feeling in charge of their health.

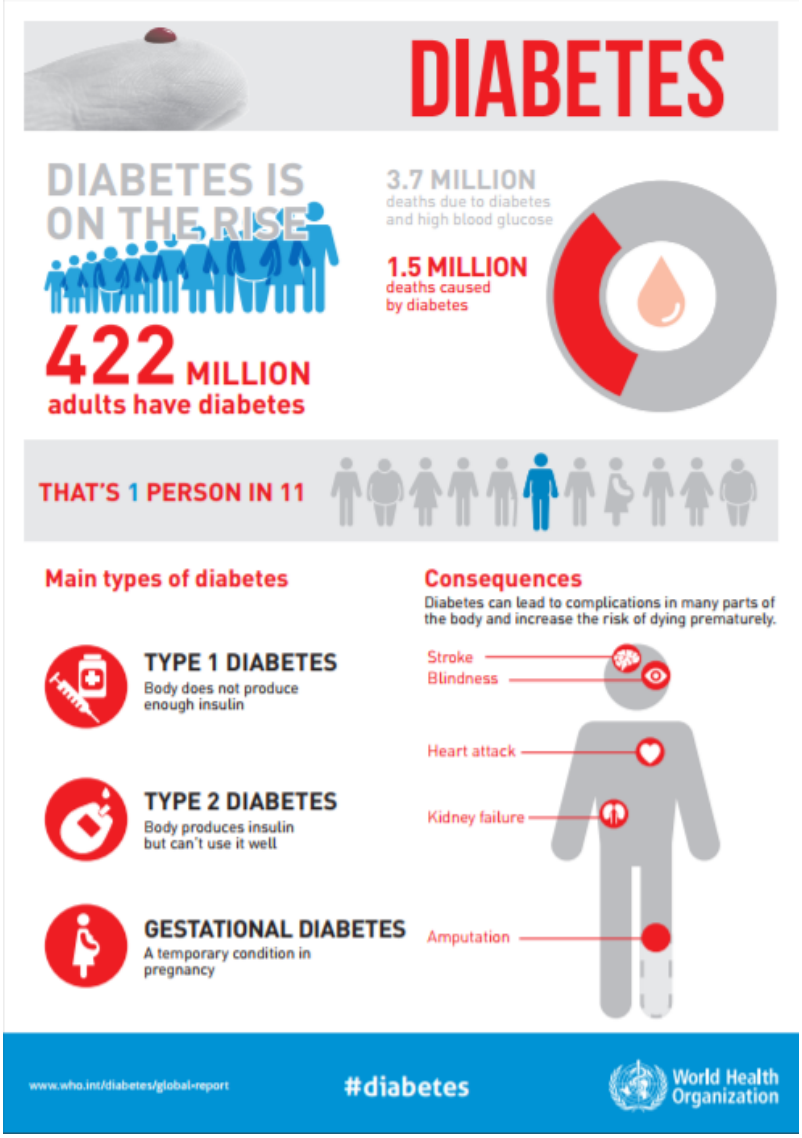

Figure 1. Report by World Health Organisation (2014)

2.2 Theoretical Framework

The backward design framework, also known as "Understanding by Design" (UbD), was created by Wiggins and McTighe in 1998 and provided the foundation for the thesis study. It is a technique for planning research investigations that starts with defining desired results before working backwards to find the necessary actions and resources to accomplish those outcomes. With this strategy, it is ensured that research investigations are supported by data and focused on the requirements and top priorities of the intended diabetic community.

The backward design framework for research about self-management applications for diabetic patients consists of three main steps:

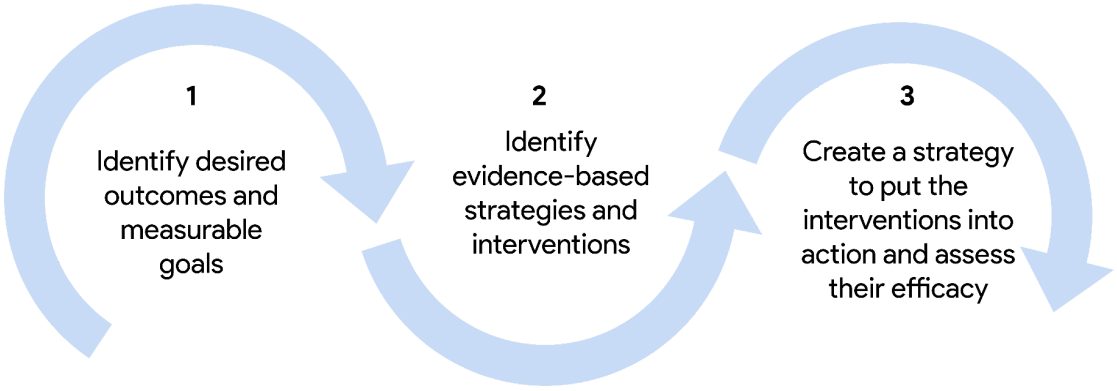

Figure 2. Understanding by Design Wiggins & McTighe

1. **Identify desired outcomes and measurable goals**: The first step in the backward design process is to identify the desired outcomes and measurable goals for the research study. This includes identifying the specific self-management behaviours that the research study aims to improve in diabetic patients, such as medication adherence, blood glucose monitoring, and physical activity. The desired outcomes and goals will be specific, measurable, and relevant to the target population.

2. **Identify evidence-based strategies and interventions**: Following the identification of desired objectives and goals, the following stage is to identify the evidence-based strategies and treatments that will result in those results. This involves determining the precise self-management tools and apps that have been demonstrated to be efficient in addressing the self-management practices that the study's research wants to enhance. For instance, the research may concentrate on a mobile application that offers tailored feedback on medication adherence or a remote monitoring system that gives patients and healthcare professionals access to real-time blood glucose data. The target audience will be considered when choosing self-management apps and technology, which will be based on the literature that is already accessible.

3. **Create a strategy to put the interventions into action and assess their efficacy**: The last stage in the backward design process is to create a concept to put the interventions into action and assess their efficacy. This involves determining the precise procedures and materials required for the study, such as enrolling participants, giving them self-management application training, and gathering data. It also involves identifying the specific evaluation methods that will be used to assess the effectiveness of the interventions. The study may also include specific metrics

that will be used to measure the outcomes and goals of the study, such as changes in quality of life and patient satisfaction.

The backward design framework is a well-accepted method for planning research studies on diabetes patients' self-management tools. It is very helpful for dealing with complicated health difficulties and challenges, such as managing chronic diseases and raising the standard of healthcare. The backward design technique is helpful in planning research projects that aim to enhance patient self-management behaviours and results. It is also a good resource for determining which diabetes patients' self-management tools and apps are the most useful.

Using systems thinking approach (Meadows, 2015), the different components of the system will be identified, including patients, healthcare providers, and the digital health service itself. Also, the interactions between these components and external factors that may impact the system will be analysed, such as social and environmental factors. The systems thinking approach enables the identification of the feedback loops, bottlenecks and other factors that may be impacting the effectiveness of the system. This approach also helps identify the opportunities for data integration, such as integrating the digital health service with electronic health records (EHRs), wearable devices, social networks, telehealth services and clinical decision support systems.

Once the problem and system interactions have been identified, the solutions will be designed to improve the system. This can include designing new digital health services, modifying existing services, or changing the way that patients and healthcare providers interact with the system. These solutions should align with the desired outcomes and goals identified using the backward design approach.

The solutions' success in reaching the targeted results and goals is assessed using data gathered during the implementation phase. The efficacy of digital health services may be increased by identifying and addressing usability concerns, according to research by Raza (2012). As a result, the researcher may carry out user testing with diabetes patients to spot usability problems and make the required design changes.

2.3 Methodology and Approach

Researching possibilities about mobile apps to improve self-care management involves the use of mixed methodologies. This methodology combines quantitative and qualitative research methods, enabling a more thorough grasp of the subject under study (Creswell & Clark, 2011).

To collect data on the use of mobile applications, their usability, and their effectiveness on self-care management outcomes such as blood glucose control, medication adherence, and

health-related quality of life, quantitative approaches, such as questionnaires, will be employed.

On the other hand, qualitative techniques like interviews will be utilized to collect information on the user experience and perceptions of mobile application use, as well as their influence on self-care management behaviours and decision-making.

Mixed-methodologies research can offer a more thorough knowledge of the potential and difficulties in self-care management utilizing mobile applications by combining quantitative and qualitative methods. Understanding the technical components of diabetes as well as user perceptions and experiences is part of this.

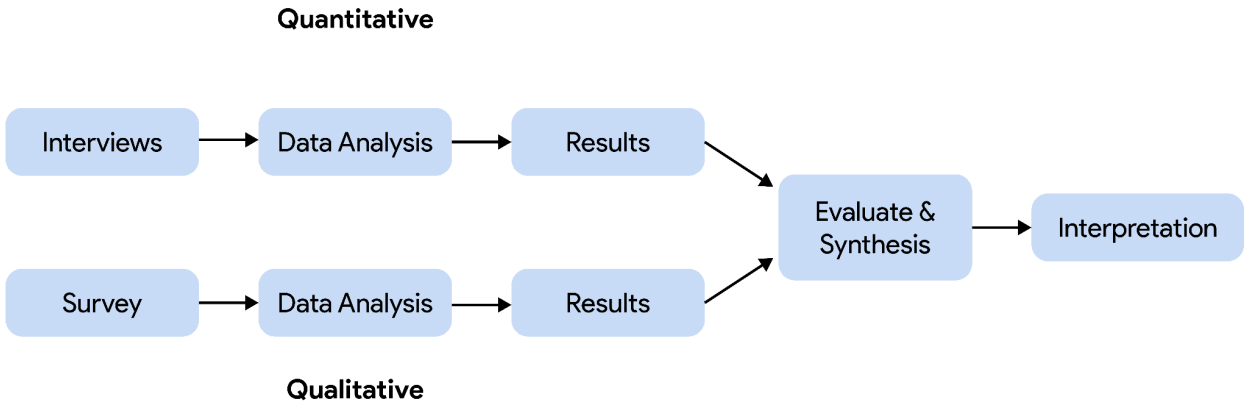

Figure 3. Mixed-methodologies research by Creswell & Clark (2011)

2.4 Design Process

Literature research

To understand the width and depth of the ecosystem of healthcare services entitled for diabetic patients, the researcher started referring to published papers and reports by American Diabetes Association (ADA), International Diabetes Federation (IDF), Diabetes UK and Indian Society of Diabetes (ISD). The information provided by these sources is used to map the system and identify interventions. My primary objective is to understand the lifestyle adaptation challenges faced by people who were diagnosed with type 1 or type 2 diabetes using technology-enabled tools available in the market. To fulfil this objective, literature research was my first step.

Survey

A survey was conducted using Google Forms and shared on over 20 Facebook groups which cater to diabetic communities from Estonia, UK, USA and India. The questionnaire's aim was to collect data from diabetic patients who are already using smartphone apps to manage their health on a daily basis. It was challenging to find participants for the survey, but during the active duration of response collection, there were 20 responses. These responses gave quantitative insights into what applications they use, how happy they are using them and what needs they did not address.

Interviews

It was very important to interview diabetic patients along with the healthcare workers who provide care to them, i.e. endocrinologists, diabetologists and diabetes nurses. The prerequisite for any diabetic patient to be eligible for the interview was that they should be in the age group of 20 - 55 years, able to speak English and actively use technology-enabled tools like smartphone applications, CGM and fitness devices to self-manage their diabetes.

A total of 9 interviews were conducted which a semi-structured way in order to understand their personal experience of self-care management in all scenarios. There were many interesting insights gained from the interviews. All the interviews were conducted online and with informed consent. The interviews only focused on the qualitative aspect of their lifestyle, and no information was asked, which is a matter of privacy. In this report, the names of the participants are hidden as preferred by them.

2.3 Literature Sources

The researcher conducted a comprehensive literature review to identify the current state of knowledge and gaps in research in this area. The literature review involved a systematic search and analysis of published studies, articles, and other relevant literature on the topic.

To search, the researcher used various databases, including PubMed, Researchgate, and Academia, and used keywords such as self-care management, diabetes, patient education, and behaviour change. The researcher also explored relevant organizations such as the

American Diabetes Association (ADA), International Diabetes Federation (IDF), Diabetes UK and the Indian Society of Diabetes (ISD).

The literature review was structured in a way that organized the literature by key themes, research questions, or types of interventions. In addition, the researcher critically evaluated the quality of the studies reviewed and assessed their potential biases, limitations, and generalizability.

3. Literature Overview

In this chapter, the researcher presents his review of desktop research he has done to learn about diabetes and explains the standard definitions of the biological phenomena behind diabetes. The researcher also discussed self-care management and the problems associated with it.

3.1 Overview of Diabetes

Diabetes is a chronic disease affecting millions globally and is highly related to morbidity and death. To determine existing knowledge and research gaps on the prevention and management of diabetes, a literature review was carried out.

Glycemic control is a key component of diabetes care. For the majority of diabetic individuals, the American Diabetes Association advises a goal haemoglobin A1c (HbA1c) level of 7% (American Diabetes Association, 2021). According to several studies (Stratton et al., 2000; UK Prospective Diabetes Study Group, 1998), keeping HbA1c levels below this goal can lower the risk of microvascular problems such as retinopathy and nephropathy.

However, obtaining and maintaining glycemic control might be difficult for many individuals. Diabetes self-management education (DSME) programs can enhance glycemic control as well as other outcomes, including quality of life, self-efficacy, and self-care behaviours, according to a systematic review by (Khunti et al., 2013). DSME is also advocated by the American Diabetes Association as a crucial element of diabetes care (American Diabetes Association, 2021).

Diabetes care involves addressing other risk factors, including hypertension and dyslipidemia, in addition to glycemic control. For most diabetic patients, the American Diabetes Association suggests blood pressure goals of 140/90 mmHg and statin medication for those with atherosclerotic cardiovascular disease or LDL cholesterol levels below 70 mg/dL.

The significance of lifestyle modifications in managing and preventing diabetes is also being increasingly supported by research. According to the Diabetes Prevention Program, high-risk individuals can lower their chance of developing diabetes by 58% by engaging in intensive

lifestyle treatments that focus on weight reduction and increased physical activity (Knowler et al., 2002). Similar results were obtained in the Look AHEAD research, which showed that intensive lifestyle interventions resulted in higher weight reduction and improved glycemic control in overweight or obese people with type 2 diabetes than conventional treatment (Look AHEAD Research Group et al., 2014).

3.1.1 Diabetes Type 1

An autoimmune disease, type 1 diabetes affects millions of people worldwide, mostly children and young adults. The root cause of Type 1 diabetes involves the autoimmune T cells' death of pancreatic beta cells, which results in a complete lack of insulin. Numerous genetic loci have been discovered as risk factors for the development of Type 1 diabetes, which is impacted by both genetic and environmental variables (Concannon et al., 2009). The development of Type 1 diabetes has also been linked to environmental variables, including viral infections and nutritional factors (Rewers et al., 2012).

Insulin replacement through multiple daily injections or continuous subcutaneous insulin infusion is characteristic of Type 1 diabetes care. According to research conducted by the Diabetes Control and Complications Trial Research Group in 1993, intensive insulin therapy can lower the risk of both microvascular and macrovascular consequences, such as retinopathy, nephropathy, and cardiovascular disease.

For many Type 1 diabetes patients, however, obtaining and maintaining glycemic control might be difficult. A frequent side effect of insulin treatment, hypoglycemia, can cause severe morbidity and death. Continuous glucose monitoring (CGM) can enhance glycemic control and lower the incidence of hypoglycemia in patients with Type 1 diabetes, according to a comprehensive review by Weisman et al. (2015).

Prevention of other risk factors, such as hypertension and dyslipidemia, is necessary for Type 1 diabetes care in addition to insulin therapy and glycemic control. For the majority of Type 1 diabetes patients, the American Diabetes Association suggests blood pressure goals of 130/80 mmHg and statin medication for individuals with atherosclerotic cardiovascular disease or LDL cholesterol levels 100 mg/dL.

3.1.2 Diabetes Type 2

People who are diagnosed with type 2 diabetes have a metabolic illness characterized by insulin resistance and poor glucose metabolism. Type 2 diabetes has a complicated aetiology that combines genetic and environmental variables. Among the known risk factors for Type 2 diabetes include age, obesity, family history, and physical inactivity (American Diabetes Association, 2021). The development of Type 2 diabetes may also be influenced by variables, including chronic stress and sleep deprivation, according to recent research (Zimberg et al., 2020).

A comprehensive strategy is used to manage Type 2 diabetes, including medical treatments, lifestyle changes, and complication monitoring. For the prevention and control of Type 2 diabetes, weight reduction and physical exercise are essential strategies (American Diabetes Association, 2021). In individuals with Type 2 diabetes, lifestyle treatments can significantly improve glycemic control and lower the risk of cardiovascular events, according to a comprehensive analysis by Nield et al. (2014).

For individuals with Type 2 diabetes, medications are frequently required to achieve and maintain glycemic control. Since it has been demonstrated to enhance glycemic control and lower the risk of cardiovascular events, metformin is the first-line treatment for Type 2 diabetes (American Diabetes Association, 2021). However, there is still ongoing research into the best pharmaceutical agent combination for the treatment of Type 2 diabetes.

The care of complications, including hypertension and dyslipidemia, in addition to glycemic control, is essential in the prevention of cardiovascular events in individuals with Type 2 diabetes. For the majority of Type 2 diabetes patients, the American Diabetes Association suggests blood pressure goals of 130/80 mmHg and statin medication for individuals with atherosclerotic cardiovascular disease or LDL cholesterol values of 70 mg/dL (American Diabetes Association, 2021).

The use of precision medicine techniques in the management of Type 2 diabetes is also gaining popularity. According to recent research (Mahajan et al., 2018; Scott et al., 2021), genetic variations linked to Type 2 diabetes risk and treatment response have been revealed. These findings help doctors build individualized treatment plans. Furthermore,

new technologies like telemedicine and mobile health apps may make it easier to manage and monitor diabetes, especially in marginalized groups (Pantalone et al., 2020).

3.2 Lifestyle Variables Affecting Diabetes Management

Diet, exercise, sleep, and stress are just a few examples of the many lifestyle variables that can affect the development of diabetes, a complicated metabolic illness. The goal of this literature review is to explore how these lifestyle variables are now understood to play a part in the management of diabetes, including any possible impacts on insulin resistance, glucose regulation, and overall health outcomes.

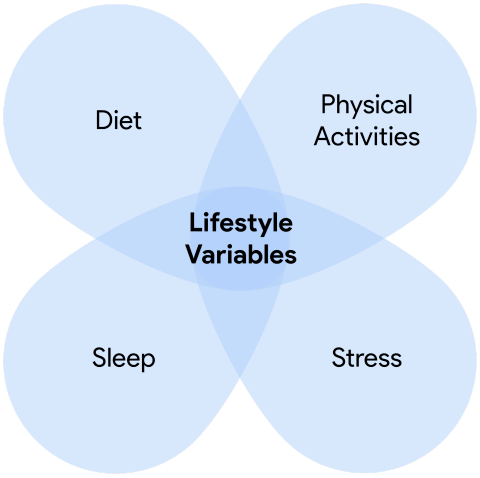

Figure 4. Figure illustrated by author

Diet

Diet is vital for managing diabetes since it has an impact on blood glucose levels and general health outcomes. Increased insulin resistance and worse glycemic control are linked to diets heavy in processed and refined carbohydrates, saturated and trans fats, and added sweets (Franz et al., 2020). The American Diabetes Association (2002) states that a diet high in whole grains, fruits, vegetables, lean protein sources, and healthy fats can enhance insulin sensitivity and glucose management. It has been demonstrated that the Mediterranean diet, which prioritizes these items, is helpful in enhancing glycemic control

and lowering the risk of cardiovascular disease in individuals with diabetes (Esposito et al., 2010).

Physical Activities

Another crucial aspect of a healthy lifestyle for managing diabetes is physical exercise. Exercise has been found to lower the risk of cardiovascular disease and enhance insulin sensitivity and glucose management (Colberg et al., 2010). The American Diabetes Association advises strength training at least twice a week and moderate-intensity aerobic activity for at least 150 minutes per week (American Diabetes Association, 2021). Additionally, standing or walking to break up sedentary behaviour can help with glucose management and general health outcomes (Dempsey et al., 2020).

Sleep

As disturbed sleep patterns can affect glucose control and worsen insulin resistance, sleep is increasingly becoming a crucial component of managing diabetes. According to Shan et al. (2015), short sleep duration and poor sleep quality are linked to a higher incidence of Type 2 diabetes and worse glucose management in diabetics. However, they could be related to changes in circadian rhythms and the stress response (Knutson et al., 2007). Therefore, improving sleep length and quality may be a key goal for diabetes treatment.

Stress

Stress is a regular occurrence that may affect the body physiologically in a number of ways, including increased cortisol release and sympathetic nervous system activation. Particularly in those with Type 2 diabetes, these reactions can worsen glucose regulation and heighten insulin resistance (Kyrou et al., 2021). Diabetes patients have been demonstrated to have improved glycemic control and fewer symptoms associated with stress when using stress management approaches such as mindfulness meditation and cognitive-behavioural therapy (Holt et al., 2021).

3.3 Glycemic Index

The rate at which food's carbohydrates are broken down into glucose and absorbed into the circulation is gauged by the glycemic index (GI). This literature review aims to investigate the existing knowledge of the function of GI in the management of diabetes, as well as its possible impacts on glucose control and general health outcomes.

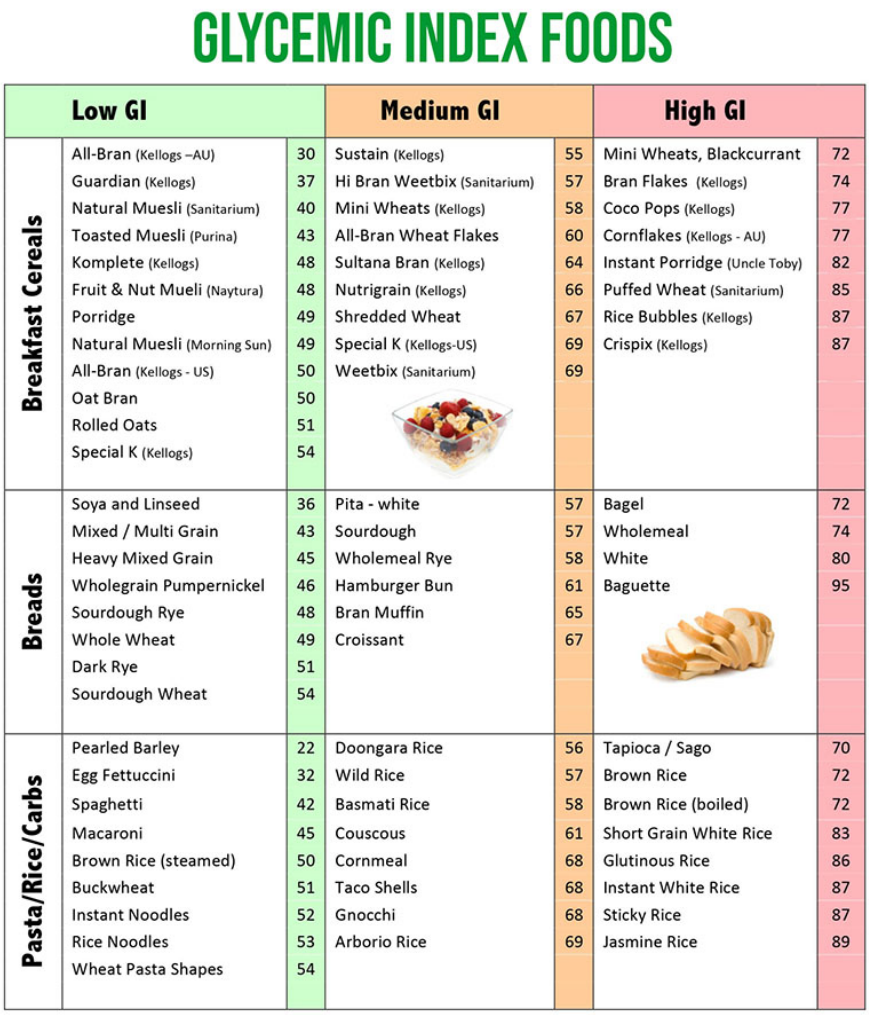

Figure 5. Glycemic Index Food Chart

White bread and sweet beverages are examples of high-GI meals that are easily digested and absorbed, causing blood glucose levels to rise quickly. As a result, there may be an increased risk of Type 2 diabetes and insulin resistance (Ley et al., 2014). In contrast, low-GI meals, including whole grains, fruits, and vegetables, digest and absorb nutrients more slowly, causing blood glucose levels to rise more gradually (Brand-Miller et al., 2003).

