mHealth Design for patients with Gestational Diabetes

Master Thesis in Information Science

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Abstract

In this study, a user-centered design approach was used to develop a mobile health application designed to support gestational diabetic patients with their self-management routine. In the requirements gathering phase, workshops, observational study, surveys and interviews were conducted. An analysis of the data collected from this phase helped identify the functional design requirements used to guide the design. Data visualizations, self-management, motivational behavior, behavior change, carbohydrate counting, activity, blood glucose levels monitoring, and chatting friend features were explored by use of prototyping. The final prototype developed in this research was evaluated for its ease of use and perceived usefulness. The design was found to be easy to use, persuasive, motivating and useful. Concerning data visualizations, participants preferred the line graph view of their readings to a bar chart. Concerning carbohydrate count, picture upload feature was like by participants. It is also found that all participants wanted to have chatting friend named "PregDia advisor" who will help answer all the questions related to gestational diabetes.

Chapter 1: Introduction

Gestational diabetes (GD) is a type of diabetes that is first recognized in the second trimester of pregnancy. Maternal insulin resistance is a physiological process developing during gestation to ensure the fetal energy supply. Whereas most women can cope with this metabolic adaptation, some develop Gestational Diabetes Mellitus (GDM). In Europe, prevalence for GDM is around five percent (Carolin Schliefsteiner, 2017).

Diagnosis of Gestational Diabetes Mellitus (Daniela, Danilo, Federica, Mario, & Ester, 2017) could significantly increase the likelihood of health problems concerning both potential risks for the mother, fetus, and child's development and negative effects on maternal mental health above all regarding a diminished structured life. Although it is always, challenging to change behavior or lifestyle, the gestational diabetic women are particularly motivated to adhere to doctors' advice to improve pregnancy or birth outcome (Zhang, et al., 2014).

Information and communication technologies have opened up for novel approaches to mediate treatment of gestational diabetes with interactive technology (Hirst, et al., 2014). Integrating an app into the antenatal care pathway for GDM has the potential to promote patient satisfaction with care. Robust satisfaction evaluations will make these applications as an adjunct to routine care. Developing innovative patient-centered approaches to care will enable pregnant women to understand and better control their gestational diabetes.

The project GraviDia ("Gravid with diabetes" in English it means "Pregnant with diabetes" in my thesis referred as PregDia) received funding from Helse Bergen and Bergen commune. Helse Bergen research and development team at Innovation camp 2015 discovered a need for a digital solution to ease the gestational diabetic monitoring process for pregnant women. It was later named as "GraviDia." The study presented here is part of project "GraviDia" done in close coordination with the project team at "Helse Bergen."

This thesis explores some of the design possibilities in mHealth (Free C. , et al., 2013)to support the challenges faced by gestational diabetes women. This research design aims at further contributing to an advancement of knowledge about the clinical link between GDM and quality of life. This thesis presents a mobile phone application "PregDia" – a design for supporting the self-management of health and well-being, targeting gestational diabetic patients by using conversational agent technology.

In pre-study stage with Helse Bergen team, it was found that healthcare providers wish to push the professional caretaking motivational force, which means there is a need for the patients' family members, friends, and communities to be involved in the care activities of a pregnant woman with Gestational Diabetes. Thus, there is a need for building a collaborative care environment to increase the quality of care by providing timely health information to professional health care providers, patients, and patients' family members or friends.

Norwegian Institute of public health (Stene, Strøm, & Gulseth, 2017) states that two sources highlight the incidence of gestational diabetes in Norway:

1. National figures from the Medical Birth Registry show that the prevalence of diagnosed gestational diabetes was approximately 4.5 percent in 2015.
2. In a study where sample of all pregnant women from Groruddalen in Oslo was tested, more than 10 percent of them had gestational diabetes (Jenum AK, 2012)

As mentioned by authors, there are many immigrants from South Asia, who are at higher risk of gestational diabetes than ethnic Norwegian women are. However, among ethnic Norwegians, about 10 percent in that study had gestational diabetes. They also state that close monitoring and routine registration of data is needed to evaluate and document any effects of interventions to reduce the morbidity of gestational diabetes (Stene, Strøm, & Gulseth, 2017). The current data in Norway are inadequate for this purpose.