As a result, there may be a decrease in the risk of Type 2 diabetes and an improvement in insulin sensitivity and glucose management (Jenkins et al., 2014).

Numerous studies have looked at how low GI meals affect diabetics' ability to regulate their blood sugar levels. In comparison to high GI diets, low GI diets significantly reduced haemoglobin A1c (HbA1c) levels, fasting blood glucose levels, and insulin sensitivity, according to a meta-analysis of randomized controlled trials (Barclay et al., 2008). A low GI diet improved glucose control and decreased the need for diabetic medication in overweight and obese patients with Type 2 diabetes, according to different research (Chiasson et al., 2002). These results imply that low GI diets may be useful for managing diabetes.

Low GI meals may help diabetics' overall health in addition to their impact on glucose regulation. A low GI diet resulted in larger triglyceride reductions and better indicators of inflammation compared to a high GI diet, according to a study of overweight and obese people with Type 2 diabetes (Foster-Powell et al., 2003). A low GI diet was linked to a lower risk of cardiovascular disease in patients with Type 2 diabetes, according to another study (Fan et al., 2012). These results imply that low GI diets can have additional health advantages than glucose regulation.

However, it's important to remember that GI is only one component of a balanced diet; other elements, such as total carbohydrate consumption, fibre content, and food quality, should also be taken into account when establishing dietary recommendations for diabetes management (American Diabetes Association, 2021). Individual reactions to GI may also differ based on things like insulin sensitivity and the existence of other medical disorders.

3.4 Hyperglycemia and Hypoglycemia

Two prevalent disorders are linked to elevated blood glucose levels: hyperglycemia and hypoglycemia. A person with diabetes normally has hyperglycemia, or high blood sugar levels, whereas a person with hypoglycemia, or low blood sugar levels, can experience any of these conditions.

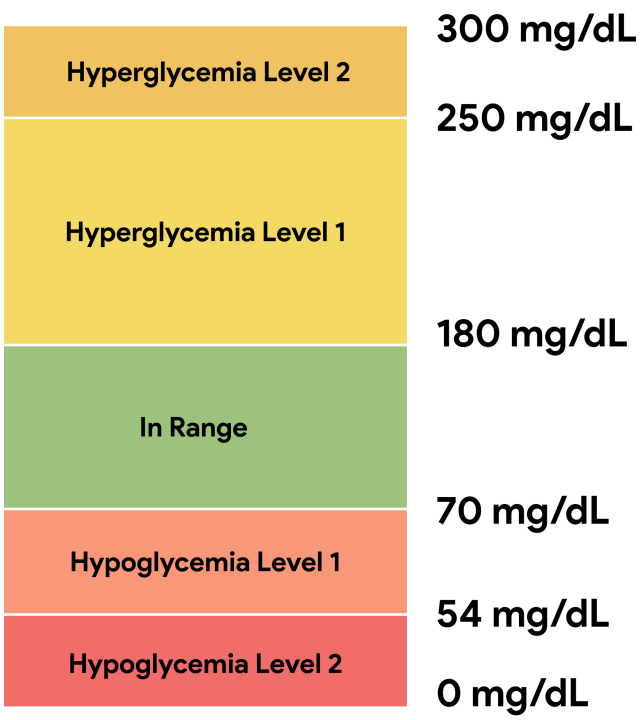

Figure 6. Thresholds for Hyperglycemia & Hypoglycemia, original figure by Battelino et. al (2019), modified by the author

Hyperglycemia

A frequent side effect of diabetes, hyperglycemia is defined by elevated blood glucose levels. A number of things, such as inadequate insulin synthesis, insulin resistance, or certain drugs, can contribute to it (American Diabetes Association, 2021). According to the International Diabetes Federation (2019), long-term hyperglycemia can result in problems such as diabetic retinopathy, nephropathy, and neuropathy. Increased thirst, frequent urination, weariness, and impaired vision are all signs of hyperglycemia (Mayo Clinic, 2020).

Insulin and oral hypoglycemic medicines are used in the management of hyperglycemia, along with dietary and activity changes (American Diabetes Association, 2021). Regular blood glucose monitoring is essential for treating hyperglycemia and avoiding complications.

Hypoglycemia

Low blood glucose levels, or hypoglycemia, can be brought on by a number of things, such as using too much insulin, skipping meals, or engaging in more physical activity (American Diabetes Association, 2021). Sweating, shaking, bewilderment, and loss of consciousness are some of the mild to severe hypoglycemia symptoms (Mayo Clinic, 2020).

Treating the underlying cause, such as changing medication dosages or boosting food intake, is part of managing hypoglycemia. Emergency care, such as glucagon injections, may be required for severe hypoglycemia (American Diabetes Association, 2021).

Regular blood glucose level monitoring, dietary and medication compliance, and avoiding excessive physical activity without appropriate meal intake are all necessary for the prevention of hypoglycemia (Mayo Clinic, 2020).

Associated with abnormal blood glucose levels are the frequent disorders of hyperglycemia and hypoglycemia. While hypoglycemia can induce immediate symptoms and could be life-threatening in severe circumstances, hyperglycemia can result in long-term consequences. A combination of lifestyle changes, medication management, and routine blood glucose testing are used to treat these diseases.

3.5 Self-care Management and its Importance

The everyday routines and behaviours that persons with diabetes adopt to control their illness and avoid complications are referred to as diabetes self-care management. It includes keeping an eye on blood sugar levels, taking medications as prescribed, exercising, eating right, and controlling stress.

According to studies, following diabetes self-care management guidelines can improve glucose control, lower the risk of complications, and improve general health outcomes. For instance, a meta-analysis of randomized controlled trials revealed that blood glucose self-monitoring, a crucial component of managing diabetes through self-care, significantly lowered HbA1c levels in patients with Type 2 diabetes (Malanda et al., 2012). According to another study, patients with Type 2 diabetes who adhered to a diabetic self-care

management program had improvements in their blood pressure, cholesterol levels, and overall cardiovascular risk. (Jannoo et al., 2017).

The control of diabetes requires careful dietary management as well. According to studies, following a balanced diet can help diabetics improve their glycemic control and lower their risk of problems (Evert et al., 2019). Low-carbohydrate diets, Mediterranean-style diets, and plant-based diets were all shown to be helpful in improving glycemic control and lowering cardiovascular risk in a study of dietary treatments for Type 2 diabetes.

3.6 Problems with Self-care Management

Self-care is an essential element of managing diabetes. Still, many diabetic people struggle with it, impairing their ability to control their condition and raising their risk of complications. Some of the difficulties with self-care that have been mentioned in the literature include the following:

- **Poor medication adherence**: It might be difficult for diabetic people to take their prescriptions as directed. Osterberg and Blaschke's (2005) comprehensive review found that oral diabetes medication adherence is generally about 50%, which can result in poor blood glucose control and a higher risk of complications.

- **Monitoring blood glucose levels is difficult**: A vital aspect of managing diabetes is self-monitoring blood glucose (SMBG). However, many patients find it challenging to do so often or to understand the data. Research by Thomas et al. (2015) found that many diabetes patients do not practice SMBG as advised, which can result in ineffective blood glucose management.

- **Lack of physical exercise**: Although regular physical activity is essential for managing diabetes, many diabetic people find it challenging to do so. Only approximately half of diabetes patients satisfy the suggested recommendations for physical exercise, according to research by Colberg et al. (2010).

- **Healthy diet adherence issues**: Many diabetes patients have trouble maintaining a healthy diet, which can result in poor blood glucose control and a higher risk of complications. According to research by Anderson et al. (2002), many diabetes

patients find it challenging to modify their diets and may not be able to maintain a healthy diet over time.

4. Design Research

In this chapter, the researcher discusses the findings from the quantitative and qualitative research conducted among diabetes patients, doctors and nurses. Furthermore, journey mapping is done, and the discussion highlights the interventions and the design brief is formulated.

4.1 Interviews and Survey

During the research phase, a total of 9 interviews were conducted, including 5 DT1 patients, 2 DT2 patients, 1 diabetologist and 1 nurse. All the interviews were scheduled and conducted in either video or audio format as preferred by the interviewee. The call durations ranged between 30 - 60 mins. The objectives and goals of the interview were sent to the interviewee prior. The interviews were semi-structured to make interviewees more comfortable and explain certain experiences clearly.

During interviews with patients, the main objective for the researcher was to understand their lifestyle before and after they had been diagnosed with diabetes (whether type 1 or type 2), their daily routine with diabetes, and specific experiences where they face difficulties. In the interviews with diabetologist and nurse, the aim was to know their experience with different types and demographics of patients they dealt with, how they provided treatment and counselled them.

Among 9 interviews, below are the 4 unique stories in terms of their journey with diabetes till now, awareness of self-care management and involvement in diabetes treatment.

Patient 1 with Diabetes Type 1

Patient 1 is a female of 55 years living in a suburban of Estonia. She was diagnosed with type 1 diabetes when she was 24 years and just started practising as a doctor. This was a major shock to her and brought her many problems. She stopped working as a doctor after

she conceived her first child. She could not manage everything very efficiently, so she prioritised her family over her profession. Before the smartphone era, she used to log her diet intake and insulin doses in a diary. This was the only way back then to manage diabetes though it was an exhausting exercise. Things have changed beyond her imagination over 30 years as she logs on to a smartphone application using CGM. A few things have been same like being considerate before eating anything, having a glucose test once per month and, scheduling doctor's appointment a week later, going to Optometrist once a year. She mentioned that her diabetes nurse introduced and educated her about the new way to manage her diabetes using a smartphone application. Though it is not helping her reduce the load of making a plethora of decisions on a daily basis. Being a mother, a housewife, and a diabetic is not easy, but over time, she accepted challenges with diabetes. She took the initiative to help other diabetic patients through a Facebook group, where she helps people who just got diagnosed with diabetes with her experience. She believes a diabetic person is the best to help another diabetic person since they carry a true sense of empathy.

There was a phase where she was overweight, and this caused complexity in her health condition. She being herself a doctor kept the positive motivation to improve her lifestyle and she learnt about Glycemic Index and accordingly started planning her diet. But she is not so happy with the manual planning because if she wants to experiment with new food then it takes some time to understand how it will affect her. So to avoid any risks, she keeps her diet restricted to food items, including soups, bread, vegetables, nuts, wheat-based items, fish and eggs. She has to eat certain food which takes care of her eyes and blood pressure other than diabetes.

Patient 2 with Diabetes Type 1

Patient 2 is a male of age 32 years who is an IT professional and lives in the outskirts of Tallinn. He was diagnosed with type 1 diabetes when he was 10 years old. Until his late teenage years, his parents were his primary caretakers, and he just followed their instructions to manage his diabetes. Now he uses CGM and a glucose-tracking app on his iPhone to keep an eye on his blood glucose levels. Since 2021 the government has been reimbursing the cost of CGM under national health insurance. He started using CGM since his doctor has encouraged him to use it as it gives a better overview and builds trust over the report presented by the patient during the consultation. The patient records what he ate, glucose levels and insulin intake on a daily basis. Though CGM automatically records

glucose levels, he must log food and insulin, which is exhausting. CGM alone is not much of a valuable help to his condition.

When he was young, he did not understand how his food habits affected his condition, but now he is very specific about his diet, as he does weightlifting and has been doing it for a few years. He explained that it's been difficult to adjust his diet aligned with his diabetes as well as his workout. He eats a 4-course meal daily, which includes breakfast, lunch, a mini-meal in the evening and dinner post-workout. The problem comes with mini-meal and dinner as he as to carefully plan them based on his glucose levels pre and post-workout. He has a past of glucose levels dropping during mid-night, which makes it very critical that what he eats in his last meal before sleeping. He kept the menu consistent due to the super complexity of calibrating the menu as per requirements, and mostly he guesses how much to eat and when to eat based on his previous experiences. But he still encounters lows sometimes in his sleep which he is afraid of as this could lead to more complications of Hypoglycemia. His 3 months average for glucose is not good, and he is trying to improve it. When asked what would help him make his life easy, he said he should know accurately how his body metabolism works with what and when he eats with the active workout and insulin dosages. His insulin sensitivity gets affected by his body fat percentage and the climate, and based on the change, he needs to modify his meals.

Patient 3 with Diabetes Type 2

Patient 3 is a male of 36 years old and is a cab driver in Tallinn. He was diagnosed with type 2 diabetes three years ago when he was exhausted very easily, affecting him at work. The doctor prescribed him oral medication and told him to take care of his diet and lose weight. Three years down the line, he did not lose weight, but his condition also did not get worse. His typical day requires most of his time in sitting in his car and driving. He makes sure to take his medicines on time, which is a pill in the morning before he eats, but he fails to follow a proper diet. He starts his day early at 7 am, has porridge in his breakfast, and gets to work. The time for his lunch and dinner is not so fixed due to the nature of his work.

In the initial days when he was diagnosed with diabetes, he tried to follow a proper diet plan but could not adhere to it for a longer time. He stopped consuming food and drinks with sugar. In his last visit to the doctor, he was recommended to lose weight as he has a higher risk of developing cardiovascular problems since his cholesterol was higher than normal. He

mostly eats out his lunch and dinner (from supermarkets and quick service restaurants) since he drives across the city to pick up and drop off his passengers. When asked how he makes his food choices, he answered that he usually goes for food with meat, but since his last doctor visit, he cut down on meat and tried veggies. He expressed that with this change in his diet, he is feeling more hungry and exhausted. He is not able to judge how much and what is optimal for him, and there is no time and motivation to think too much about planning his meals.

Diabetologist

The diabetologist has been in practice for 15 years, serving diabetics patients. He was asked to describe step by step process of care delivery to his patients and what and how the guidelines are given, to which he answered that patients come to him once they are diagnosed with diabetes (both type 1 and type 2) in the Hb1Ac test. Then the doctor assesses the patient's health condition and, based on the observations and analysis, prescribes medicines and educates the patients on how and why they should manage diabetes. Every patient comes from a different lifestyle and behaviour. For the first few months, the patient is asked to visit him on a regular basis so that he can assess how well the patient is maintaining the time in range and coping with the lifestyle adjustments. The majority of the patients feel overwhelmed by the sudden diagnosis of diabetes and get stressed, and give up on the med type 2 diabetes ways puts the patients in the diabetes communities so that they get proper education, motivation and a safe environment where they have no reason to be afraid of their condition.

It's not only a diabetologist whom a diabetic patient must visit but also a dietician, an optometrist and a nephrologist. But the patients barely give importance to preventive care as there need to be more methods to do so for them. Right now, patients get to know any complexity only after they see any symptoms, and often it's too late to be cured with mild medicines. This happens when a patient fails at self-care management. Fundamentally diet and physical activity are the core elements of diabetes; if a person follows a diet based on his/her body metabolism, adheres to medicines and does physical activity based on his/her goals, then even being a diabetic, a person can be healthy.

Key findings

Insight	How might we
Managing Diabetes is a full-time job You don't necessarily want to do it, but have to do it as a survival imperative.	HMW make their 'job' easier.
I am my own caregiver While many individuals have spouse or other family assist in one form or another, adults with Diabetes take on most if not all the tasks required for their daily management.	HMW add value to their daily toolkit?
I get to know its low (BG) when I feel dizziness The BG spikes or drops are identified mostly after it happens which could bring additional complications.	HMW alert person in prior about the upcoming spikes and lows?
It is exhausting sometimes It needs motivation to follow their treatment plans which includes diet, exercise and medication.	HMW goal-setting feature to engage them in their treatment plan?

Figure 7. Key findings and how might we statements

The survey

The survey was published on diabetes groups on Facebook and received 14 responses. The survey aims to collect data about how they manage diabetes, what applications they use, what devices they use, how convenient they are with their current available tools and what challenges they face.

17. What challenges do you face in managing your diabetes?
Difficulty keeping track of blood glucose levels
No remarkable difficulties
Difficulty maintaining a healthy diet
when i go out...its more difficult(sorry my language is estonian)
Overcompensating highs and lows.
Difficulty maintaining normal blood glucose levels
Difficulty maintaining an exercise routine
Difficulty keeping track of blood glucose levels
Difficulty remembering to take medication, Difficulty maintaining a healthy diet, Difficulty maintaining an exercise routine
Just the day to day activities that affect my blood sugar. Stress, work, exercise and food and what they do to my blood sugars.
It can be overwhelming sometimes, due to its non-stop, neverending nature
Difficulty remembering to take medication, Difficulty maintaining a healthy diet, Difficulty maintaining an exercise routine, Difficulty keeping track of blood glucose levels
Difficulty keeping track of blood glucose levels

Figure 8. Challenges faced by participants

78% of respondees use CGM to monitor their glucose levels and use mobile applications to log their glucose levels. 92% of respondees log their glucose levels and food intake on a daily basis. Key findings from the survey are the challenges they face in managing diabetes which align with the challenges found in desktop research, which are difficulty in maintaining glucose levels in range, exercise routine, healthy diet, remembering medication and getting overwhelmed to manage diabetes. Full survey results are presented in Appendix 1.

4.2 Journey from Being Normal to Diabetic

To understand the interventions and problem space, a person's journey from being normal to being diabetic has been mapped. The journey can be divided into 5 stages: current reality, clarity, coping, caring and life with diabetes. The journey map is also presented in Appendix 2.

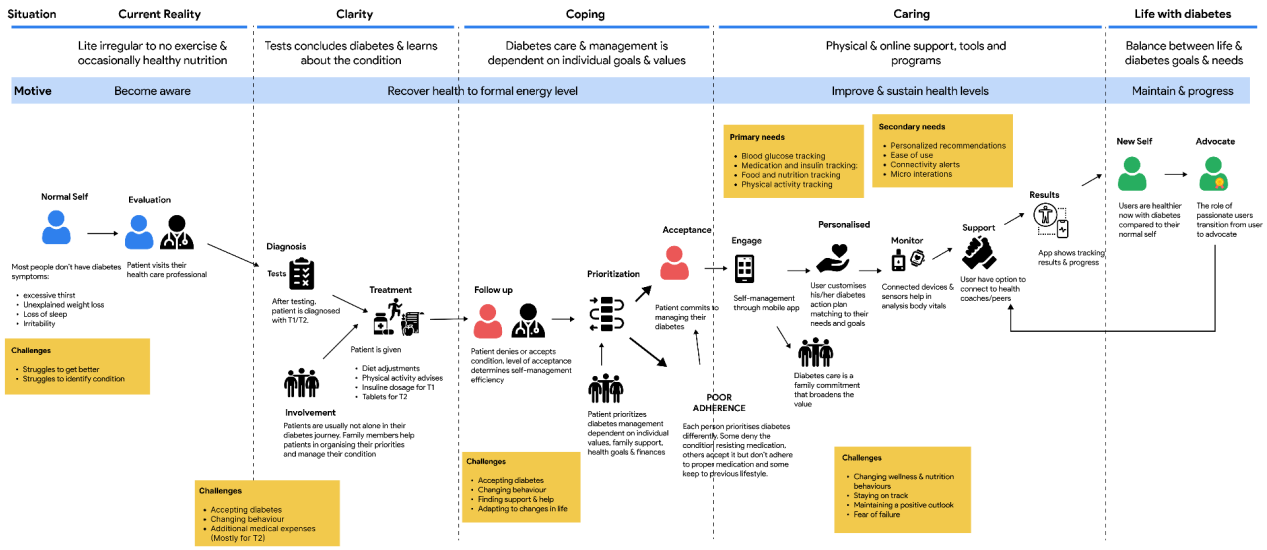

Figure 9. Journey Map from being normal to diabetic developed by the author

For any diabetic person in the current reality, it starts with symptoms like urinating a lot, often at night, losing sleep, being very thirsty, losing weight without trying, being very hungry, having blurry vision, having numb or tingling hands or feet, feeling very tired and having very dry skin. Ironically, these symptoms are underseen by many people as they presume it is not a symptom.

In the clarity stage, when the person visits doctors, and the symptoms are familiar with diabetes, then an H1bAc test is done before and after eating to check glucose level fluctuations. If diagnosed with diabetes, the doctor counsel the person about his/her condition (type 1 or type 2), which the doctor prescribes medicines, diet modifications, physical activities and emotionally supports the person in accepting the situation. At this phase, the person sees it challenging to accept diabetes and change behaviour. Family and peer support helps this adaptation smooth.

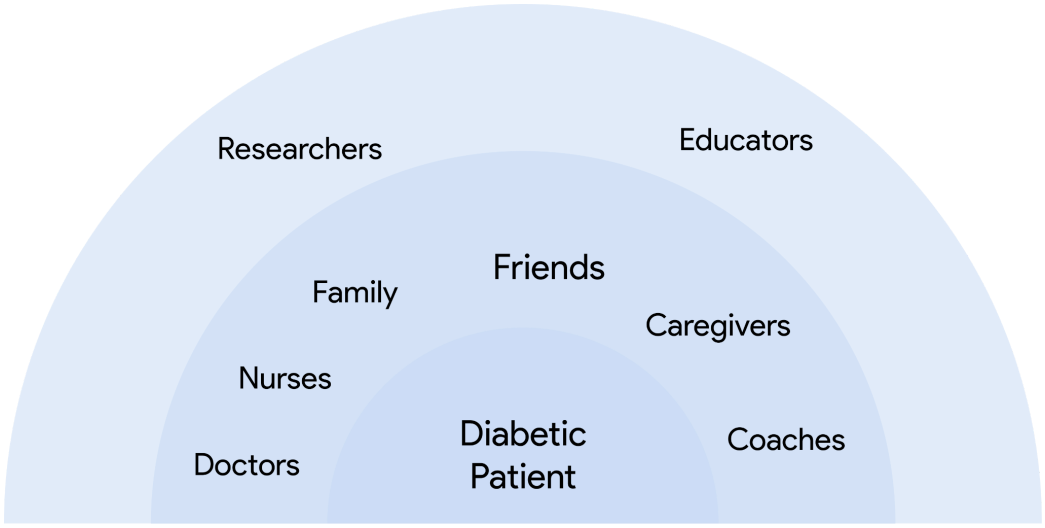

Figure 10. Stakeholder map by the author

In the coping stage, the patient regularly follows up with the doctor. If the patient is motivated towards the treatment, it's easy for the doctor to guide the patient. Still, in many cases, it takes a couple of months for the patient to get on the proper routine of medicines, diet and physical activities. The doctor or nurse helps the patient plan and prioritise health goals and educates about self-management. There are organisations, communities and online resources which provide training on the ABC of diabetes where a patient can learn how to use a glucometer or CGM, plan a diet, dos and don’ts and manage stress.

Now the long phase starts, which may last the entire life, which is caring. Based on the education and training received, the patient starts practising step by step routine. Patients use smartphone apps to fulfil their needs. These needs can be categorised into primary and secondary. The primary needs are to track glucose, food, medicine and physical activity. The secondary needs are the app should provide personalised recommendations to help them in decision-making, ease of use, micro-interactions and alerts. In this never-ending process, the patient faces challenges in changing wellness and nutrition behaviours, staying on track, maintaining a positive outlook and developing a fear of failure.

The last stage is living with diabetes. Both patients with type 1 and type 2 learn how to live with diabetes, and many become advocates for others. Patients who fail to manage diabetes properly worsen their health condition and may develop other health problems. According to research, type 2 diabetes is reversible in some cases, but it needs patients to follow a strict and very personalised plan which improves their pancreas functioning.

4.3 Challenges in Self-care Management

Compiling all the challenges gathered from desktop research, interviews and survey could be grouped and explained as:

Blood glucose monitoring

- Difficulty in checking their blood glucose levels regularly, particularly when they are busy with work or daily activities.
- Difficulty in avoiding spikes and falls beyond the permitted range.

Diet and nutrition

- Challenging to maintain a balanced diet when eating outside or faced with temptation.
- Difficulty in planning diet for specific situations like travelling, working long hours, sick days, workouts, extreme climates, stressful days, etc.
- Lack of knowledge of food causes fear about consequences if the wrong food is consumed.
- Challenges in choosing foods low in carbohydrates, sugar, and saturated fats, while still meeting their nutritional needs.

Physical activity

- Difficulty in incorporating regular physical activity into their daily routine due to a sedentary job or lack of time and facility.
- Challenges in choosing the right types of activities and managing the impact of physical activity on their blood glucose levels.

4.4 Evaluation of Mobile Applications Currently in Use

The researcher evaluated the mobile applications (mySugr, Dexcom One, Shuggah, Sugarmate, xDrip+) which were named by the diabetic persons in the interviews and survey. The evaluation is done upon key parameters like availability, accessibility, usability

and efficacy. All the applications have basic features like CGM connectivity, automatic glucose logging, and features to log food, medicine and physical activity.

	mySugr	**Dexcom One**	**Shuggah**	**Sugarmate**	**xDrip+**
Supported OS	Android, iOS	Android, iOS	iOS	iOS	Android
Smartwatch support	No	No	No	Yes	Yes
Connects with Car	No	No	No	No	Yes
Able to share data with family	No	Yes	No	Yes	No
Able to share data with doctor	Through .pdf	Through Dexcom Clarity	No	No	Through Tidepool
Connects to all CGMs	Selective	Only Dexcom	Only Dexcom	Only Dexcom	Only Dexcom
Can log food intake?	Yes	No	No	Yes	Yes
Can log physical activity	Yes	No	No	Yes	Yes
Price	Free,Paid	Paid	Free	Free	Free (Opensource)
Usability Score (Given by interviewee)	3/5	2/5	1/5	3/5	3.5/5

Figure 11. Evaluation of mobile applications currently in use

The users of these applications expressed the following likes and dislikes:

Likes

- They save time and effort in logging glucose levels,
- Helps in keeping a digital log diary which is easy to be shared with doctors as reports.
- Users can set alerts for spikes and lows.
- Users can add family members to be notified in times of emergency.

Dislikes

- Users want apps which support a variety of CGMs. Some apps like Dexcom One only support Dexcom CGM.
- Users want the app to connect with their smartwatch so that they quickly see alerts and glucose levels. mySugr, Dexcom One and Shuggah don’t support smartwatches.
- Apps like Dexcom One and Shuggah don’t have features to log food intake and physical activity.
- Users are mindful of the cost and the value that they are getting from the app. Just for a digital log of glucose levels, they are not willing to use paid apps.

4.5 Mapping the Journey

After the interviews, I compiled a set of user journey maps which shows how a day of a diabetic person looks like, where all the activities, glucose trends, pain points and opportunities were mapped by hours. The patient journey is also attached in Appendix 3.

6:00 am: The diabetic person wakes up and checks their glucose level. They take their insulin injection or medication as prescribed. He has breakfast and records their glucose level. He faces difficulty in finding a balanced breakfast that won't cause a spike in their blood sugar levels.

7:00 am: He starts his workday. He sits for extended periods during driving so he keeps quick bites as snacks in his car.

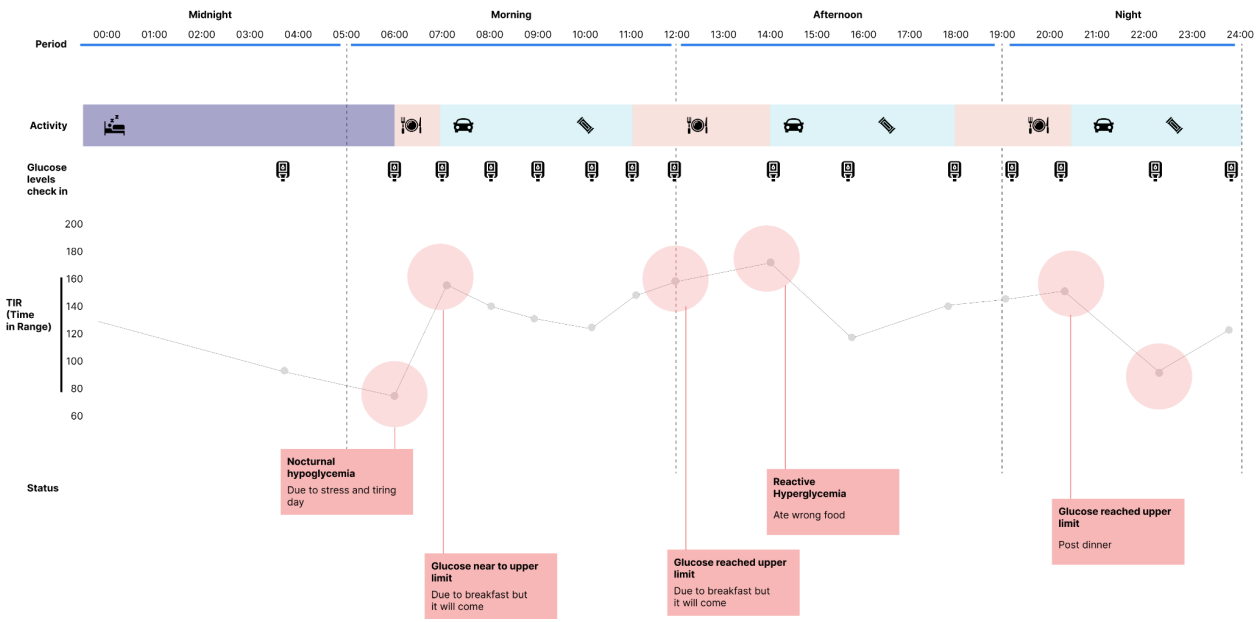

Figure 12. Patient journey map. Developed by the author

12:00 pm: Lunchtime. He takes a break from work and checks their glucose levels again. He finds eating healthy or balanced meals difficult due to a lack of options.

3:00 pm: Afternoon slump. The person feels fatigued and has low glucose levels. He needs to have a snack to keep their glucose levels stable.

6:00 pm: Break time. He meets his friends or has a power nap in his car.

8:00 pm: Dinner time. He struggles to find a balanced meal that won't cause a spike in their blood sugar levels.

9:00 pm: Resumes back to driving. Post dinner, his glucose levels show spikes.

12:00 am: Bedtime routine. He checks his glucose levels before bed and takes his medication.

Through this mapping, opportunities for improvement include:

- Encouraging the person to find healthier breakfast, lunch, and dinner options.
- Reminding the person to take their medication on time and regularly.
- Encouraging the person to exercise regularly.

- Providing healthy snack options for the afternoon slump.
- Helping the person find ways to manage stress levels due to long work hours, which can affect glucose levels.

4.6 Zooming into diet-related challenges

Here are some specific issues that the interviewed people with diabetes have while making dietary decisions daily:

Meal choices: To maintain appropriate blood glucose levels, diabetics must make well-informed meal selections. They have trouble selecting meals that would satisfy their nutritional demands while being minimal in sugar, carbs, and saturated fats.

Portion control: They must decide how much food to consume and have trouble doing so. This is because eating too much food may raise blood glucose levels, while undereating might result in hypoglycemia.

Meal preparation: Diabetics must choose what to eat and when throughout the meal preparation process. Planning healthy, diverse, and fulfilling meals may be difficult for them.

Eating out: They need help while dining at restaurants or during social gatherings. They could find it challenging to manage portion sizes, choose nutritious meals, and avoid things that might increase their blood sugar levels.

Temptation: They find it difficult to resist temptation, especially if they are among meals with a lot of calories and sugar. They struggle to stay away from meals they know are bad for them, which can make it difficult to keep blood sugar levels in a healthy range.

Well-being goals: Evey individual has some personal well-being goals, and it's difficult to plan a diet to achieve those goals without the intervention of a dietician. Many don’t have a personal dietician as they come for a cost.

Diet for complications: Diabetic patients with other health complications must be very critical about their diet. It gets overwhelming to micro-plan diets according to the condition.

4.7 Design Brief

When creating the design brief, the results of the desktop research and the design research are taken into account. The design concept's direction is how we might make diabetes patients manage diabetes through preventive actions since diabetics are usually not able to proactively act on things before they go bad and instead have to react after something has already gone wrong. The ideation is centred on three primary findings from the study and analysis:

- It is stressful and takes a lot longer for diabetics to figure out how many carbohydrates are in the unusual food they are eating. High-carb meals, like rice bowl, may also often cause blood sugar levels to fluctuate since it is difficult to predict what they do to the body.

- New diabetics get so much information after being diagnosed that it is sometimes confusing and challenging to understand it all. It may take some time for them to fully comprehend what they are doing, why they are doing it, and how various circumstances impact their blood sugar levels.

- Diabetics gain skills over time from routine experience and knowing how to handle various scenarios. This entails developing their ability to estimate the number of carbohydrates in their meals, but still understanding how different foods and environmental circumstances affect their blood sugar, and being prepared for a variety of eventualities is difficult for many.

5. Design concept

Based on the design brief from Chapter 4, the concept is designed, and in this chapter, the researcher gives holistic details about the concept, from how it works to what value it creates for the users.

5.1 Overview of Glen

The proposed design concept, "Glen", is an AI-powered smartphone application to make diabetes self-care management more inclined towards preventive and personalised care. The name is derived from "Glucose" and "Energy". The application holistically helps patients achieve their chosen goals by providing meal suggestions, activity suggestions and reminders based on real-time glucose levels. The core objective is to keep glucose levels within range by guiding the patient in his/her daily routine.

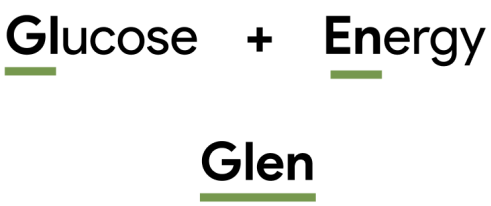

Figure 13. Diagram made by author

The application is designed on four major principles:

- **Short-term planning**: To allow users to plan their meals just before a few minutes or hours.
- **Preventive care:** To notify users of upcoming highs or lows and recommend actions to prevent them.
- **Playful engagement:** To make self-management more goal driven and personalised.
- **Decision support system:** To help users make decisions easily without much effort through smart insights.

Application Architecture

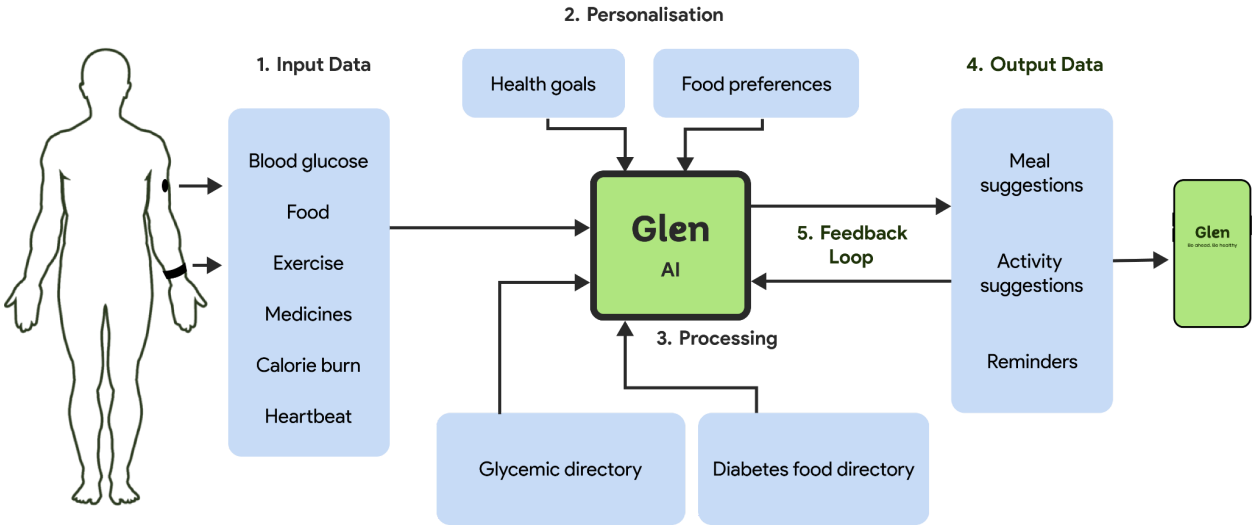

Figure 14. Application architecture made by the author

The architecture consists of five blocks, i.e. input data, personalisation, processing, output data, and feedback loop.

1. **Input data:** In order to make Glen work, data input is a prerequisite. The primary data consist of real-time glucose level data from connected CGM, calories burned data from connected smartwatch/fitness watch, log of food intake, log of medicines taken, and log of activity done. This regular data stream will train Glen's AI model to the optimal state where Glen understands patients' metabolism and behaviour and is able to forecast glucose levels for the next 2 hours. There are a few secondary data points for goals which are not required continuously but depend on the goals.

2. **Personalisation:** The recommendation engine work best when the patient customises Geln to his/her personal needs and goals. After the training period, the food preferences and goals must be chosen.

3. **Processing:** The AI model of Glen processes input data and feedback loop data with food preferences and goals and trains Glen towards identifying the interventions and

understanding the volatility of patient health and metabolism due to food, activity and medicines.

4. **Output data:** After Glen identifies interventions, it produces suggestions and reminders on the connected devices, ensuring the patient doesn't miss acting upon them. The output data are either shown in-app or as notifications on the lock screen based on the state of usage.

5. **Feedback loop:** Every time patient logs in food intake, activity done and medicine taken, Glen runs an analysis of how patient health vitals affect compared with previous data. By this, Glen identifies patterns and creates a digital profile of the patient.

5.2 User Journey

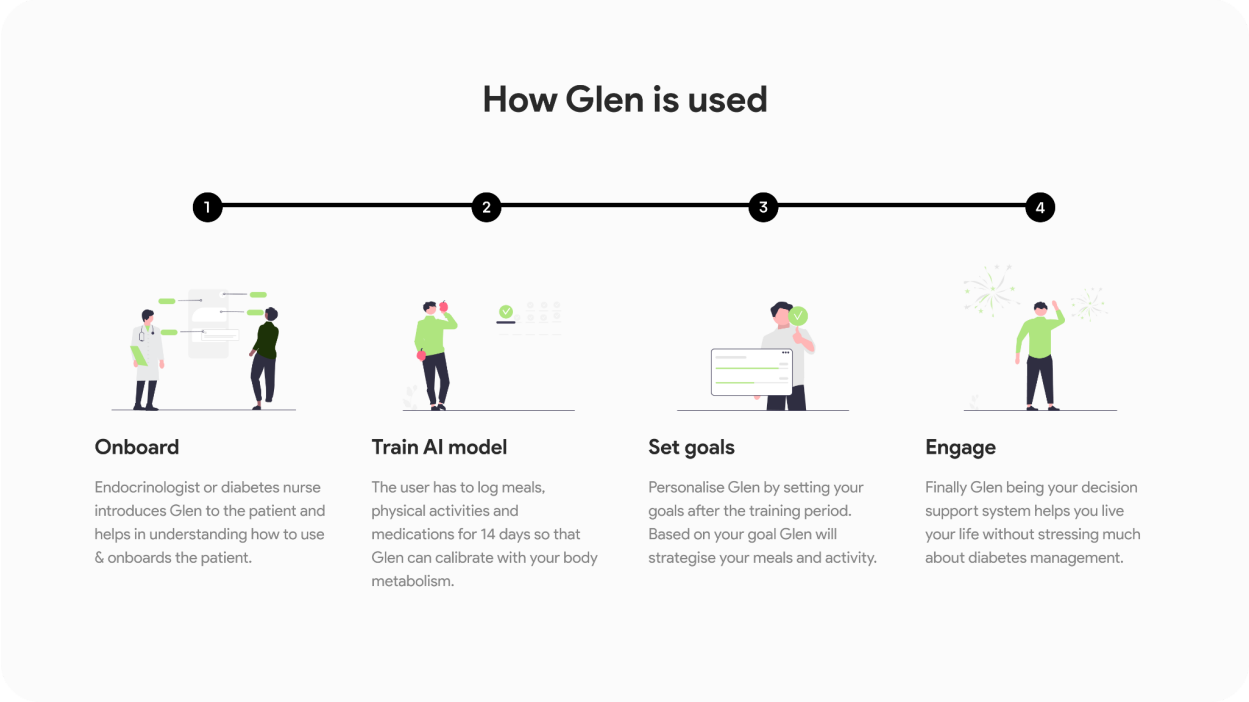

Figure 15. User journey overview made by the author

1. **Onboarding:** The endocrinologist or diabetes nurse introduces Glen to the patient and helps in understanding how to use & onboards the patient.

2. **Training AI:** The patient has to log meals, physical activities and medications for 14 days so that Glen can calibrate with the patient's body metabolism.

3. **Setting up:** Personalise Glen by setting the goals and food preferences after the training period. Glen will strategise your meals and activity based on your goals and preferences.

4. **Engage:** Finally, Glen being the patient's decision support system, help them live their life without stressing much about diabetes management.

5.3 Components of Concept

Onboarding to Glen

The patient gets introduced to Glen mostly in diabetes-related articles, workshops, training, social groups, or during a doctor or nurse consultation. At this point, it is very important to educate how to use the application and what the prerequisites are like having CGM, a fitness watch and a smartphone.

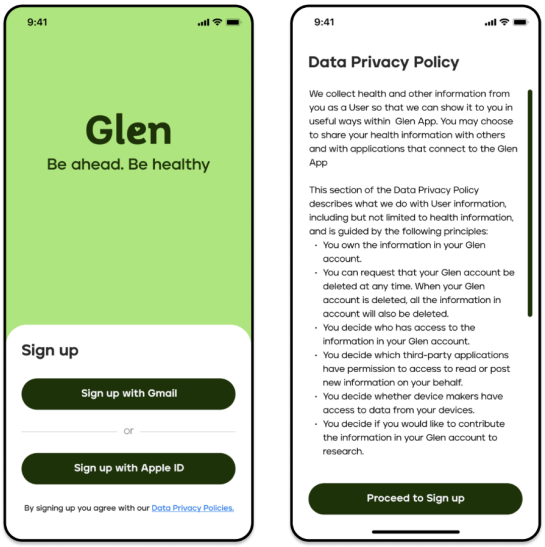

Figure 16. Screenshot of signing up with Glen, made by the author

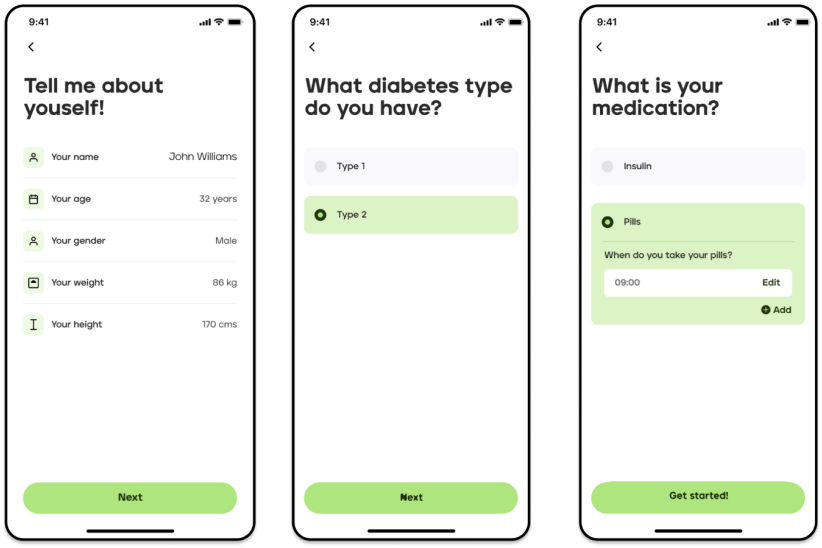

Figure 17. Screenshot of onboarding flow, made by the author

The onboarding flow on the application allows a new user to sign up with Glen. In the process of creating a new account, the user is asked for details which include personal, diabetes and medication. By signing up, the user holds the ownership of the data, and the privacy policy complies with GDPR guidelines and HIPPA.

Training AI

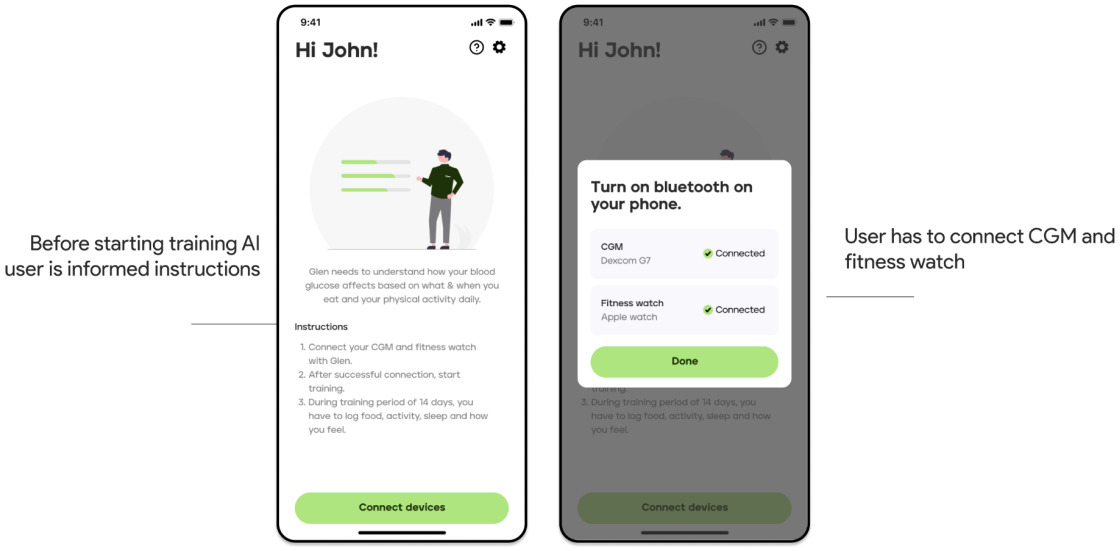

Figure 18. Screenshot of prior to starting training flow, made by the author

After onboarding is done, the user is taken to the home page. At this stage, the user can not do anything on the app except to start the training. Clear instructions would be given for how to train and what are user's responsibilities are to be fulfilled. The user has to connect CGM and any fitness/smart watch with Glen, then tap "Start Traning".

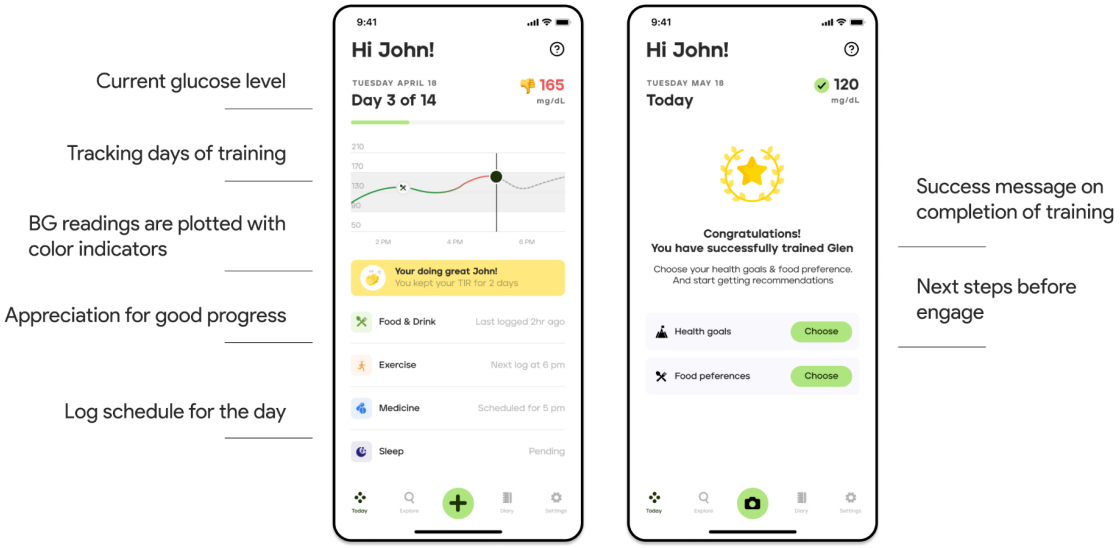

Figure 19. Screenshot of during and after training flow, made by the author

The training lasts for 14 days, and the user has to log food, activity, medicines and sleep whenever the event occurs. Other data like glucose levels and calories burned are automatically transmitted to the application from the connected peripherals.

The user would be shown the training progress on top of the home page. To maintain the quality of training, the user would be nudged to log in based on previously recorded log timings and also, the user is appreciated when he/she shows consistency in the training period.