Currently patient tracks medicine intake and lifestyles, e.g., carbohydrate intake, exercise, and weight mostly on paper or spreadsheets. Research also shows that glucose level measurements kits are available for all the patients, which allows convenient and non-intrusive monitoring of patients' blood glucose. Also, contemporary 4G smartphones are now available for everyone. There are 4.1 million mobile-phone users in Norway by the end of the year 2017 as compared to the total number of the mobile users was 3.1 million in 2014 (Statista, 2017).

These statistics show that Mobile phones make a particularly promising platform for health management applications due to their central role in people's lives as well as their technical capabilities. In this thesis, a design was made to bring glucose test kit with Bluetooth or Wi-Fi, and smartphone together. It will create a personalized, integrated, and collaborative care system for real-time, long-term and self-monitoring of patients like blood glucose level, activity and carbohydrates intake, on a daily basis.

PregDia (PD) – A mobile application design will help patients maintain a structured lifestyle through the continuous vigilance of key parameters. PregDia is a mHealth diabetes solution that will not only assist patient to record weight, carbohydrate intake and blood glucose values but will also assist them in taking corrective action to maintain those levels when they go off the threshold value.

PregDia have a conversational agent named as PregDia Advisor (PDA) that will assist patient while texting. With the stored information about the diabetic values, activity, what the patient eat and how they feel in various conditions, PDA can analyze better. With this insight, patients can manage their key parameters more efficiently. For example, a midwife can improve the treatment plan, a partner can get a better idea how his wife is doing, and researchers can investigate the relationship between food, activity, mood, and blood glucose values more closely.

1.1 Research Questions

This research will contribute to constructive and empirical levels to the enhanced understanding of Human-computer interaction (HCI) in the field of self-management of gestational diabetes. My combined interests in gestational diabetes (GD) and Information Science are the basis of these research questions.

1. *How to design mHealth application for gestational diabetic patients that can guide the user towards attainable goals?*

2. *How to introduce conversational agents in such designs and how will users perceive these designs?*

These questions possessed a lean towards exploring the present process and techniques followed by patients and healthcare providers in managing GD. It is important to understand the key challenges faced by patients in managing and monitoring GD presently.

To answer these questions, firstly literature review was conducted to find previous work related to the research questions. That further possessed a great lean towards a study to manage care in patients. By the following research through the design process, a prototype "PregDia" was constructed with the aim to support women with gestational diabetes to manage and monitor their key health parameters.

1.2 Research Aim

The purpose of this study is twofold, constructive and empirical.

Constructive
Constructive refers to the development of design-rationale and iterative development of a persuasive technology for self-management of women with gestational diabetes. Including a selection of methods for constructing such a system, as well as establishing user requirements. The main contribution of this research is the produced knowledge about how to design a persuasive conversational agent for self-management of gestational diabetes.

Empirical
Empirical refers to the presentation of data collected in investigating and elaborating characteristics of use and user experience from using the constructed prototype, PregDia. Through conducting requirements analysis and usability testing with patients with gestational diabetic patients, this research helped to develop a deeper understanding of user expectations and attitudes towards mHealth applications. This research work also presents the importance of persuasion principles for designing for behavior change in persuasive text-based conversational agent systems.

Furthermore, this thesis seeks to communicate the findings of this study in a way that is extensible to future research in the Field of HCI in mHealth.

1.3 Structure of thesis

The following list presents the structure and outline of this thesis.

Chapter 1: Introduces the problem domain, the research question, and aims of this study.
Chapter 2: Presents literature relevant to this study before discussing related work.
Chapter 3: Describes methods used to conduct the presented research.
Chapter 4: Details the requirements gathering for research and the analysis of data.
Chapter 5: Details the design and development of PregDia Prototype.
Chapter 6: Describes the evaluation of PregDia and the results of said evaluation. Discusses the evaluation results in respect to the research question and the research contribution of this thesis. Chapter 7: Concludes this thesis with a summary of what was found in research.
Chapter 7: Details open points from research for futher discussion.
Chapter 8: Concludes this thesis with a summary of what was found in research.
Chapter 9: Presents a proposition for future work to extend the presented research.