Setting up

After the training period, now the final steps before Glen fully deployed are setting up goals and food preferences. Setting up goals can be done individually or with the help of a doctor/nurse. In this step, the user has to choose certain goals which are essential for their treatment plan. Glen has a few recommendations and other goals to choose from. For each

goal, specific parameters are measured. By following and acting upon the suggestions given, the user can achieve the chosen goals.

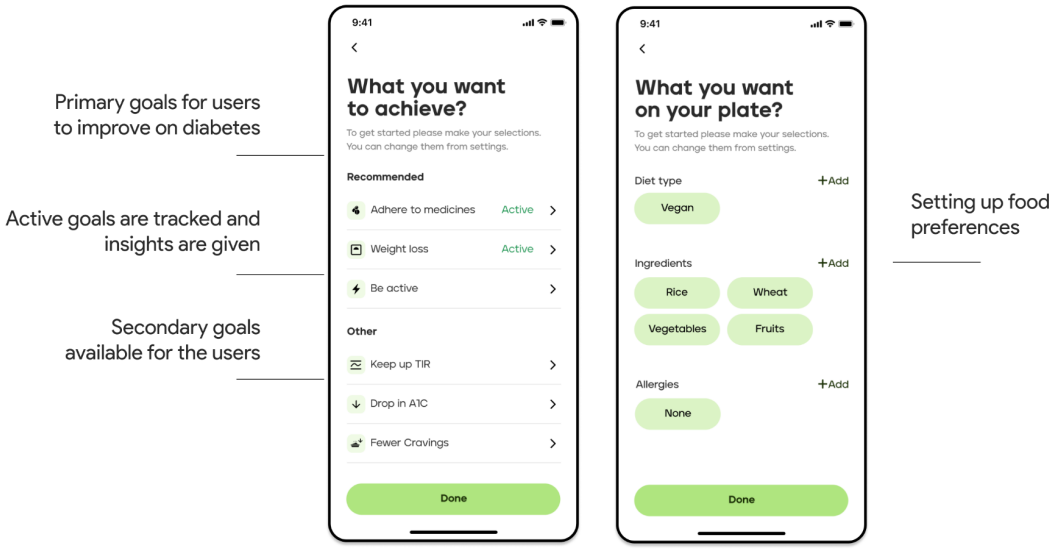

Figure 20. Screenshot of setting up goals and food preferences, made by the author

Finally, the user has to choose food preferences and details about any food allergies so that the meal recommendations are optimised to what the user would like to eat. The preferences are categorised in terms of the diet with and without meat, ingredients to be included and any allergies.

Engage

Meal suggestions

After choosing goals and food preferences; the application starts giving out recommendations using AI. The application knows the times when the user prefers to eat breakfast, lunch, dinner and snacks. Users check the best options and learn about their glycemic and micronutrition information. Then for the chosen meal, the user can see where he can buy it nearby, or if he/she wants to prepare it at home, then he/she can check out the recipe.

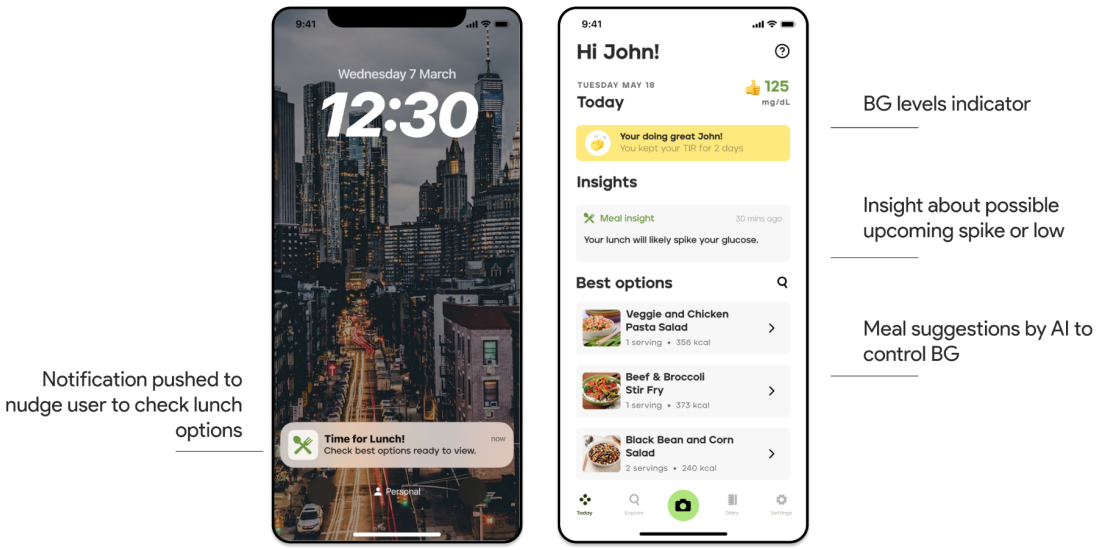

Figure 21. Screenshot of meal suggestions, made by the author

The app notifies the user in the below-explained scenarios:

a) Regular meal: The user is notified 30-60 mins in advance about the best options for him/her. The user can opt for one and make the decision either to cook, order or buy.
b) Quick bite: When it's not a regular meal timing but snack time, the user is notified 15-30 mins in advance about the best snack options to keep up the glucose levels.
c) Critical time: When the application forecasts an upcoming extreme drop in glucose, it notifies the user what to consume immediately.
d) Improvements: Based on past incidents, the application suggests users opt for and replace certain food in their meals.

Know your meals

The key feature of Glen is to recommend a meal or analyse food before the user consumes it and tell whether it is adequate for the user so that his/her glucose levels stay within range. In both the scenarios, the user can see whether the meal/snack is adequate to consume or not.

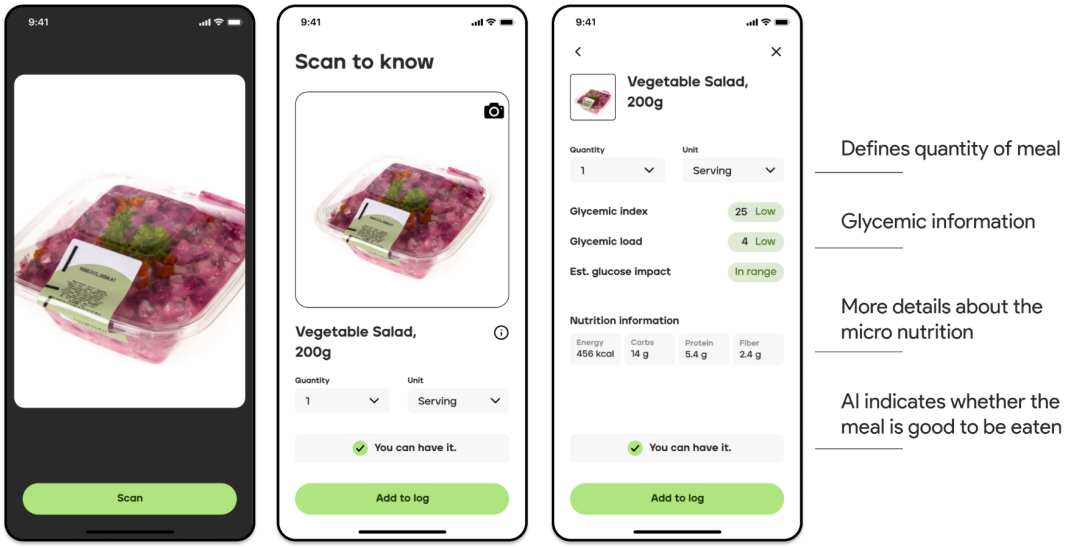

Figure 22. Screenshot of know your meal flow, made by the author

On the full information page, users can find more information about the meal/snack, like glycemic index, glycemic load, and estimated glucose impact upon consumption based on the serving. Along with this, users can also learn about the micro nutrition. This data is sourced from official food directories such as *diabetesfoodhub.org and FoodData Central.*

Activity suggestions

Figure 23. Screenshot of activity suggestions, made by the author

This feature is very goal specific as it quantises the physical activity needed for the user to achieve the goal. For example, if the user has chosen the goal to lose weight, then the physical activity recommendations are made in collaboration with food intake and glucose level measures. The users can customise their physical activities as per their lifestyles.

Set & track goals

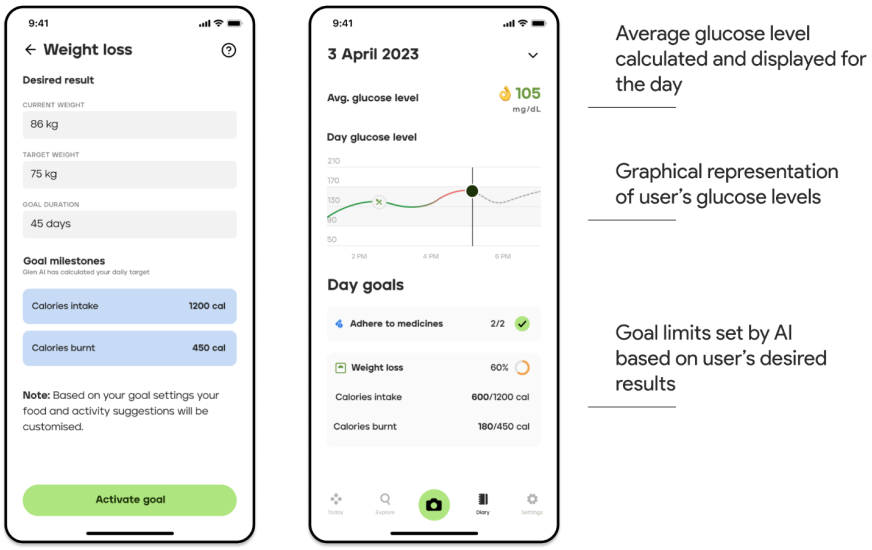

Figure 24. Screenshot of goal setting & progress tracking, made by the author

The goal setting process involves user defining their desired result based on which Glen sets the daily milestones to be achieved. Glen has a traditional dairy keeping feature with an emphasis on tracking goals to show the developments users do on their goals on a daily, weekly and monthly basis. This record makes the user motivated towards positive changes he/she undergoes. Glen's AI makes sure to emotionally uplift users to reach each goal milestone.

Reminders

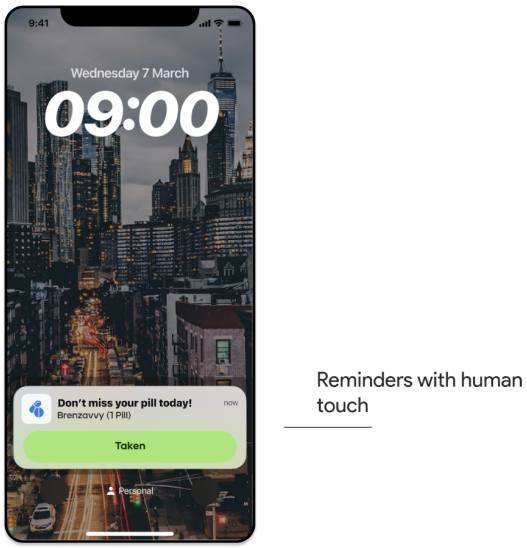

Figure 25. Screenshot of reminders, made by the author

Reminders are sent for medicines, missed/delayed meals, snacks and physical activity. Due to irregular lifestyles and distractions, the user might miss attention towards one-time notifications. And missing any of the daily essentials is not good for the user. Reminders ensure users don't miss their primary duties and help them perform well for their health goals.

Appreciations

Figure 26. Screenshot of appreciation in notifications, made by the author

Motivation is the most important aspect of the long journey with diabetes. The user must enjoy the ride of maintaining their health with some tangible performance indicators. To make the engagement playful, dosage of motivation is given through appreciation for small to big milestones completions by the user under their goals. The culture of appreciation is introduced to the user in the training period itself.

5.4 User Scenarios

Glen is designed to work in different scenarios for users with different lifestyles, below we can see how Glen is placed in possible user archetypes (built based on the interviews).

A

Emily, 32

Sarah has been type 2 diabetic since 2 years.

He is an IT professional and loves to socialise and eat out.

Goals

To improve her health habits.

To become active.

Emily leads a busy life and often gets caught up in her work, forgetting to take breaks and experiencing high levels of stress. Due to her hectic schedule, she frequently relies on ordering food to the office and struggles to plan her meals effectively. Additionally, on weekends, Emily enjoys socialising and going out to parties or restaurants with her friends. To improve her health habits, become more active, and manage her diabetes better, Emily starts using Glen.

On a typical workday, Emily wakes up early and starts her day with her CGM device already in place. She checks her glucose levels using the CGM app on her smartphone and gets ready for work. Realising she often forgets to take breaks and eats unhealthy meals during work, now Emily gets advance suggestions for food and physical activity in notifications.

The Glen app, taking into account Emily's glucose levels and her goal to improve her health habits, suggests reminders for taking short breaks during work. These breaks serve as an opportunity for her to stretch, relax, and have a healthy snack. The app recommends simple exercises, such as stretching or walking around the office, which can be done within a few minutes. It also provides suggestions for nutritious snacks that can be easily prepared or ordered from nearby healthier options.

Throughout the day, Emily follows the Glen app's reminders, taking short breaks to relax, stretch, and enjoy a healthy snack. The app's recommendations help her maintain stable glucose levels and combat stress, contributing to her overall well-being.

During lunchtime, Emily opens the Glen app to plan her meal. The app analyses her glucose levels, dietary preferences, and offers suggestions for healthier lunch options based on her location. It recommends nutrient-rich meals with a balanced combination of lean proteins, whole grains, and plenty of vegetables. Emily can conveniently order these options from nearby restaurants or plan to bring a homemade meal to work.

After work, Emily often engages in social activities with friends, which sometimes involve dining out at restaurants or attending parties. Before heading out, she checks her glucose levels forecast on Glen app for next coming hours. The app, taking into account her glucose levels and her desire to make healthier choices, suggests food options that align with her dietary needs and preferences.

When dining out, the app provides recommendations for selecting healthier dishes on the menu, such as grilled proteins, steamed vegetables, and whole grain options. It also suggests portion control strategies to help Emily make mindful choices. At parties, the app suggests opting for healthier appetizers or sharing indulgent dishes with friends to enjoy without overindulging.

Over time, Emily realises that she has become more mindful of her food choices, thanks to the guidance provided by the Glen app. She starts to incorporate healthier eating habits, both during her busy workdays and social outings, which positively impacts her overall health and diabetes management.

On weekends, Emily continues to use the Glen app and CGM device to monitor her glucose levels in real-time. The app suggests exercises and activities that align with her preferences and fitness level, helping her stay active. Whether it's going for a hike, attending a fitness class, or even engaging in simple home workouts, the app provides personalised recommendations to keep Emily motivated and physically active.

By using the Glen app and the CGM device together, Emily not only manages her diabetes more effectively but also becomes more conscious of her health

B

John, 46

John has been diagnosed with type 2 diabetes 3 years ago.

He is a cab driver and a family man.

Goals

To keep glucose levels in range.

To be energetic during work hours.

John started using a new AI-powered food and activity recommendation app called "Glen" to help him manage his diabetes effectively as told by his doctor.

One sunny morning, John wakes up feeling refreshed and ready to start his day. He checks his glucose levels on the phone, as he does every morning. The app syncs with his CGM and displays his current glucose level on the home screen.

John knows that maintaining stable glucose levels throughout the day is essential to his overall well-being and keeping his energy levels up for his long hours of driving. He checks the app to see personalised suggestions based on his real-time glucose reading.

The app analyses John's glucose level, takes into account his medical history, preferences, and dietary restrictions, and generates a list of suitable food options for him to choose from. It suggests a balanced breakfast that includes whole grains, lean protein, and healthy fats, which will help him start the day with sustained energy and avoid blood sugar spikes.

John finds the recommendation helpful and heads to his kitchen to prepare his breakfast. As he follows the recipe provided by the app, he notices that Glen provides nutritional information for each meal, including the carbohydrate, protein, and fat content. This information is crucial for him to make informed decisions about portion sizes and monitor his intake of macronutrients.

After enjoying his well-balanced breakfast, John proceeds to his cab and starts his work shift. The app continually adjust its recommendations based on his changing glucose levels, ensuring he receives accurate and up-to-date suggestions.

During his break, John takes a moment to check his glucose levels and opens the Glen app to see what the app suggests for his lunch. Based on his current glucose reading, the app recommends a healthy salad with a variety of fresh vegetables, grilled chicken, and a light vinaigrette dressing. John finds the suggestion appealing and decides to visit a nearby restaurant that offers a salad bar.

As the day goes on, John continues to follow the Glen app's recommendations for snacks and dinner. The app suggests a handful of nuts as a mid-afternoon snack to keep his energy levels stable and a dinner that includes a lean protein source, non-starchy vegetables, and a small portion of whole grains.

In the evening, after completing his shift, John sits down to review his glucose readings for the day on the Glen app. He notices that his glucose levels have remained within the target range, and he feels satisfied knowing that he made healthier food choices throughout the day. The app also provides a summary of his daily macronutrient intake and offers suggestions for improvement, such as reducing sodium or increasing fiber intake.

Feeling empowered and motivated by his successful day of managing his diabetes with the help of the Glen app, John heads to bed, knowing that he has taken a significant step towards maintaining a healthy lifestyle. He looks forward to using the app in the future and continuing to make positive changes to his diet to manage his diabetes effectively.

C

Sarah, 42

Sarah has been type 1 diabetic since 12 years.

She is a housewife and a mother of 2 children. She likes gardening and cooking.

Goals

To loose weight.

To live healthier life.

Sarah got to know about Glen through a Type 1 diabetes community admin. She want to use it for achieving two primary goals i.e. loosing weight and leading a healthier life as she seeing complications coming due to her weight and diabetes due to age.

Sarah wakes up and checks her glucose levels using her glucose meter, as she does every day. She takes her insulin and starts her day. She checks Glen for suggestions for breakfast she can prepare, the AI algorithm in Glen analyses her glucose level, insulin dosage, weight loss objectives, and dietary preferences to generate a list of suitable food options. The app asks her to log her weight weekly so that AI can analyse her progress.

The app suggests a nutritious and balanced breakfast for Sarah, comprising of high-fibre cereal, low-fat milk, and fresh fruits. It also recommends portion sizes and offers alternative options in case she prefers different ingredients. The app takes into account Sarah's personal goal of losing weight and ensures the recommended meals are within a calorie range that supports healthy weight loss. Sarah finds the app's recommendations helpful and heads to the kitchen to prepare her breakfast. She makes more portions of the same recipe for her children and husband.

During her mid-morning break after gardening work, Sarah checks her glucose levels using the CGM device and opens the Glen app to see the suggested snack options. The app recommends a combination of protein-rich foods, such as Greek yogurt and nuts, which will help her feel satiated and maintain stable glucose levels until lunchtime.

For lunch, based on her real-time glucose reading and weight loss goal, the app suggests a nutritious salad with lean protein, leafy greens, colorful vegetables, and a light dressing. Sarah appreciates the suggestion and prepares the salad at home.

Throughout the day, Sarah diligently follows the Glen app's recommendations for snacks and dinner, making choices that align with her weight loss and diabetes management goals. The app suggests healthy and filling options, such as roasted chickpeas or a vegetable stir-fry with lean protein, ensuring Sarah stays satisfied while keeping her glucose levels stable.

After using for 8 weeks, Sarah has seen significant changes with minimal effort as Glen has been adaptive to her lifestyle and behaved as a friend. It encourages her with measurable actions and progress. She knows that by continuing to make healthy food choices and following the app's recommendations, she is taking significant steps towards living a healthier and more fulfilling life. Sarah heads to bed with a sense of accomplishment.

D

Alex, 24

Sarah has been type 1 diabetic since 10 years.

He is an IT professional and started doing heavy weight lifting since 1 year.

Goals

To make diet balanced for workout and diabetes.

To prevent hypoglycemia.

On weekdays, Alex's daytime is spent at office and in the evening he goes for heavy weight lifting.

One evening, after a long day at work, Alex prepares to hit the gym for his heavy lifting workout. Before leaving his office, he checks his glucose levels using his glucose meter and logs the reading into the Glen app on his smartphone. Aware of the importance of maintaining stable glucose levels during his workout and avoiding hypoglycemia, Alex opens Glen app. The app's AI algorithm analyses his glucose level, workout routine, and dietary preferences to generate suitable food options tailored to his needs.

Based on his current glucose reading and the heavy lifting workout planned for the evening, the app recommends a pre-workout snack rich in complex carbohydrates and a moderate amount of protein. The suggested options include a banana with almond butter or whole grain toast with cottage cheese. These choices will provide him with sustained energy and help stabilise his glucose levels during the workout.

Alex finds the recommendation helpful and prepares the suggested snack before heading to the gym. As he consumes the snack, he notices that the Glen app provides information about the macronutrient composition, including the carbohydrate, protein, and fat content of the suggested foods. This feature allows him to track his intake and ensure he maintains a balanced diet throughout the day.

After an intense workout, Alex returns home and checks his glucose levels again using his meter. The app adjust its recommendations based on his post-workout glucose level. The app suggests a recovery meal that includes a lean protein source, such as grilled chicken or fish, accompanied by whole grains and a generous serving of non-starchy vegetables.

This meal will aid in muscle recovery and replenish his energy stores while keeping his glucose levels stable.

As bedtime approaches, Alex remembers his past experiences with low glucose levels during sleep. He knows that a carefully chosen bedtime snack can help prevent overnight hypoglycemias.

Based on past behaviour app forecasts glucose drops and the need to maintain stable levels throughout the night, the app recommends a bedtime snack that combines complex carbohydrates and a source of protein, such as a small apple with a string cheese or a handful of almonds.

Grateful for the Glen app's personalised recommendations, Alex prepares the suggested bedtime snack and consumes it before going to sleep. He feels confident that he has taken the necessary steps to avoid low glucose levels during the night.

Throughout the day and before sleep, the Glen app continues to monitor Alex's glucose levels in real-time, adjusting its recommendations accordingly. This feature ensures that the app provides accurate and up-to-date suggestions, considering any fluctuations in his glucose levels.

Alex appreciates the support provided by the Glen app, which allows him to maintain optimal glucose levels for his workouts and manage his diabetes effectively. By making informed food choices with the help of the app, he can pursue his fitness goals while prioritising his health and overall well-being.

Figure 27. A, B, C & D are user scenarios, made by the author

5.5 Value Proposition

Glen becomes a holistic application on a diabetic person's smartphone which acts as a smart companion, not just a digitised version of diary keeping but brings value from a preventive and personalised care perspective.

- Glen helps diabetics to maintain glucose levels within range
- Glen adapts and manages the diabetic adjusted lifestyles without hassle
- Glen avoids post-action consequences instead takes preventive action for good results
- Glen enables personalisation by providing a goal-driven approach in the treatment plan
- Glen places the patient in the centre of the care and helps manage diabetics physically and mentally.

5.7 Feedback & Further Development

When the design proposal was presented to the two of the individuals who participated in the initial research interviews, in the first place, they appreciated the idea of preventive care. They were shown a quick demo of the mobile application and explained how it works. They presented their desire to have something like Glen immediately, if available. They felt easy to use in terms of navigating through the application and understanding the application. Also, they asked whether the application helps in planning food when travelling to a new place which was taken as input for further development of the concept.

Further development includes more user feedback sessions and creating a complete solution from the design concept. Creating an MVP with an AI model coded to be trained and tested with potential users under considerations of healthcare regulations.

5.8 Conclusion

The thesis concludes with the development of the design concept, which is a smartphone application. The user journey of the application is designed diligently for diabetic users in order to cater for their unmet needs, which they want the application to fulfil. The most unmet needs are personalisation, value-driven and less effort.

Since the solution concept uses AI, the more user is engaged with the application, the more value can be created as AI will improve its data model about the user’s metabolism and blood sugar behaviour more accurately. The user-centric design of the application provides flexibility to the user on how he/she wants the application to be personalised as per their lifestyles.

The design concept is user-friendly and ensures accessibility to the user from different walks of life, except for users below 18 years, as they need the supervision of their parents in their diabetes treatment. This thesis's scope is limited to the concept's design stage, where the visual designs demonstrate the application's working principle and user experience.

6. Summary

The healthcare ecosystem has been evolving to provide the best point of care to the diabetic patients in terms of diagnosis, training, medication, insurance and support. According to the American Diabetic Federation, the healthcare system is experiencing a burden due to the growing number of diabetic patients. Experts believe that patients if they manage diabetes on their own with the guidance of a healthcare professional, can avoid many serious health complications related to diabetes.

In this thesis, the researcher presents a study focusing on self-care management by diabetic patients in their daily lifestyles. The research is conducted using mixed methods with the objective of understanding patients' experiences, how self-care has been changed with the use of technology, what are the needs unmet by the digital tools available to them and designing solutions to improve the quality of self-care.

Feedback from patients, doctors and nurses is synthesized to identify the interventions for pain points and opportunities. From patients' journeys, the researcher has identified some currently unmet factors which make self-care fail. Mostly the interviewees expressed difficulties in effectively planning diet and physical activities and getting overwhelmed by the tiring process of managing diabetes for years. Based on the findings, a design brief is defined, and further concept is developed.

The concept "Glen" is designed with the aim to simplify the way patients manage their health daily. Till now, they have been given curative care, but Glen introduces preventive care, which gives a new method of how self-care can be done with less effort and more efficiency. The concept is a mobile application which uses Artificial Intelligence to analyze users' body metabolism and blood glucose fluctuations to generate food and physical activity recommendations. These recommendations are tailored to the health goals chosen by the users which makes it easy and motivates the user to manage their health playfully. With Glen, the major burden of planning ahead for their food and physical activities is taken care of, giving them more space to concentrate on other professional or personal work.

Kokkuvõte

Diabeetikutele parima ravi pakkumiseks keskendub tervishoiusüsteem eelkõige diagnoosimisele, koolitusele, ravimitele, kindlustusele ja toe pakkumisele. Kuid vastavalt Ameerika Diabeediföderatsiooni andmetele on tervishoiusüsteem kasvanud diabeetikute arvu suurenemise tõttu koormatud. Ekspertide arvates suudavad patsiendid, kui nad juhendaja abil iseseisvalt oma diabeeti haldavad, vältida paljusid tõsiseid terviseprobleeme, mis on seotud diabeediga.

Käesolevas magistritöös esitleb uurija uuringut, mis keskendub diabeetikute igapäevaelus enesehooldusele. Uurimus on läbi viidud kasutades kombineeritud uurimismeetodeid. Uuringu eesmärgiks oli mõista patsientide kogemusi, kuidas enesehooldus on muutunud tehnoloogia kasutamisega, millised on nende hetkel kättesaadavate digitaalsete tööriistade abil saadud rahuldamata vajadused ning kujundada uusi lahendusi enesehoolduse kvaliteedi parandamiseks.

Uuringu käigus saadud patsientide, arstide ja õdede arvamused on sünteesitud, et tuvastada probleemsete kohtade ja võimaluste kokkupuutepunktid. Patsientide teekondade põhjal tuvastati seni varjatud tegureid, mis ei ole võimaldanud efektiivset enesehooldust. Enamik küsitletuid väljendasid raskusi toitumise ja füüsiliste tegevuste tõhusas planeerimises ning kurnavat diabeedi haldamise protsessi. Uurimistulemuste põhjal on koostatud disainilahendus ja edasiarendatud kontseptsioon.

Kontseptsioon "Glen" on loodud eesmärgiga lihtsustada patsientide igapäevast tervisehaldust. Seni on neile pakutud kuratiivset ravi, kuid "Glen" tutvustab ennetavat ravi, mis pakub uut viisi enesehooldust vähese vaevaga ja suurema efektiivsusega. Kontseptsiooniks on mobiilirakendus, mis kasutab tehisintellekti kasutajate ainevahetuse ja veresuhkru kõikumiste analüüsimiseks ning genereerib toitumis- ja füüsilise aktiivsuse soovitusi. Need soovitused on kohandatud kasutajate poolt valitud tervise eesmärkidele, mis muudab selle lihtsaks ja innustab kasutajat oma tervist mänguliselt haldama. "Glen" võtab enda kanda suurema osa toidu ja füüsiliste tegevuste planeerimisest, andes neile rohkem aega keskenduda teistele tööalastele või isiklikele tegevustele.

7. Acknowledgement

First and foremost, I am profoundly thankful to my supervisor, Martin Pärn, for his guidance, expertise, and unwavering support throughout the entire research process. His insightful feedback, constructive criticism, and valuable suggestions have been instrumental in shaping the direction and quality of this thesis.

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My heartfelt thanks go to the participants of this study, especially the diabetic patients who generously shared their experiences, insights, and time for interviews and feedback. Without their willingness to participate and provide valuable input, this research would not have been possible. Their contributions have shed light on the challenges faced by diabetic individuals and have guided the development of the design concept.

I would also like to express my gratitude to my colleagues and friends who have provided support, encouragement, and valuable discussions throughout this journey. Their enthusiasm and camaraderie have made the research process enjoyable and have inspired new ideas and perspectives.

To everyone who has contributed in one way or another, I am truly grateful for your support and encouragement. This thesis would not have been possible without your invaluable contributions.

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10. Appendices

Appendix 1: Survey results

Below is the link to the full survey results:

https://docs.google.com/spreadsheets/d/1BfYo44ggStDyDqzvz1bpgwvR-8YBIHLpGnv07G24llw/edit?usp=sharing

Appendix 2: Journey Map

Situation	Current Reality	Clarity	Coping	Caring	Life 2.0
	Lite irregular to no exercise & occasionally healthy nutrition	Tests concludes diabetes & learns about the condition	Diabetes care & management is dependent on individual goals & values	Physical & online support, tools and programs	Balance between life & diabetes goals & needs
Motive	Become aware	Recover health to formal energy level		Improve & sustain health levels	Maintain & progress

Normal Self

Most people don't have diabetes symptoms:

- excessive thirst
- Unexplained weight loss
- Loss of sleep
- Irritability

Challenges

- Struggles to get better
- Struggles to identify condition

Evaluation

Patient visits their health care professional

Diagnosis

Tests

After testing, patient is diagnosed with T1/T2.

Challenges

- Accepting diabetes
- Changing behaviour
- Additional medical expenses (Mostly for T2)

Treatment

Patient is given

- Diet adjustments
- Physical activity advises
- Insuline dosage for T1
- Tablets for T2

Involvement

Patients are usually not alone in their diabetes journey. Family members help patients in organising their priorities and manage their condition

Follow up

Patient denies or accepts condition, level of acceptance determines self-management efficiency

Challenges

- Accepting diabetes
- Changing behaviour
- Finding support & help
- Adapting to changes in life

Prioritization

Patient prioritizes diabetes management dependent on individual values, family support, health goals & finances

Acceptance

Patient commits to managing their diabetes

POOR ADHERENCE

Each person prioritises diabetes differently. Some deny the condition resisting medication, others accept it but don't adhere to proper medication and some keep to previous lifestyle.

Primary needs

- Blood glucose tracking
- Medication and insulin tracking:
- Food and nutrition tracking
- Physical activity tracking

Secondary needs

- Personalized recommendations
- Ease of use
- Connectivity alerts
- Micro interations

Engage

Self-management through mobile app

Diabetes care is a family commitment that broadens the value

Personalised

User customises his/her diabetes action plan matching to their needs and goals

Monitor

Connected devices & sensors help in analysis body vitals

Support

User have option to connect to health coaches/peers

Results

App shows tracking results & progress

Challenges

- Changing wellness & nutrition behaviours
- Staying on track
- Maintaining a positive outlook
- Fear of failure

New Self

Users are healthier now with diabetes compared to their normal self

Advocate

The role of passionate users transition from user to advocate

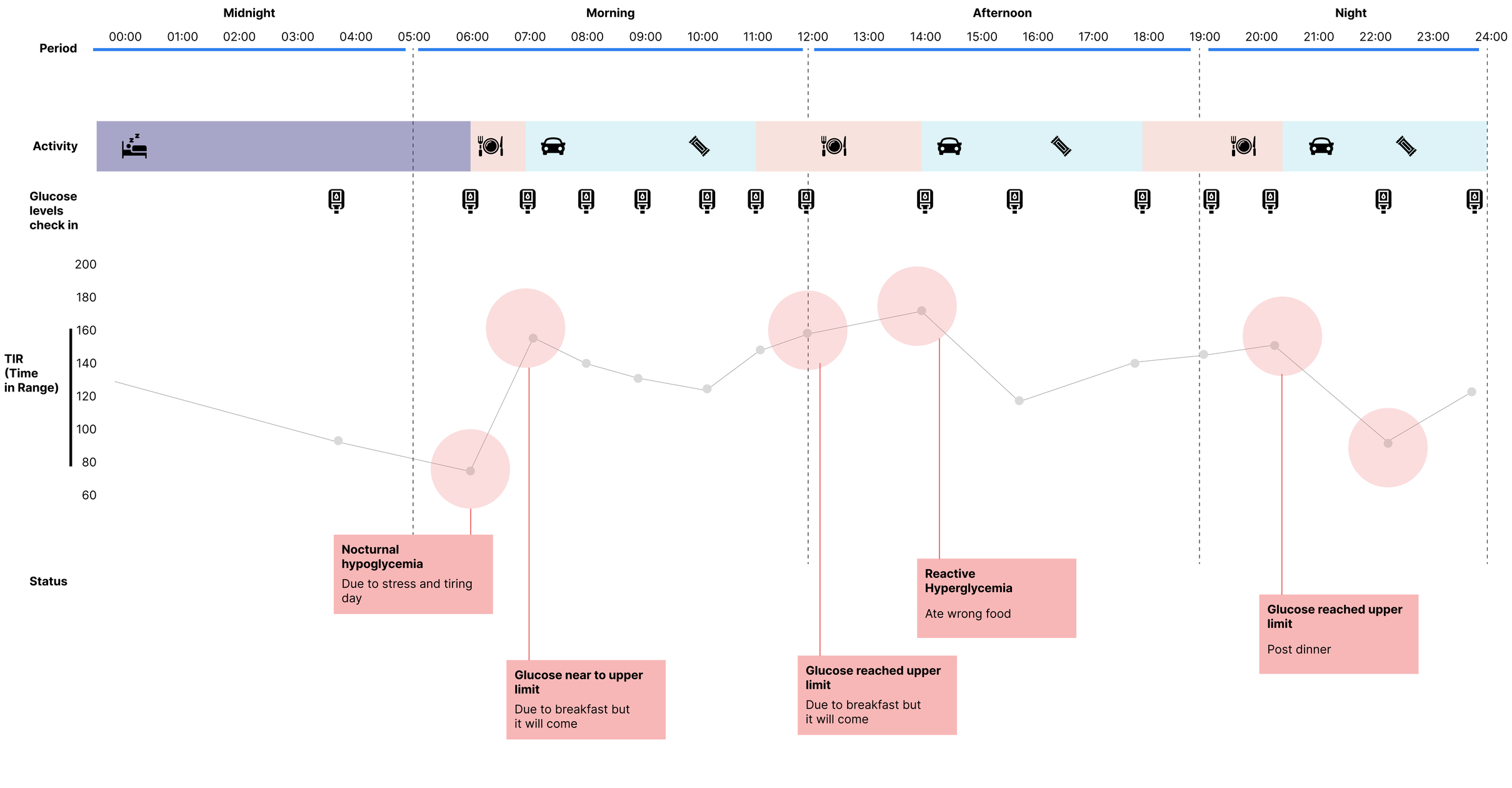
Interventions

Concepts

Appendix 5: Patient Journey

Meal Driving Snacks Sleep Glucose level check

Cab driver



Appendix 4: User flow

Onboarding

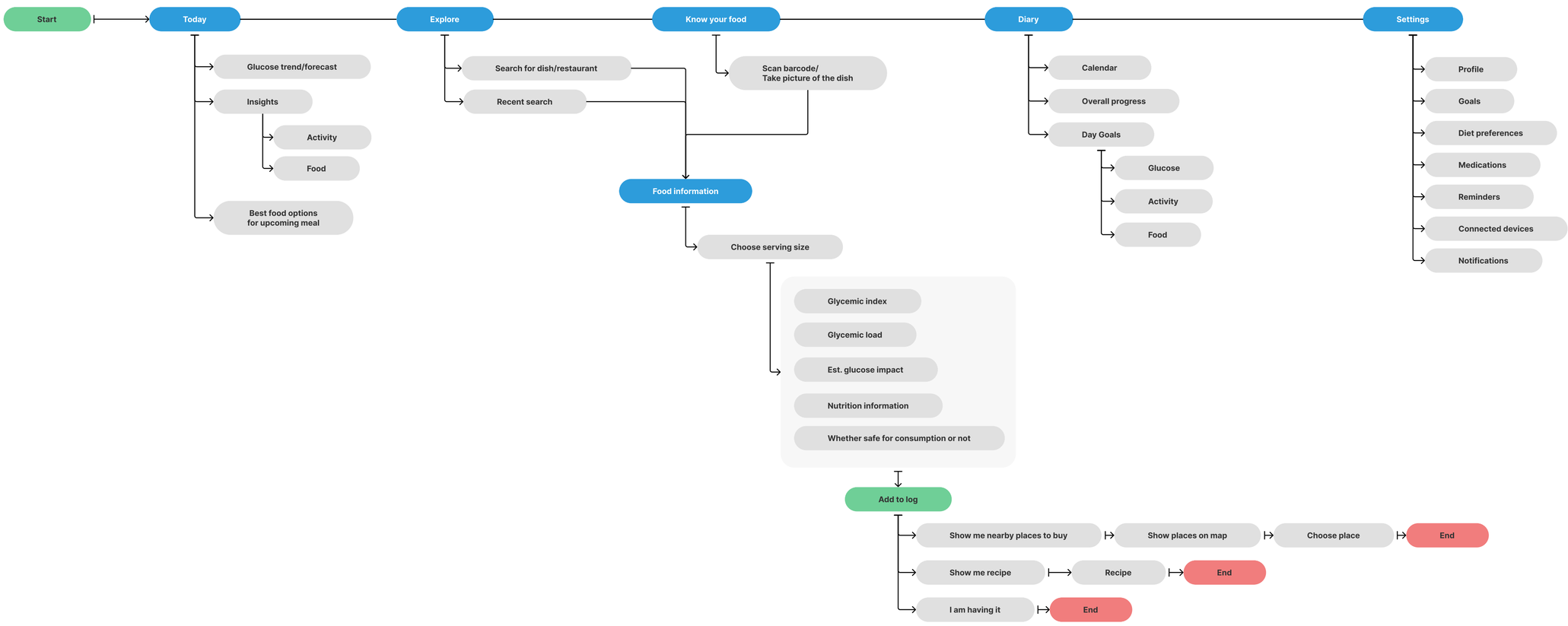
New user

Training
14 days

Setting up
Post training

Engage

Active user



Notifications

Recommendations

- Food recommendations
- Physical activity recommendations

Normal nudges

- Glucose forecast upper limit
- Glucose forecast lower limit
- Activity required
- Meal time

Critical nudges

- Glucose crossed upper limit
- Glucose crossed lower limit
- CGM connection lost

Goals

- Steps to achieve goal
- Achievements

Reminders

- Goal specific log required
- Glucose log (if manual)

Logging

Daily

- Activity log — Manual
- Glucose log — Automatic
- Food log — Manual
- Heartbeat log — Automatic

Upon triggers

- Sleep log — Manual
- Emotion log — Manual

Goal based

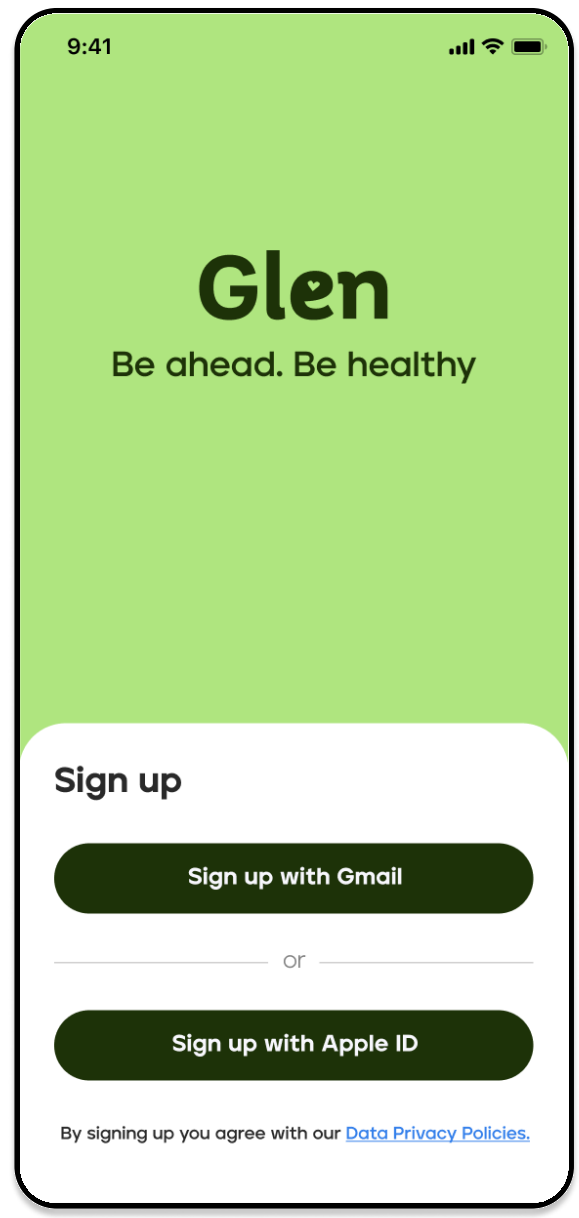
- Weight log — Manual
- Medication log — Manual
- HbA1c log — Manual

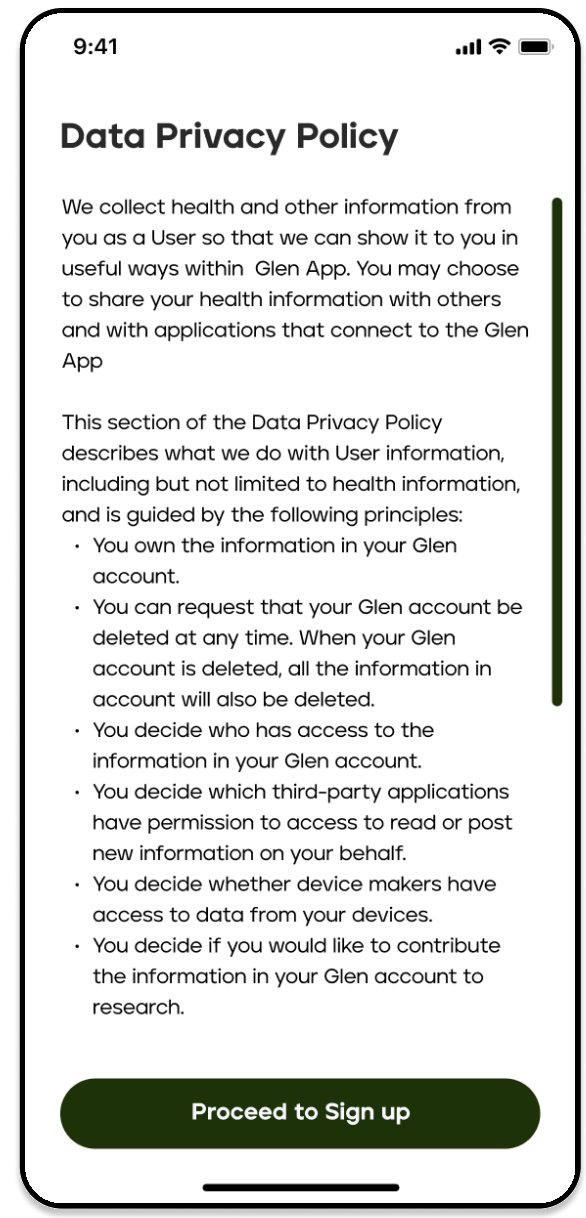
Appendix 5: Service Blueprint

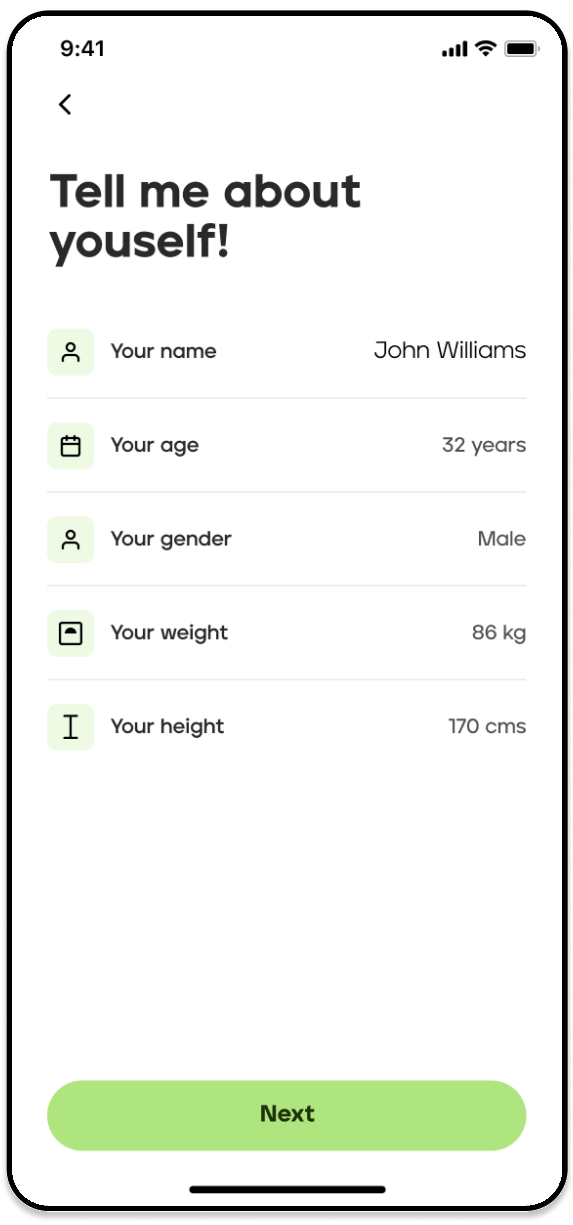
Physical evidence	**Awareness**	**Sign Up**	**Onbaording**	**Training**		**Setting Up**		**Engage**		
Goals	To introduce users to the application and educate how to use it.	To initiate new user account creation with legit user information.	To collect required data about the user which would be used by AI to understand the user.	To make AI model efficient enough to calibrate itself as per user's metabolic behaviours.		To personalise application as per user's needs and aspirations.		To help user with recommendations to ease their decision making.		
User actions	Introduced to Glen by doctor, nurse, family, friend or support groups. Also user can discover Glen through blogs, YouTube videos or advertisements	Downloads Glen on his/her smartphone and signs up with Gmail or Apple ID	Enters details fields under personal information and medications	User initiates training process by connecting the CGM and fitness watch after understanding the instructions properly	During training period of 14 days, user logs food, physical activity, medication, glucose levels, heartbeat, sleep and emotions	User chooses goal(s) which their doctor has prescribed or personally decided	User adds his/her food preferences by choosing diet type, ingredients and allergies	User sees insights and recommendations about food and physical activity based on goals on "today" page or through notification	User searches or scans the food/ barcode to know whether it is fir for consumption or not to make a choice.	User tracks his/her progress on chosen goals on "diary" page.
Frontstage actions	Website explaining features, benefits and compliances. Advertisements and promotional campaigns on social media, blogs and public showcases	New account is created in cloud server through secure sign-up process By signing up user accepts Glen's data privacy policies	Data is collected and stored in secure data servers for which only user has the access	App shows instructions and asks user to connect CGM and fitness watch before initiating training process	App pushes notifications to log food, physical activity, medication, sleep and emotions. App automatically fetched glucose levels and heartbeat data	Goals are presented as recommended and optional. Each goal has instructions and requires goal specific data to initiate the goal	Food preferences are collected and sent to AI model	AI generated insights & recommendations based on trained data sets, chosen goals and current glucose levels data.	Upon search results are shown or upon scanning, food is detected by AI and shows glycemic information, micro nutrition and tells whether it is for consumption.	Progress is logged for each day and displayed as cumulative report by day, week and month.
Backstage actions	Go to market strategies, website development and maintenance, digital marketing	user account management, data management and legal compliance	user account management, data management and cyber security	Bluetooth connection with CGM and fitness watch, AI algorithm, machine learning, data security	Data integration, data modelling, AI algorithm, machine learning, data security	User data management, AI algorithm, machine learning, data security	User data management, AI algorithm, machine learning, data security	AI algorithm, machine learning, data sets, data security	Image recognition API, data management, Food directory, AI algorithm, machine learning, data sets, data security	data management, AI algorithm, machine learning, data sets, data security
Support system	Marketers, diabetes advocates and experts, digital platforms	Sign up CTAs, data privacy policy page, SSO integration	Personal information page, medications information page	Training page with instructions and call to actions	Training page, log pages, notifications	Goals list page, goal information page with call to action	Food preference page	Today page, notifications	Scan food page, food information page	Diary page