Chapter 2: Background

This chapter presents the research fields within which this research work is situated. Then, an introduction of mHealth, followed by an overview of persuasive text-based conversational agent's technology for behavior change and self-management. Lastly, a literature search for related work is detailed and discussed.

2.1 Human-Computer Interaction

As a field of research, Human-Computer Interaction (HCI) is situated at the intersection of computer science, behavioral sciences, design, media studies, health care and several other fields of study. In its formative years in the 1970s, HCI research was primarily concerned with issues relating to usability (John D. Gould, 1985). HCI as a field of study gained prominence in 1980 when personal computing became a widespread phenomenon (Carroll, 2001). An important facet of HCI is user satisfaction because human-computer interaction studies a human and a machine in communication it draws from supporting knowledge on both the machine and the human side.

> *"Human-computer Interaction (HCI) is a discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."*
>
> - (Hewett TT, 2009).

Some diverse methodologies outlining techniques for human-computer interaction design have emerged since the rise of the field in the 1980s (Wikipedia). Modern methodologies from HCI tend to focus on a constant feedback and conversation between users, designers, and engineers and push for technical systems to be wrapped around the types of experiences users want to have, rather than wrapping user experience around a completed system. User-centered design (UCD) (Donald & Norm, 1986) is one of the modern methodology, widely practiced rooted in the idea that users must take center-stage in the design of any computer system. Often, user-centered design projects are informed by ethnographic studies of the environments in which users will be interacting with the system. This practice is similar but not identical to participatory design (Brandt, 2006), which emphasizes the possibility for end-users to contribute actively through shared design sessions and workshops.

Recent research shows potential revolution in HCI with movement toward natural language user interfaces (Følstad & Brandtzaeg, 2017). The new version of interactions with digital systems will happen through text in a natural language, for example, Chatbots, one of the emerging technology. Asbjorn Folstad and Petter Bae Brandtzag (2017) further adds that HCI is not new to chatbots, it has its roots in Natural language user interfaces for example conversational systems. This research shows that in future, HCI needs to consider conversations as the main object of design, focus on services rather than user interfaces, and design for interaction in networks of human and machine actors.

HCI as a problem-solving research consists of three paradigms namely empirical, conceptual, and constructive. These paradigms of problem-solving in HCI research exist one behind the other, usually by combining two paradigms to explore some novel or an established pattern of human use of computing. For example constructive-empirical studies that produce some novel interaction modality and contribute to the understanding of related phenomena.

Empirical research paradigm is defined as creating a description of real-world phenomena, related to human use of computing that is, exploring some phenomena novel to HCI research. That discovers some fundamental factors of this phenomena, and in turn measuring and quantifying the effects on something of interest (e.g., the usability of utilizing this phenomenon in interaction) (Oulasvirta & Hornbæk, 2016).

Whereas conceptual research is defined as work that tackles the explanation of previously unconnected phenomena occurring in interaction. Lastly, constructive research aims to produce understanding about the construction of an interactive artifact for some purpose in the human use of computing. Referred as how a prototype was made (Oulasvirta & Hornbæk, 2016).
A common contribution of the constructive research is design principles which contribute to the HCI communities knowledge of how to design for a given context or domain.

This thesis' contribution is the construction (see chapter 5) of PregDia as a mHealth application for self-management of gestational diabetes using persuasive conversational agent technology, and the empirical study of usability (see chapter 6) of its design.

2.2 Role of mHealth in Gestational Diabetes

mHealth (mobile health) is a general term for the use of mobile computing and communication technologies in health care and public health (Free C. , et al., 2010). mHealth, which is a part of eHealth, appears to have tremendous potential for improving the quality of life of people. mHealth has gained importance by targeting not only patients but also doctors, nurses and healthy people aiming to cultivate a healthy lifestyle. A systematic literature review conducted by Spyros et al. (2017) shows that mHealth interventions have improved glycemic control compared to standard care or other non-mHealth approaches by 0.8% for patients with type 2 diabetes and 0.3% for patients with type 1 diabetes (Spyros Kitsiou, 2017).