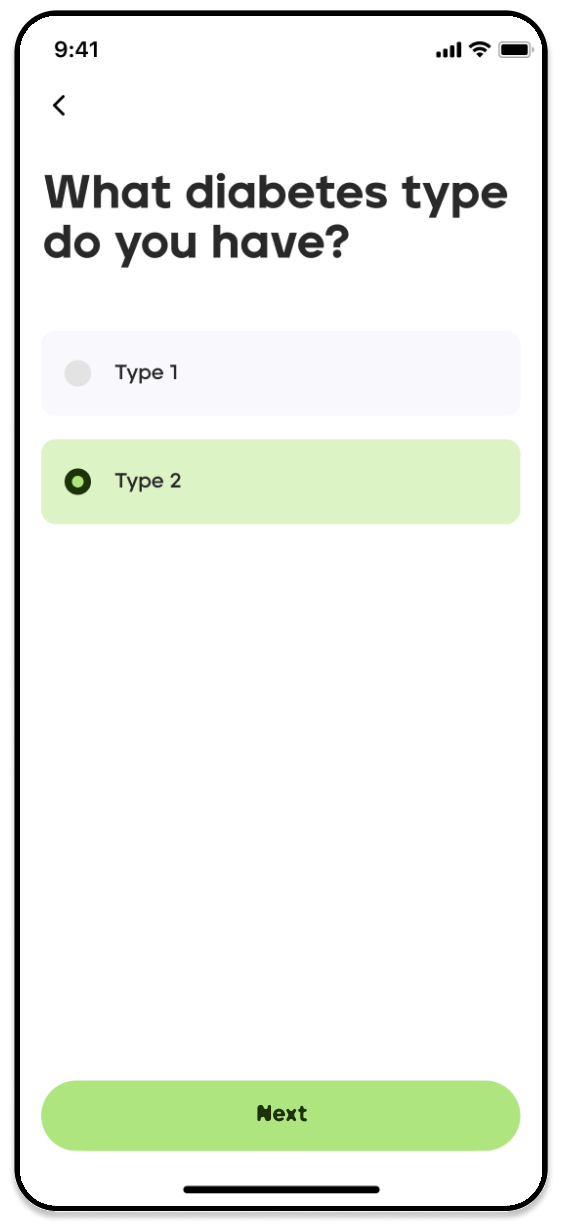
Appendix 6: App design

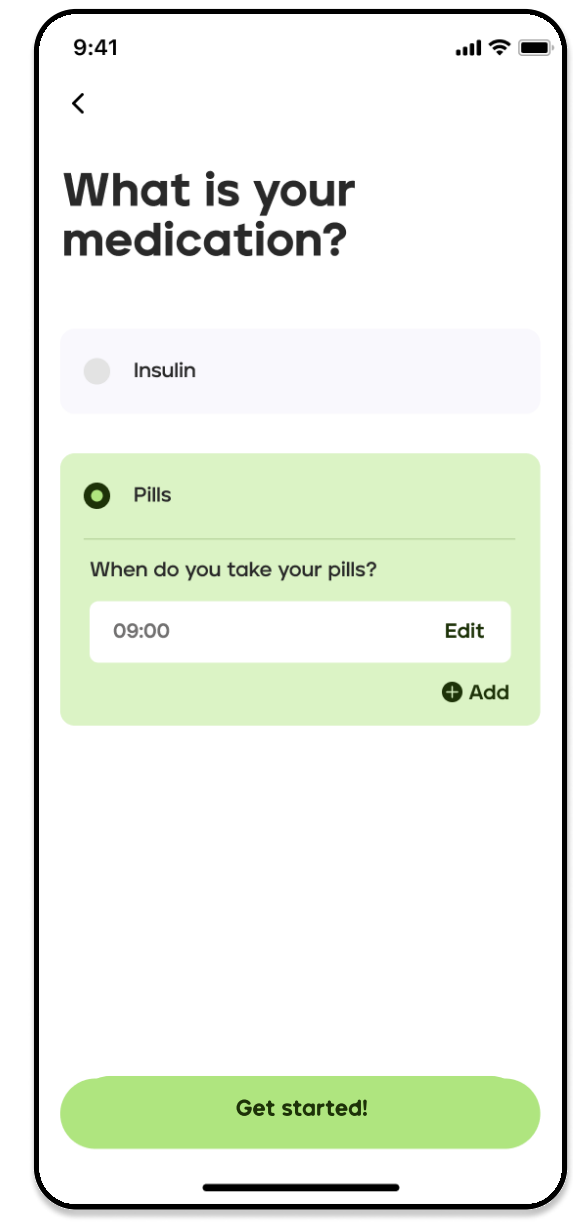
Onboarding



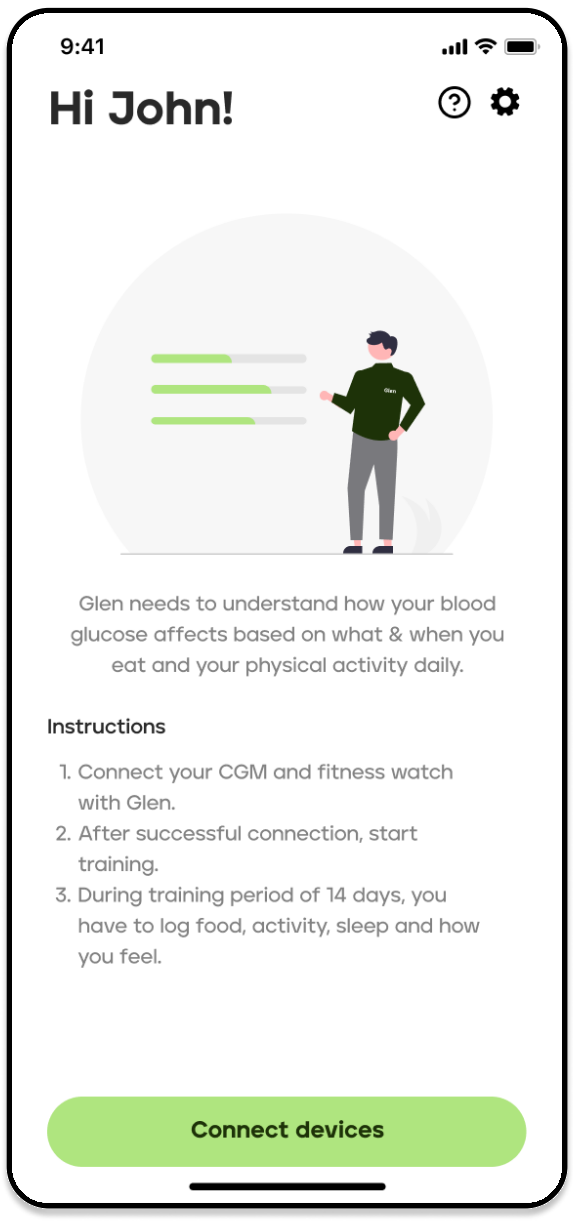


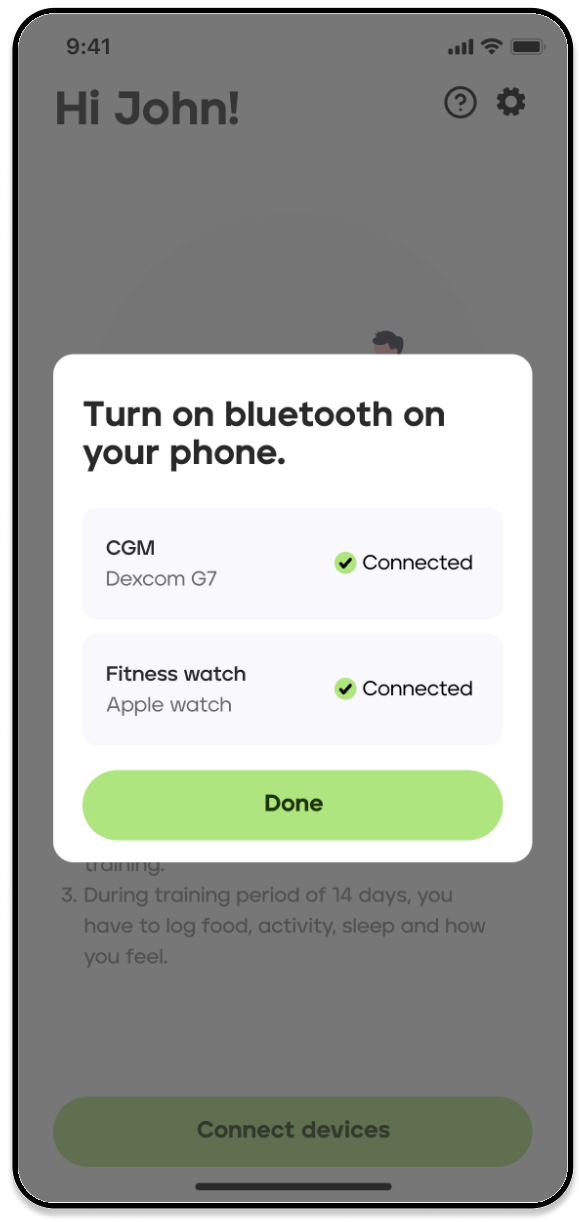


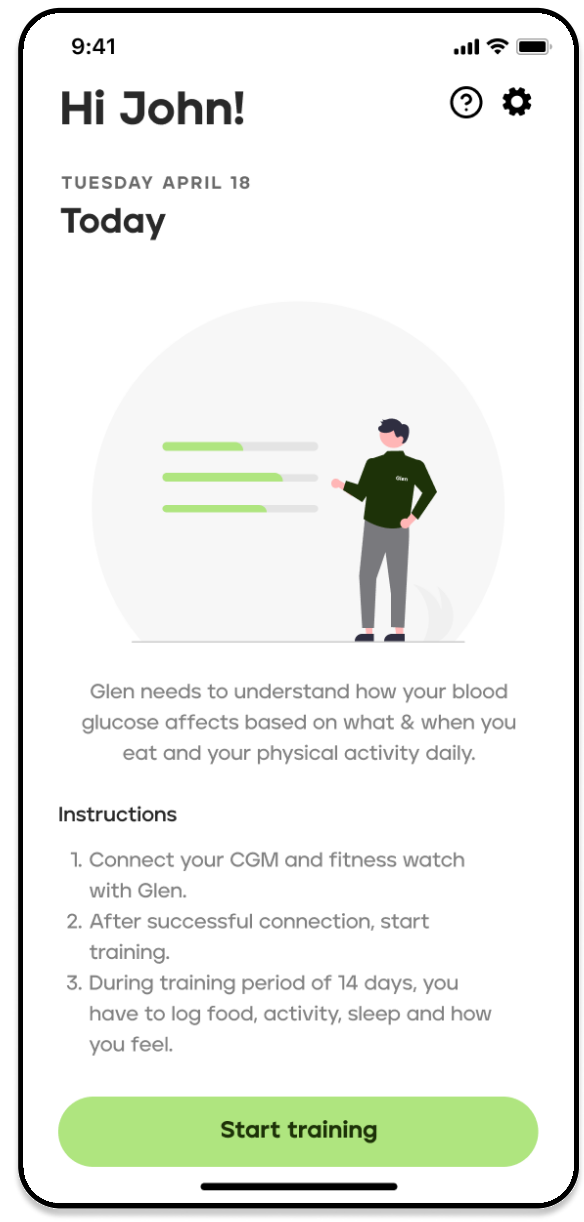


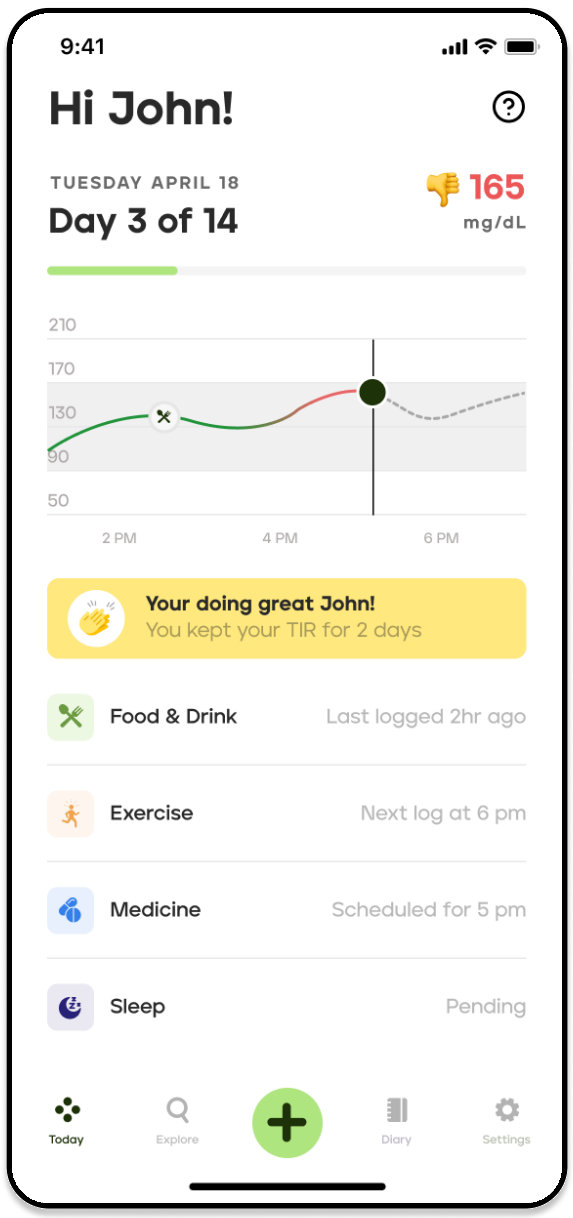


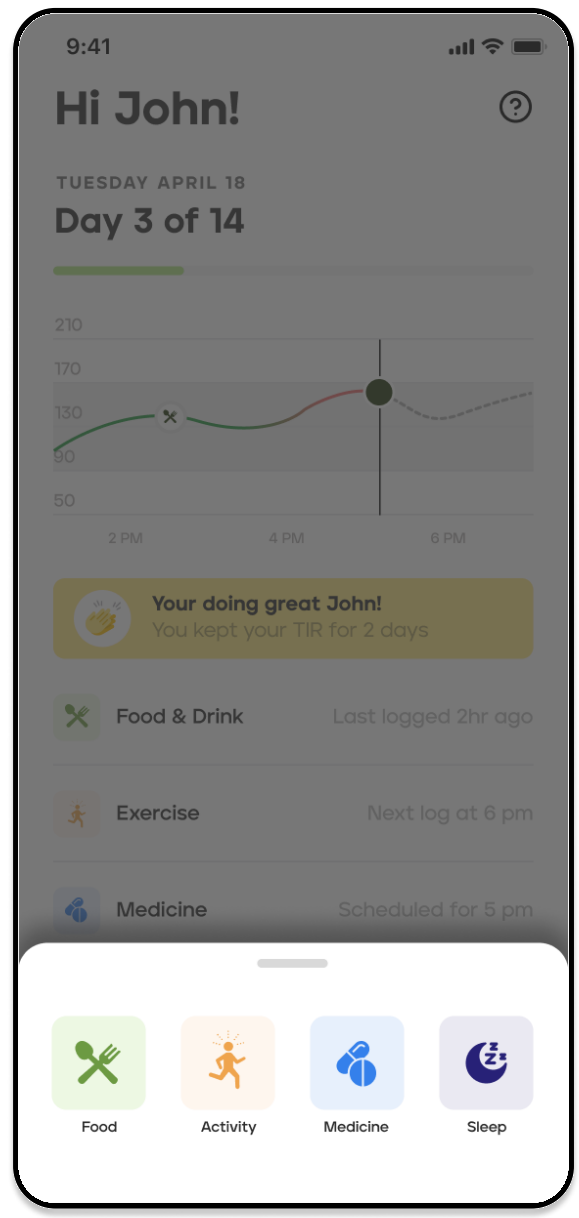
Training AI

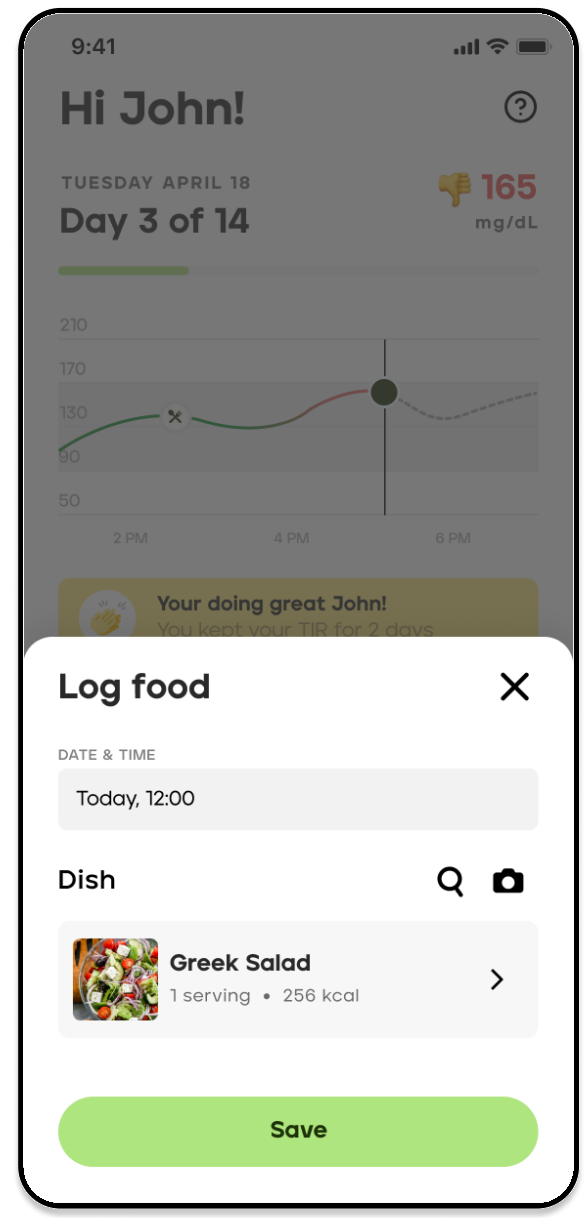

9:41
Hi John!
Glen needs to understand how your blood glucose affects based on what & when you eat and your physical activity daily.
Instructions
1. Connect your CGM and fitness watch with Glen.
2. After successful connection, start training.
3. During training period of 14 days, you have to log food, activity, sleep and how you feel.
Connect devices


9:41
Hi John!
Turn on bluetooth on your phone.
CGM
Dexcom G7
Connected
Fitness watch
Apple watch
Connected
Done
3. During training period of 14 days, you have to log food, activity, sleep and how you feel.
Connect devices

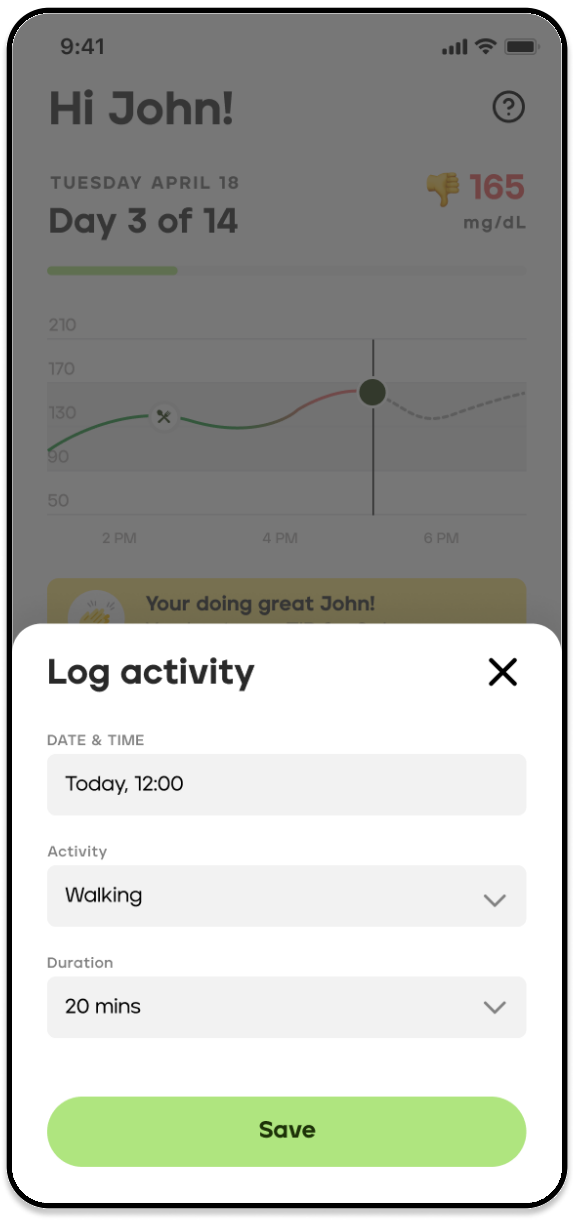

9:41
Hi John!
TUESDAY APRIL 18
Today
Glen needs to understand how your blood glucose affects based on what & when you eat and your physical activity daily.
Instructions
1. Connect your CGM and fitness watch with Glen.
2. After successful connection, start training.
3. During training period of 14 days, you have to log food, activity, sleep and how you feel.
Start training

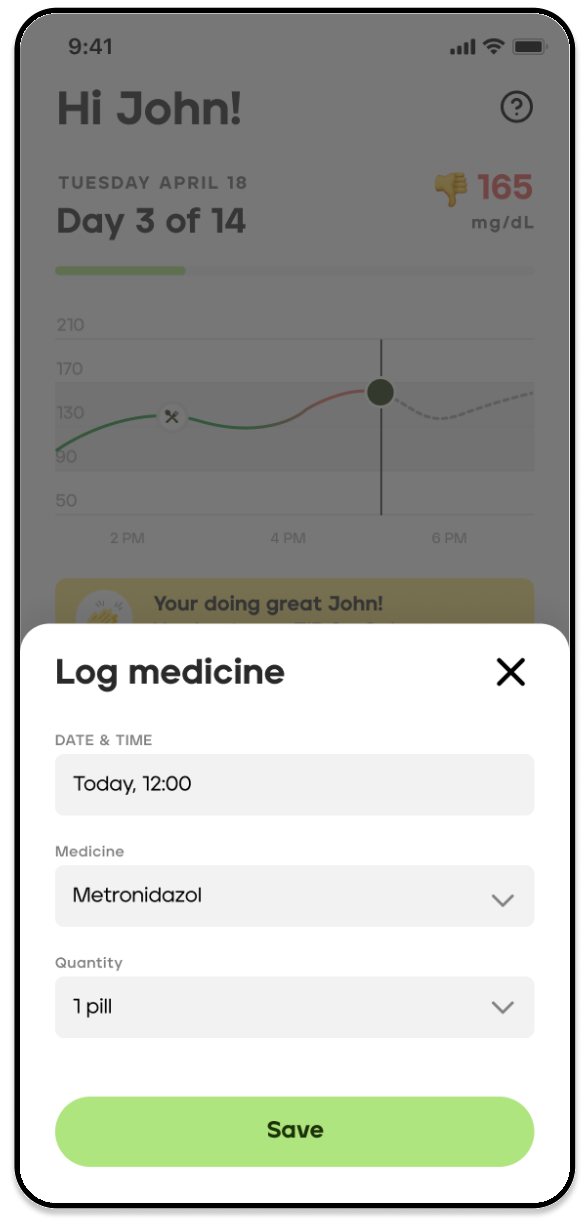

9:41
Hi John!
TUESDAY APRIL 18
Day 3 of 14
165
mg/dL
210
170
130
90
50
2 PM
4 PM
6 PM
Your doing great John!
You kept your TIR for 2 days
Food & Drink
Last logged 2hr ago
Exercise
Next log at 6 pm
Medicine
Scheduled for 5 pm
Sleep
Pending
Today
Explore
Diary
Settings