Gestational Diabetes is a condition where the patient needs to take continuous care for his/her health. With the help of mHealth applications, the patients can monitor and manage their health by themselves. Not only can they monitor their health, with the connectivity feature of the mobile they can share their status of their health with their doctors. Kleinberger et al. (2007) observed that the increase in accessibility of mobile information and communication technologies has made the use of mobile phones a common way of communication or sharing information for treatment or advice (Kleinberger, Becker, Ras, Holzinger, & Müller, 2007).

Reflecting the high prevalence of gestational diabetes and penetration of high-end mobile phones, the number of scientific research works on mHealth has rapidly increased. Unfortunately, in spite of the number of mHealth research for diabetes, more quantitative methods of evaluation are needed to demonstrate that mHealth holds more than mere potential (James O'Donovan, 2014). Therefore, evaluation of mHealth from HCI perspective should focus on understanding usage and uncover potential problems that stem from the design of an employed mHealth technology for intervention (Ali, Chew, & Yap, 2016). Improved design methods and developed ideas from persuasive technology field can help users gain knowledge and change their attitudes and behavior to achieve positive health outcomes from mHealth technology (Oinas-Kukkonen & Harjumaa, 2009).

In next sections, I will describe the Persuasive technology used to make design principles in this research (Oinas-Kukkonen & Harjumaa, 2009). Persuasive technologies have emerged as

a sophisticated research field where IT artifacts are developed to promote behavior change in a much wider scope using software functionalities such as reminders, rewards, and social learning.

2.3 Persuasive Technology

Daily management of gestational diabetes requires control of blood sugar levels, medications, healthy diet, and physical activities, which are particularly challenging for patients especially in pregnancy (Seidel, Kruse, Sze´kely, Gau, & Stieger, 2017). This section details how to design persuasive technology to foster and support self-management of gestational diabetes.

> "Interactive information technology designed for changing users' attitudes or behavior is known as persuasive technology
>
> - (Fogg, 2003)

By enriching Fogg's work (Fogg, 2003), Oinas-Kukkonen and Harjumaa developed a systematic framework for designing and evaluating persuasive information systems. Persuasive system design model (PSD model) recommended by Oinas & Harjumma consisted of four distinct software categories (Oinas-Kukkonen & Harjumaa, 2009).

The four distinct categories namely primary task support, user-system dialogue support, credibility support and social support aim to improve persuasiveness of information systems. PSD model providing a range of design features and software functionalities for developing effective behavior change support system is now accepted as a practical framework by researchers, designers and practitioners for better understanding and estimating target audiences' needs and expectations.

Alahäivälä (2017) have used the PSD model for designing for persuasive information systems that promote healthy behavior (Alahäivälä, Jokelainen, & Oinas-Kukkonen, 2013). Figure 1 provides a detailed description of the model, its seven postulates, and the four design principles.

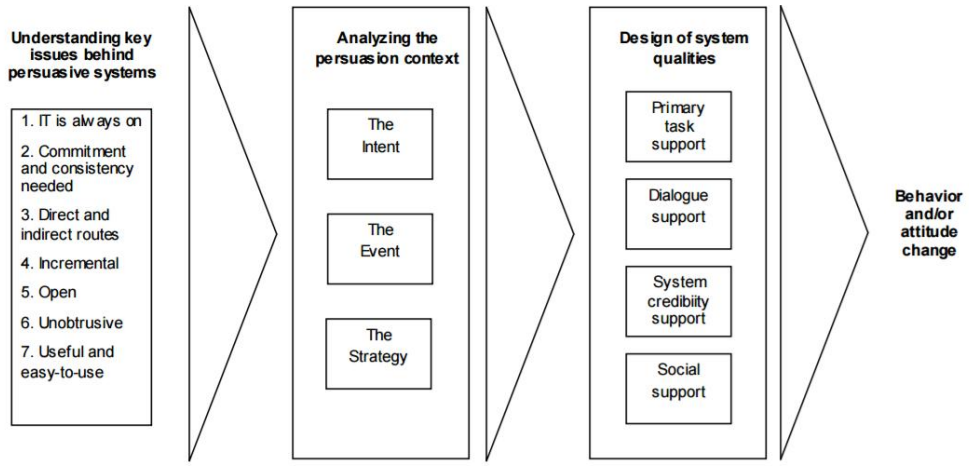


Figure 1: Phases of persuasive system development by Oinas-Kukkonen and Harjumaa (2009)

The first principle that is primary task support refers to user's primary task in the application. The design principles in this category are; reduction, tunneling, tailoring, personalization, self-monitoring, simulation, and rehearsal (In reference to thesis work these are discussed in detail in section 4.2.1).