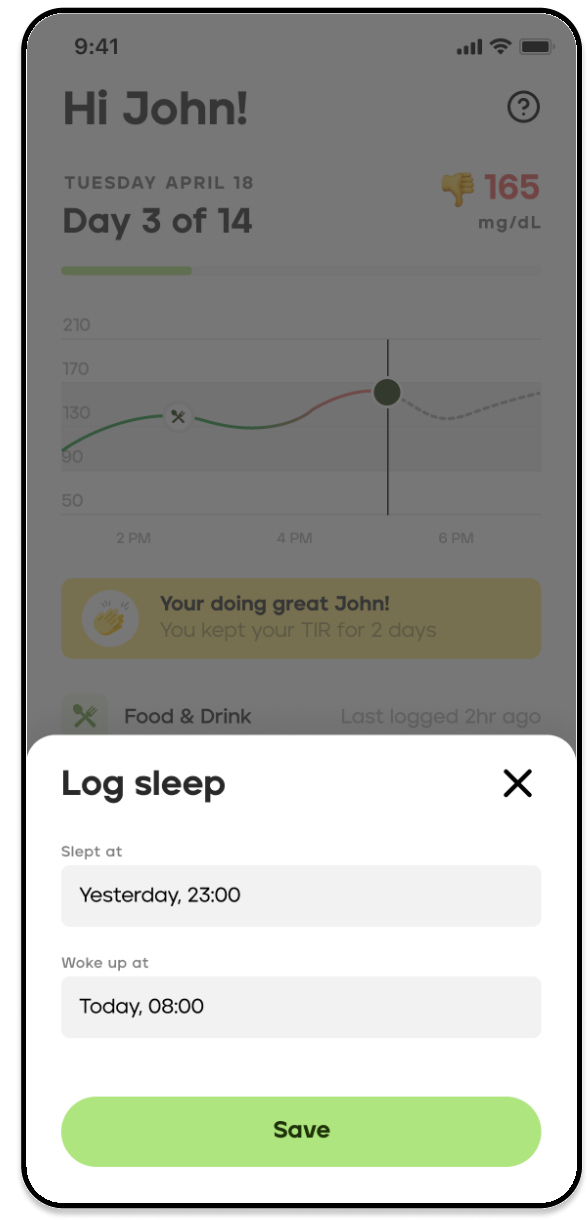

9:41
Hi John!
TUESDAY APRIL 18
Day 3 of 14
165
mg/dL
Your doing great John!
You kept your TIR for 2 days
Food & Drink
Last logged 2hr ago
Exercise
Next log at 6 pm
Medicine
Scheduled for 5 pm
Food
Activity
Medicine
Sleep


9:41
Hi John!
TUESDAY APRIL 18
Day 3 of 14
165
mg/dL
Your doing great John!
Log food
DATE & TIME
Today, 12:00
Dish
Greek Salad
1 serving • 256 kcal
Save