The second principle is dialogue support, and it refers to implementing computer-human dialogue support in a manner that helps users keep moving towards their goal or target behavior. These include praise, rewards, reminders, suggestion, similarity, liking, and social role. Researchers from the field of Human-Computer Interaction also support the importance of enhanced dialogue between users and information systems. For example, (Consolvo, McDonald, & Landay, 2009) propose that users should be rewarded for performing a desired behavior or reaching their goals (more examples are discussed in section 2.4.5).

The third design principle is the system credibility, and it describes how to design a system so that it is more credible and thus more persuasive. This category consists of trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements, and verifiability.

The fourth design principle is the social support, and it describes how to design the system so that it motivates users by leveraging social influence. The design principles that belong to this category are social facilitation, social comparison, normative influence, social learning, cooperation, competition, and recognition.

The PSD model contributes to information systems research by providing a systematic approach to design and evaluates the context of persuasion and appropriate techniques. While carrying out an analysis of the persuasion context, it is essential to identify (Oinas-Kukkonen & Harjumaa, 2009) the Intent (of the persuader and anticipated change type), the Event (use context, user context and the technology context) and the Strategy (message and the route) employed.

To motivate healthy behavior in patients persuasive technology is a growing area of research within HCI and ubiquitous computing. In this thesis, persuasive conversational agent technology is proposed to motivate people toward healthy behavior and achieve the goals to have controlled gestational diabetes.

2.3.1 Persuasive Conversational Agent

For providing information naturally to patients with gestational diabetes, conversational agents that have spoken or text-based natural language interface is a proposed solution to this problem. There are two types of conversational agents (CA): one kind of agents use linguistic aspect such as spoken language or text, and the other kind of agents uses both linguistic and non-linguistic aspect including gestures or facial expressions.

> "Persuasive conversational agents persuade people to change their attitudes or behaviors through conversation,"
>
> - (Narita & Kitamura, 2010)

Narita and Kitamura developed a learning agent with the Wizard of Oz method in which a person called Wizard talks to the user pretending to be the agent. The agent observes the conversations between the Wizard and the user and learns how to persuade people. In this method, the Wizard has to reply to most of the user's inputs at the beginning, but the burden gradually falls because the agent learns how to reply as the conversation model grows. This study shows that, that the burden (the input ratio) of the Wizard was reduced from 55% (without tactics) to 33% (with tactics), although the success ratio of persuasion was little improved.

Similarly, Ada and Grace (Traum, Aggarwal, Artstein, Foutz, & Gerten, 2012) are two Conversational Agents at the Museum of Science in Boston. These virtual guides visit a museum more interesting by answering visitor questions, suggesting exhibitions and explaining the technology behind the products.

Speaktoit Assistant (O Hear, 2014) another CA based on natural language interfaces, computational linguistics, and voice technologies. A future goal of Speaktoit is to create Conversational Agents for mobile devices to deliver an interactive experience for the user. Figure 3 represents an idea of a talking friend for Windows device. It can perform a task, answer questions and can connect with other web services like facebook, twitter or google.

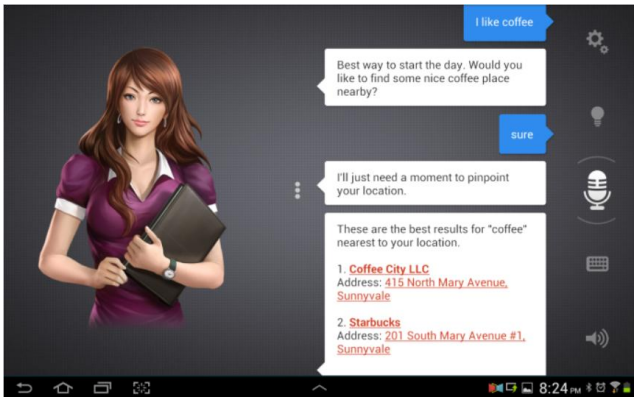


Figure 2: Speaktoit Assistant

In HCI, the most common way to have natural language interaction agents with the user is a chatbot system that is a conversational agent (Dale, 2016). In this thesis, the focus is on developing text-based interactive conversational agent and improving human-computer interaction. Lester, Branting & Mott (2004) mentions that conversational agents need to be scalable, secure, reliable, and interoperable with the IT infrastructure in large deployments. The architecture proposed and tested by them for the webpage is shown in figure 3.

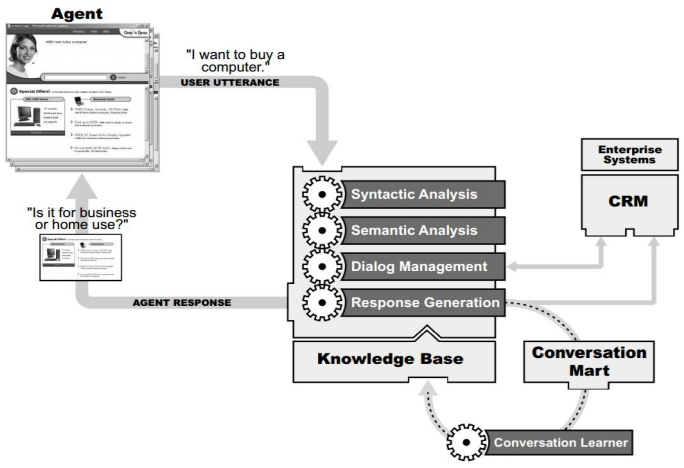


Figure 3: Data flow in conversational agent (Lester, Branting, & Mott, 2004)

In the study, they conclude that without a robust language processing facility, agents cannot achieve accuracy rates necessary to meet the business objectives of an organization (Lester, Branting, & Mott, 2004) mentions. Figure 4 details the model recommended for language

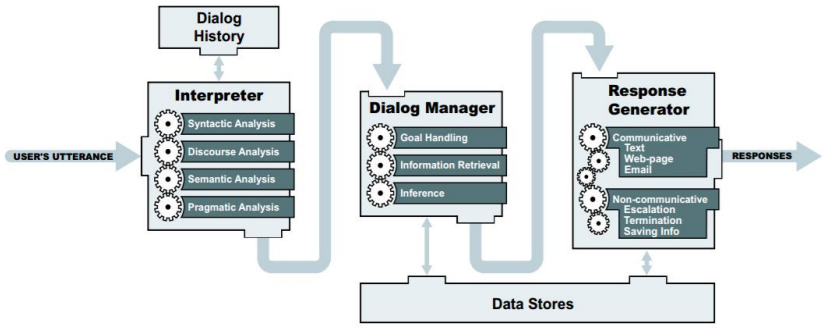


Figure 4: Language processing model (Lester, Branting, & Mott, 2004)

processing is showing how utterances lead to a response. “Sequence-to-sequence” model is the building blocks of good task-oriented dialogue agents, like maintaining dialogue state and also being able to extract and use relevant entities in its responses, without requiring intermediate supervision of dialogue state or belief tracker module (Eric & Manning, 2017).

The main challenge in the conversational agent is dialogue management, specifically when same input can produce a different output relating to previous output. Extension and Prerequisite algorithm is prepared to enable relation between responses by using Relational Database Model approach Extension and Prerequisite is implemented both in keywords matching process and knowledge-based authoring process. Lokman and Zain have developed and tested Extension and Prerequisite algorithm on a chatbot virtual diabetes physician (ViDi) (Lokman & Zain, 2010).

The main feature of this algorithm is that it can link to multiple responses by creating utterance in user. It is achieved by updating response data with two variable names Extension and Prerequisite (refer figure 6). These variables are used to store the unique Response/Match ID. By default value for each variable is zero that change as VIDI’s knowledgebase links that particular response with other responses, by linking to more than one response. Another user interface does the process of linking response (vBrain in case of chatbot ViDi) Refer figure 7 for details.