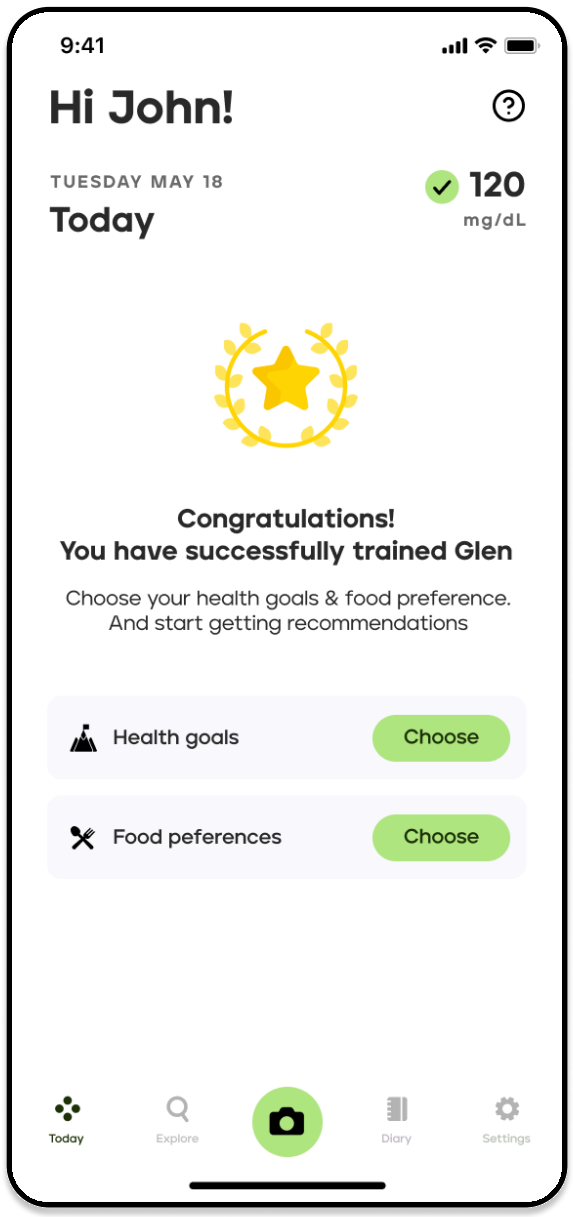
Training AI

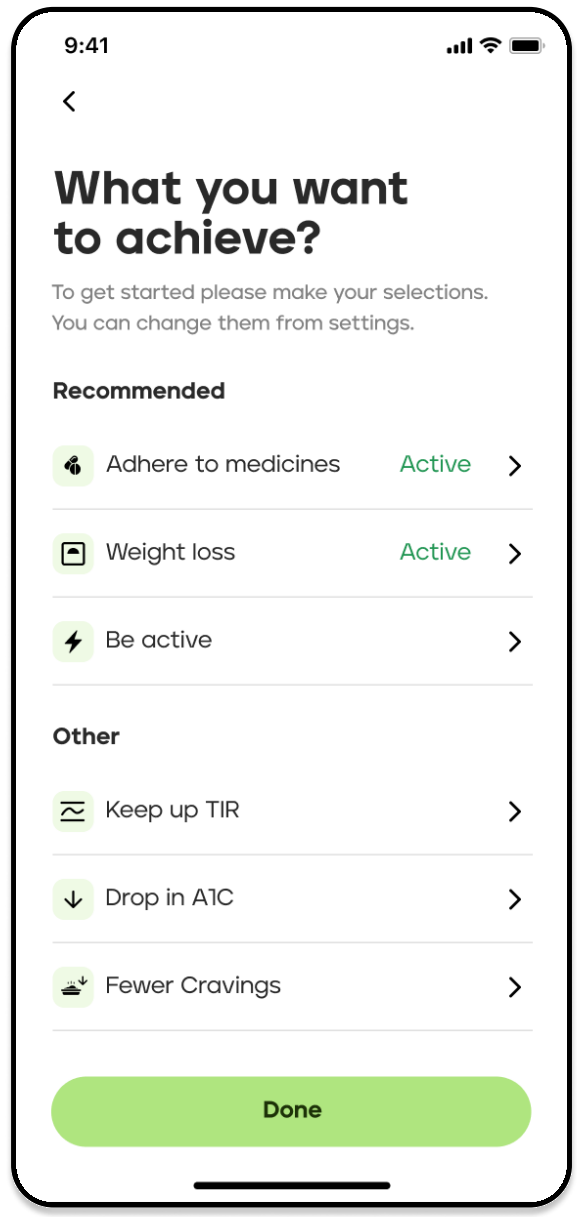


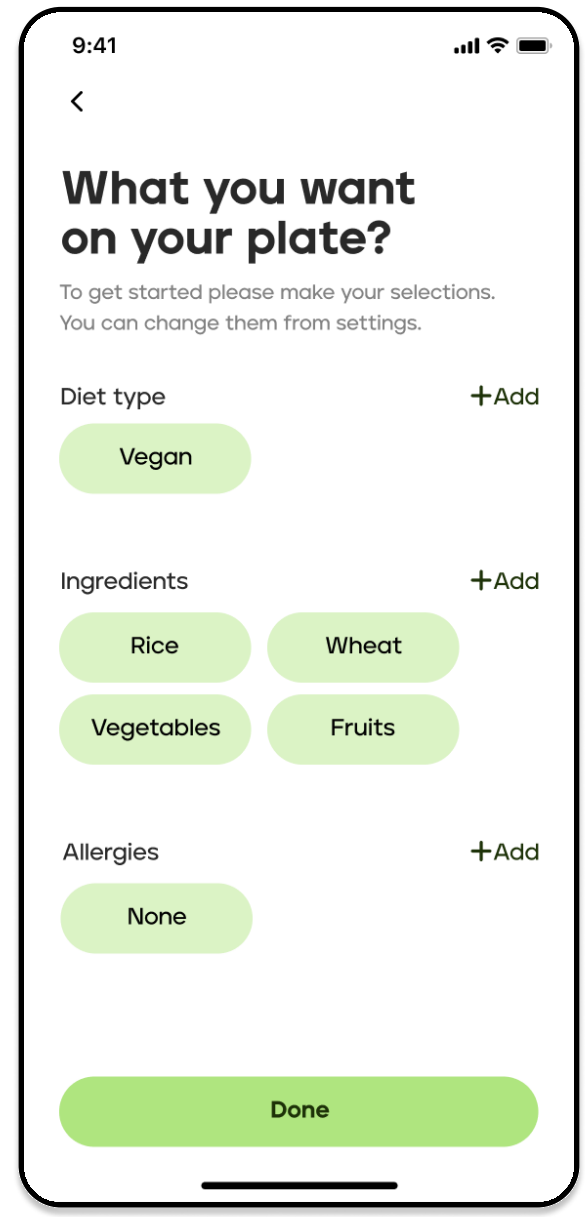




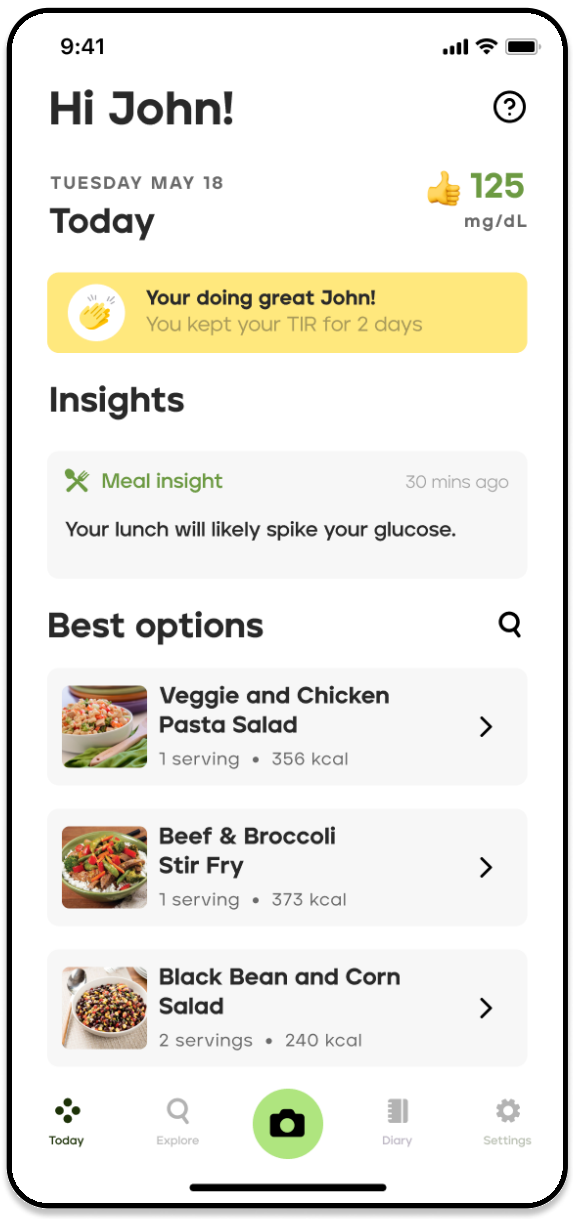
Post training AI

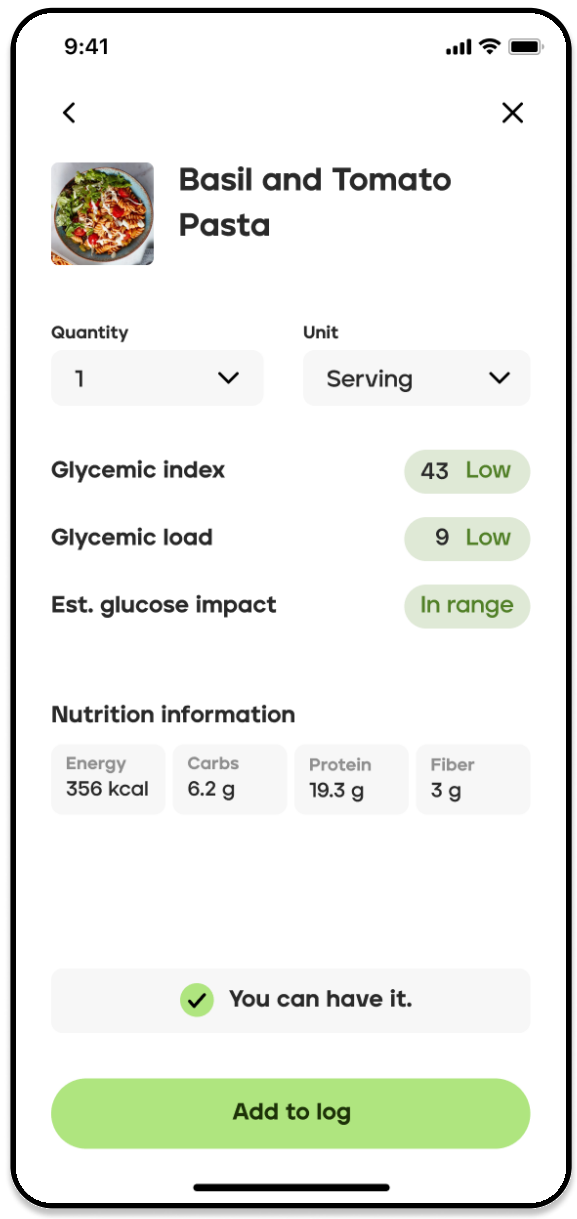


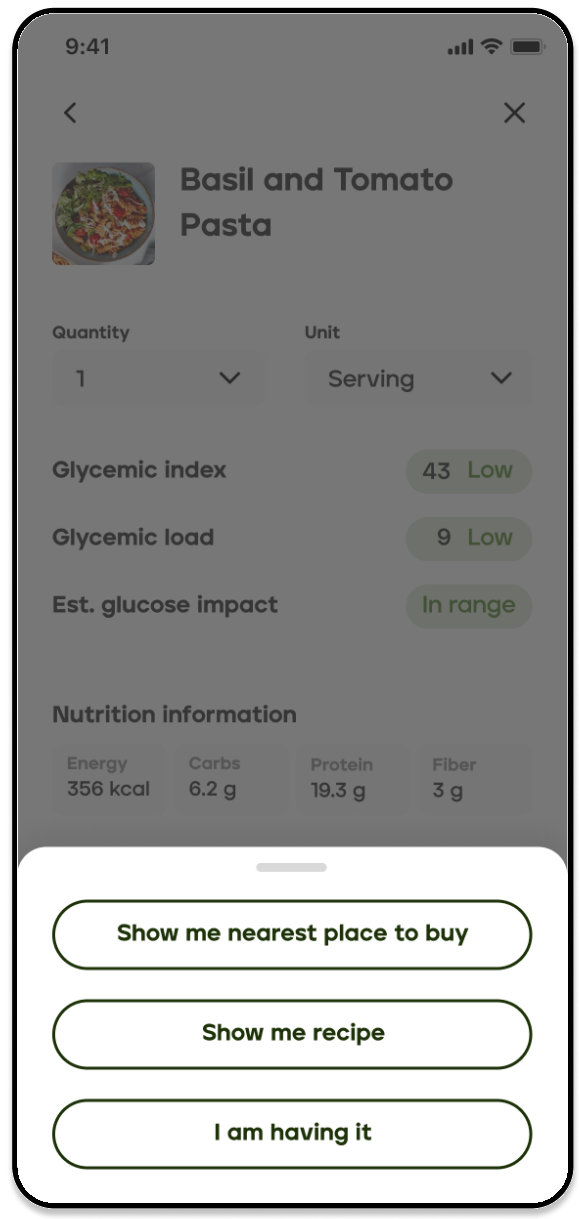




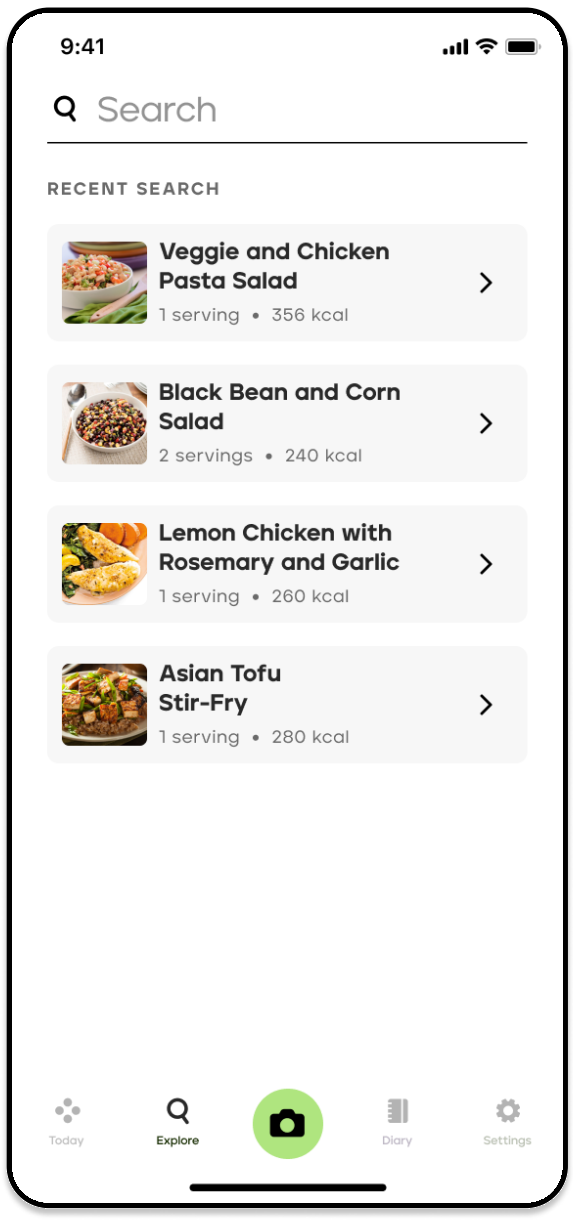
Meal suggestions

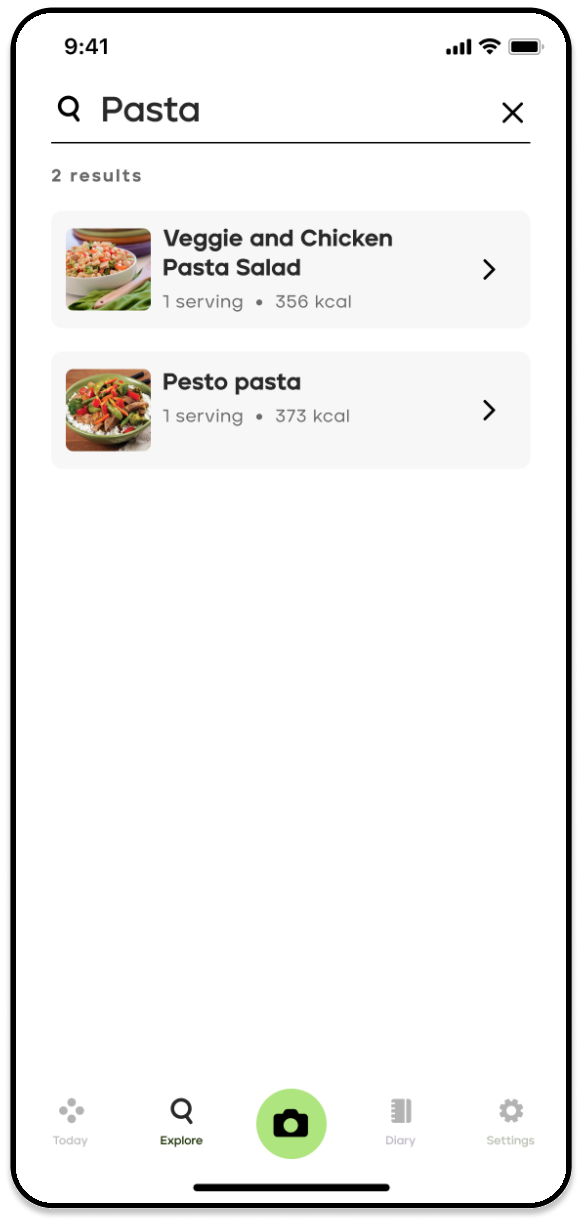




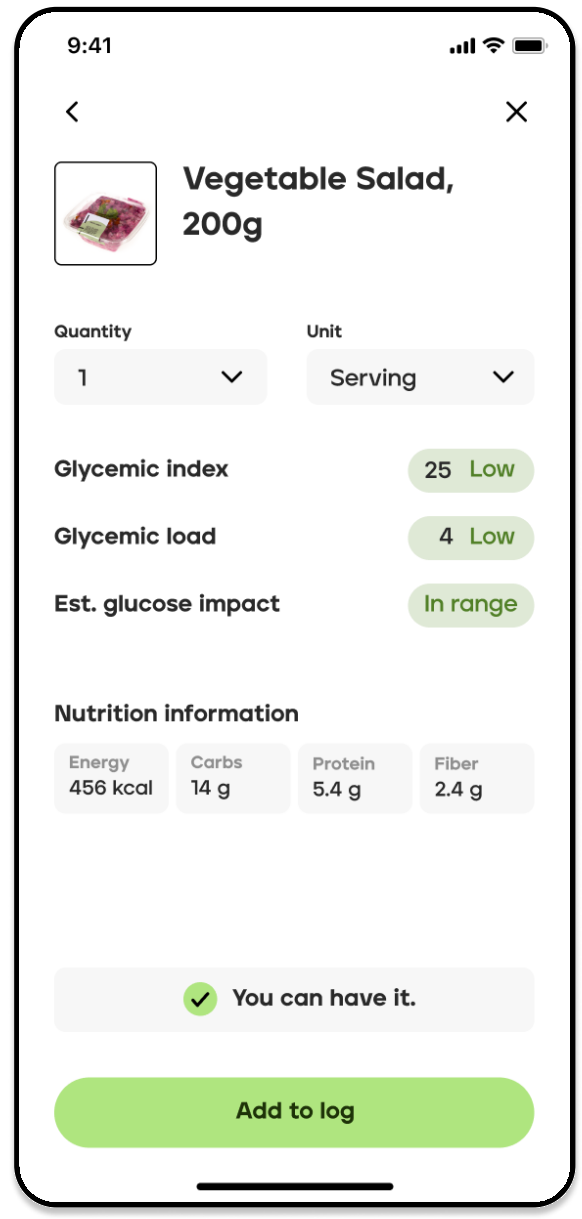


Explore food

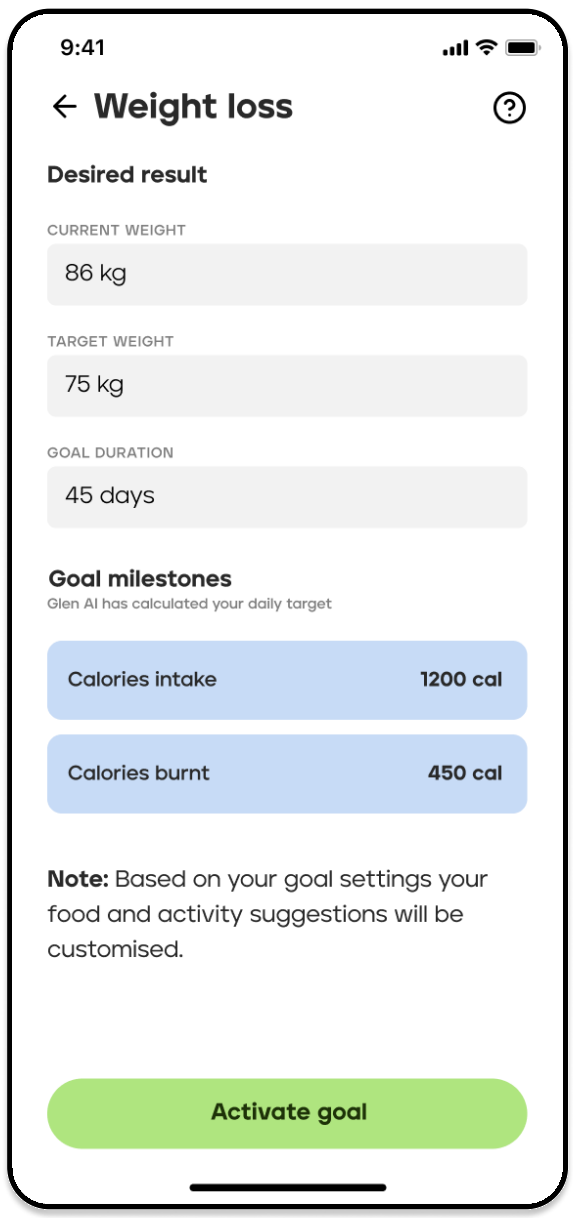


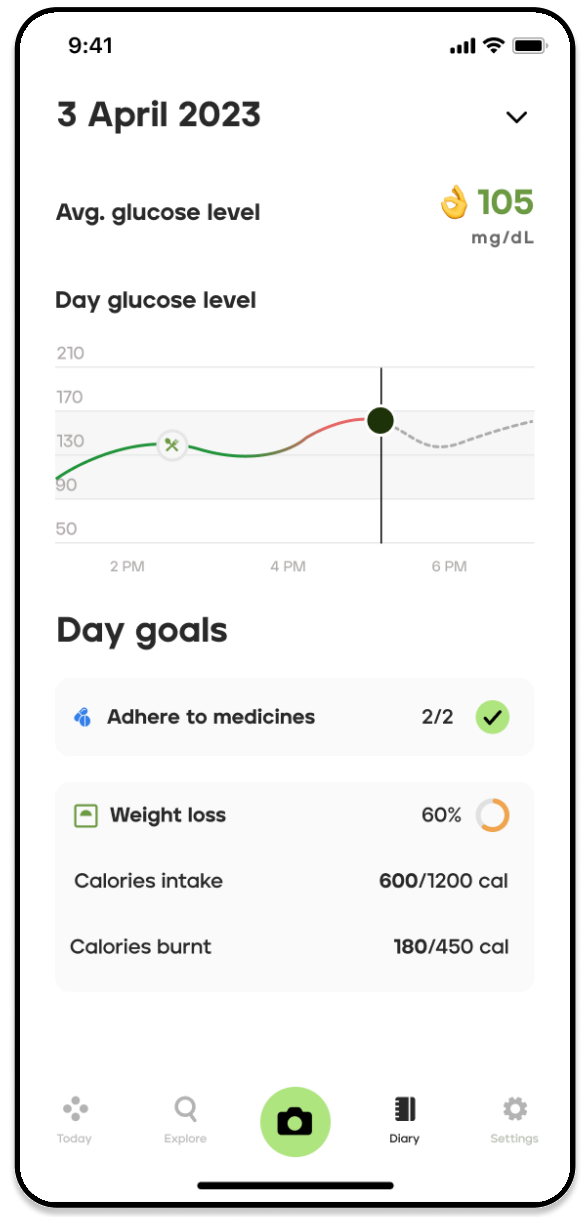


Meal suggestions

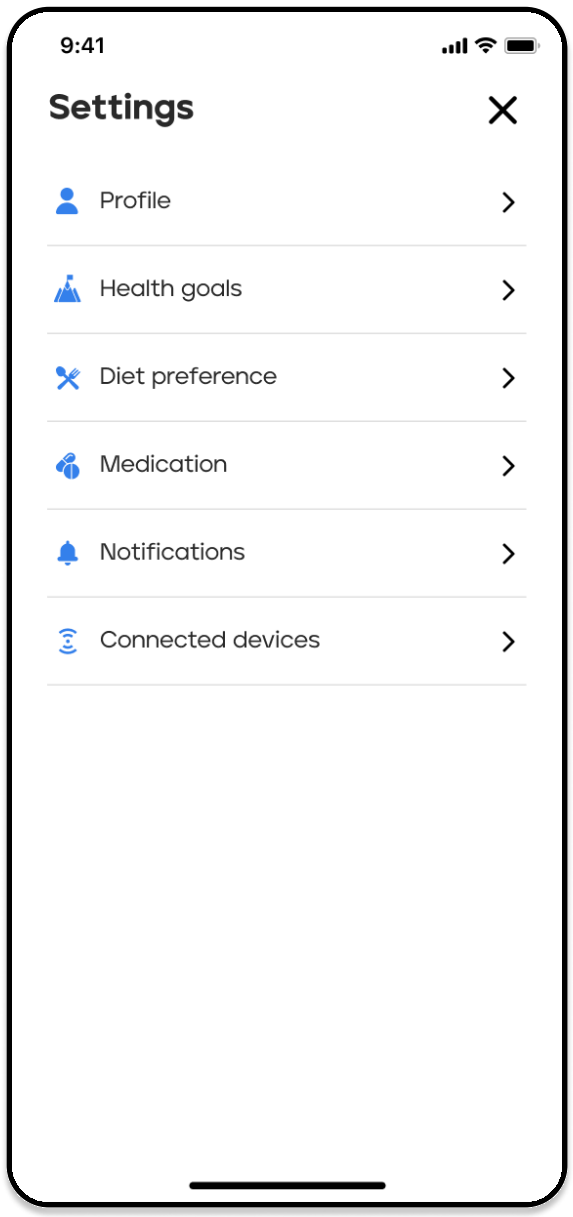


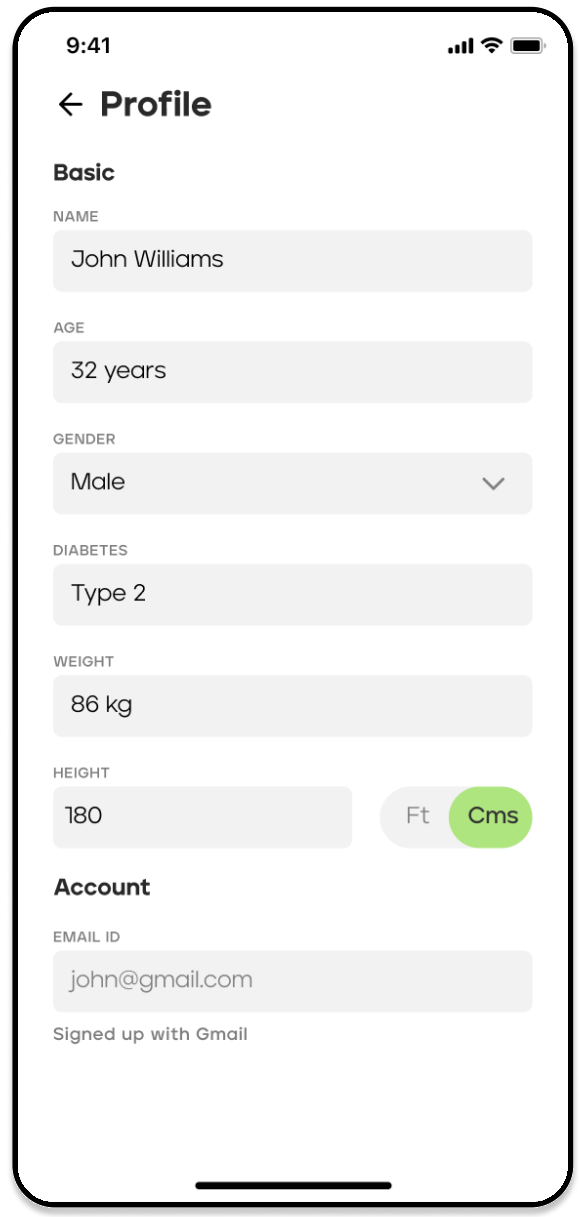
Setting & tracking goals

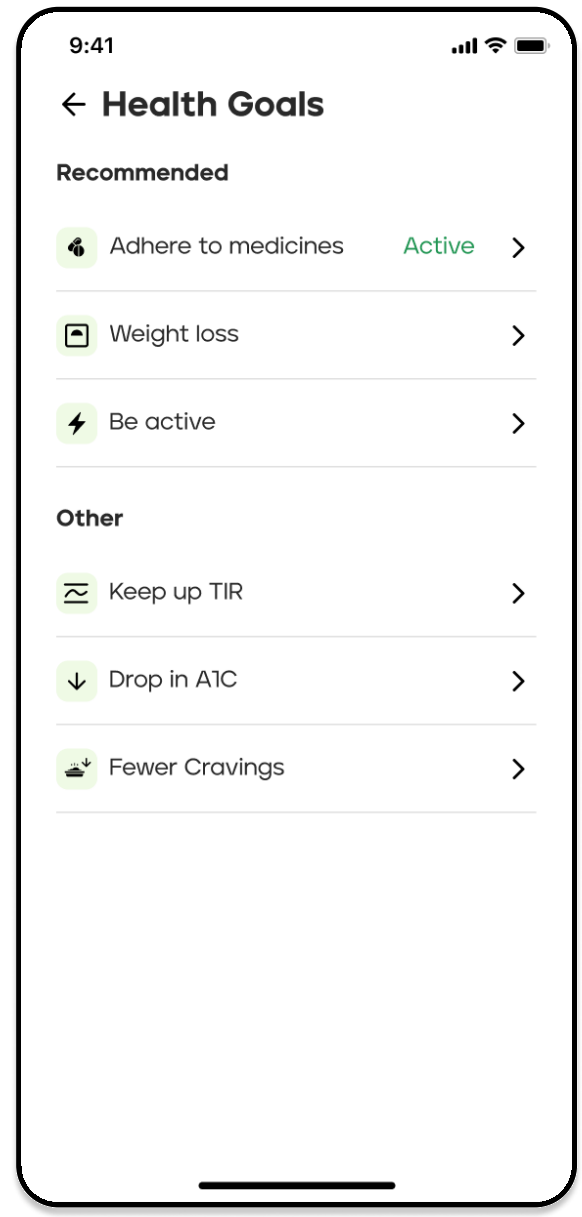


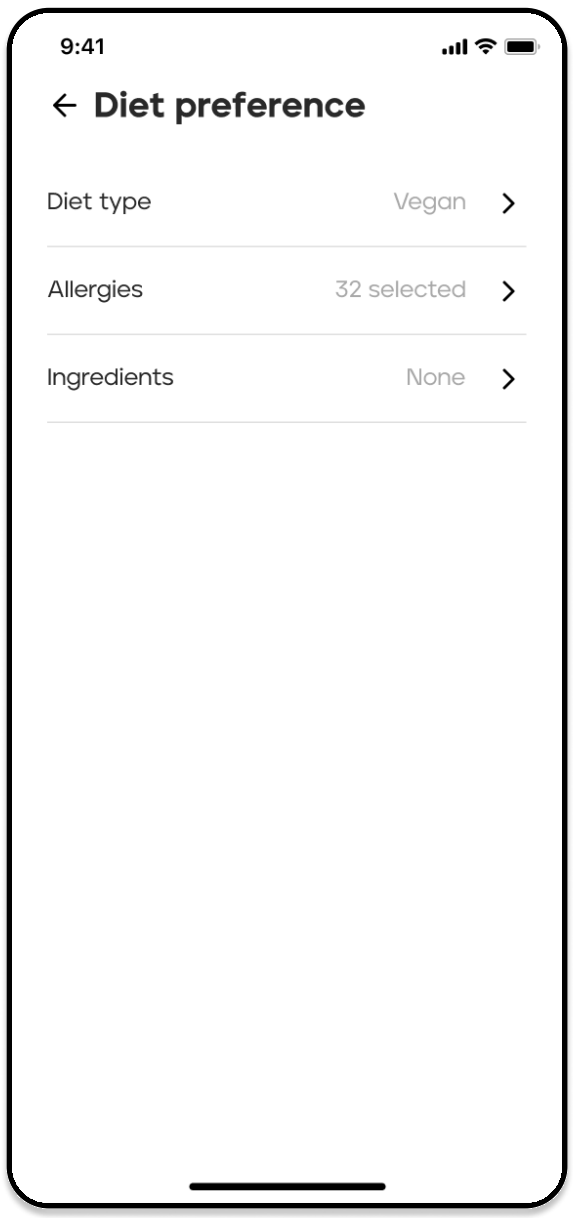


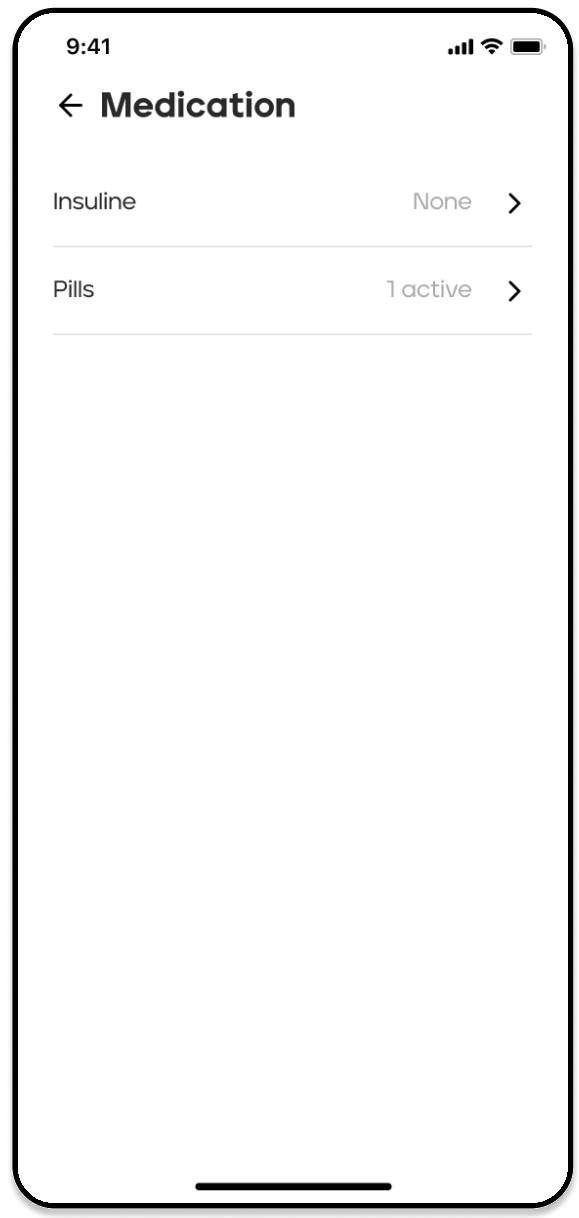
Settings

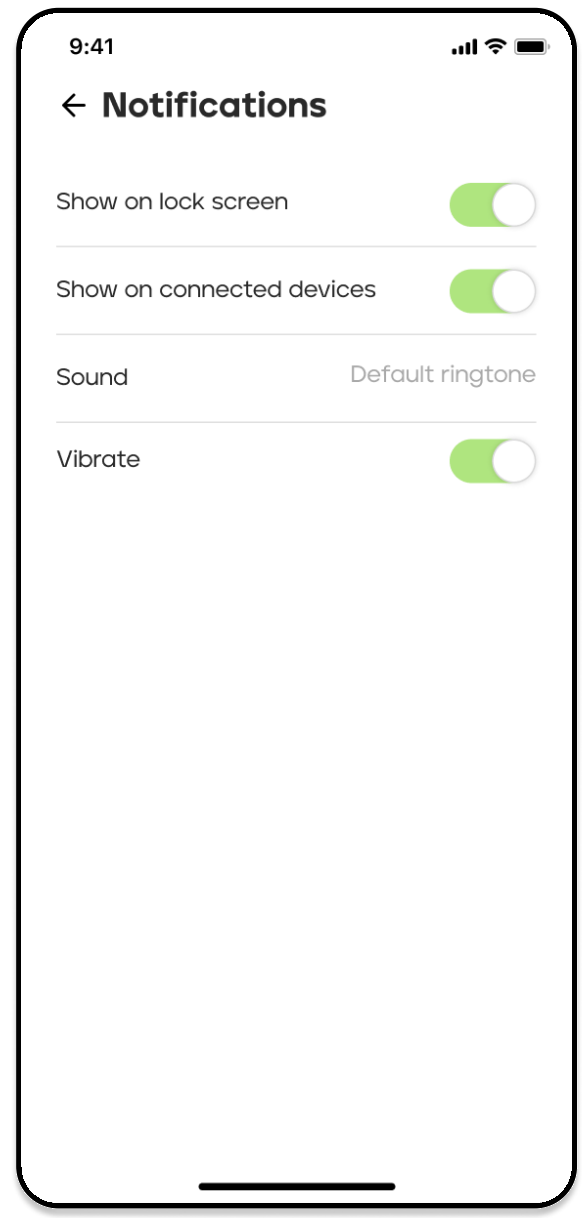

9:41
Settings
Profile
Health goals
Diet preference
Medication
Notifications
Connected devices


9:41
Profile
Basic
NAME
John Williams
AGE
32 years
GENDER
Male
DIABETES
Type 2
WEIGHT
86 kg
HEIGHT
180
Ft
Cms
Account
EMAIL ID
john@gmail.com
Signed up with Gmail

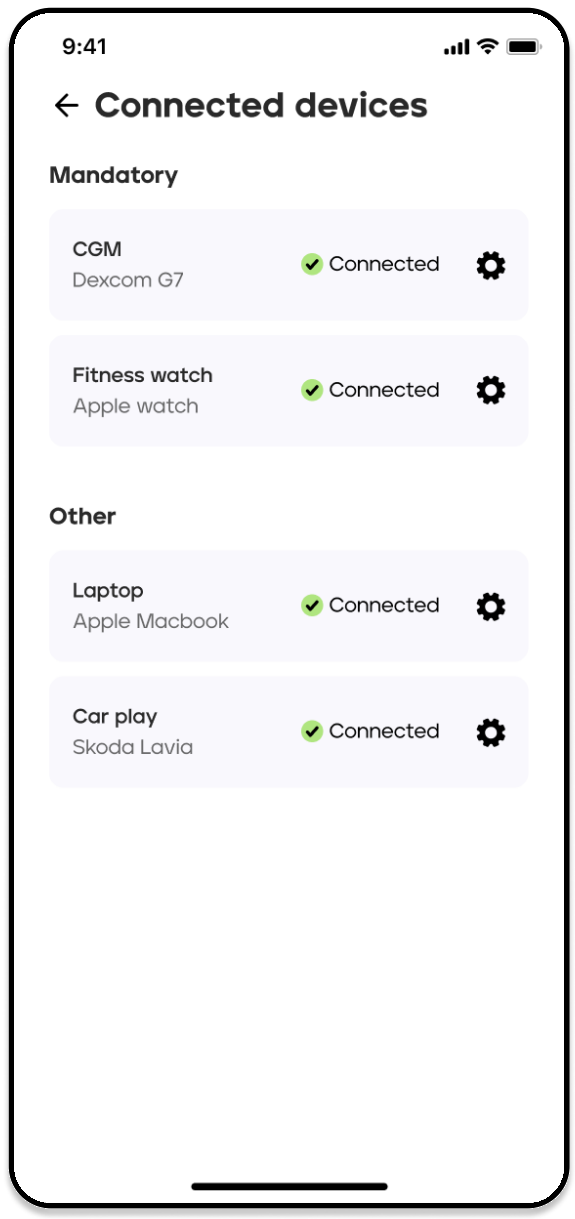

9:41
Health Goals
Recommended
Adhere to medicines
Active
Weight loss
Be active
Other
Keep up TIR
Drop in A1C
Fewer Cravings


9:41
Diet preference
Diet type
Vegan
Allergies
32 selected
Ingredients
None

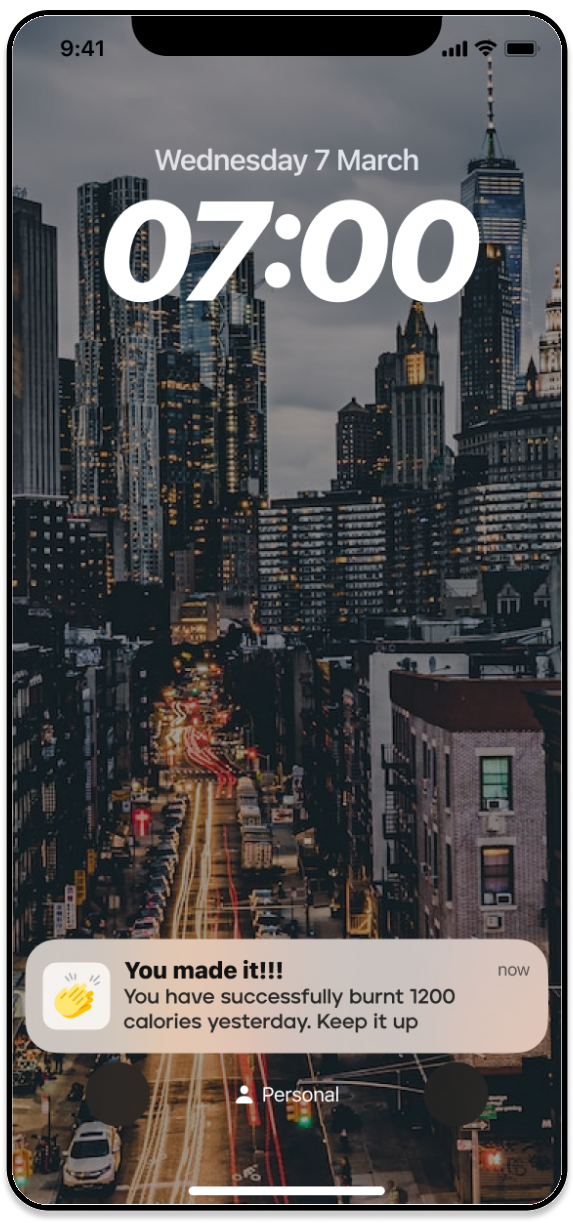

9:41
Medication
Insuline
None
Pills
1 active

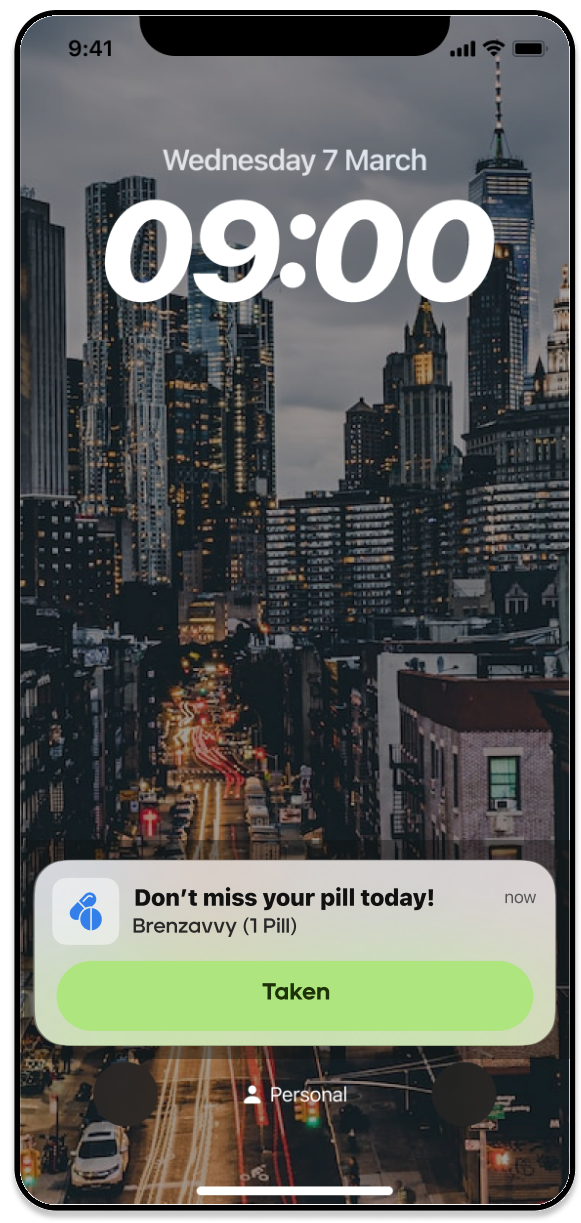

9:41
Notifications
Show on lock screen
Show on connected devices
Sound
Default ringtone
Vibrate

Settings



Notificaitons





Notifcations