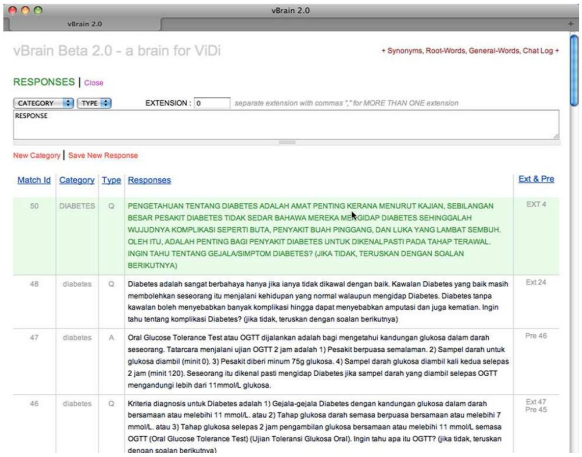


Figure 5: vBrain with variables extension and Prerequisite

For that being the case, the algorithm will incorporate the instruction utterance at the end of agent s responses to be the guidance for users on how to proceed.

In an evaluation study for text-based conversational agents by (Crockett, Bandar, & Hijjawi, 2016) shows that the lack of a comprehensive evaluation framework has been a limiting factor in the growth of Conversational Agents. Results also show that different types of conversational agents might require different frameworks of evaluation. As a field of studying interaction processes and error recovery, HCI at present does not have much to contribute toward well-functioning conversational processes between chatbots and human users (Følstad & Brandtzaeg, 2017).

In the proposed framework, the evaluation of Conversational Agent should focus on the "Information Requirements" shared between the utterance and the fired rule. All these parameters were evaluated (Refer Section 5&6) and results show that PDA can support most of the user requirements. Most of the research on chatbots explores mainly the problems related to dialogue management of the conversational process. Next section will detail about the conversational process and their effect on changing user's relationship with PDA.

2.3.2 Understanding a Conversational Processes

To make any conversational agent a success there is a requirement of deep understanding of conversational process (Følstad & Brandtzaeg, 2017).

In PregDia conversation is considered to take place when these guidelines are fulfilled by the participant (refer figure 5), one after another. These are 1) Open a conversation, 2) Commitment to engage in conversation, 3) construct meaning 4) evolve, 5) converge on the agreement and 6) Act as transact (Refer figure 3). Regarding PD, "Opening a conversation" refers to participant sending an initial message; this opens a possibility for a conversation with PDA.

For a conversation to follow the message must establish common ground; it must be comprehensible to PDA. After the initial dialogue, both participants must commit to engage. PDA must pay attention to the message and then commit to engaging with the patient. Such a commitment may amount to nothing more than continuing to pay attention. For a conversation to persist, the commitment must be symmetrical, and either side may break off for any reason, at any time.

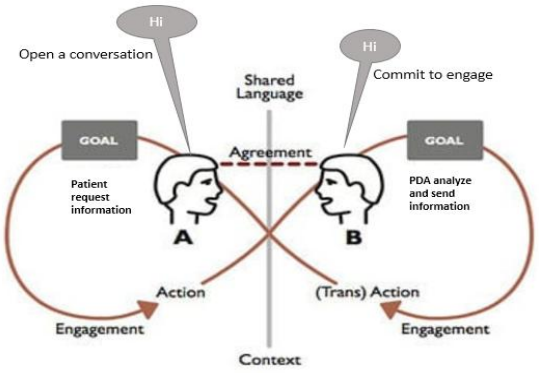


Figure 6: Conversation process

Another way, the patient must see value in continuing the conversation. This value should be measurable regarding time, attention, and stress required. After commitment next is to construct some meaning from the conversation. Conversation enables us to construct (or reconstruct) meaning. For example, the patient mentioned "the month of pregnancy" during registration (2

months back), now PDA can compose a message using the information that patient shared earlier and can describe the fetus growth to the patient.

To update gestational diabetes parameters, the patient may sometimes use the message channel and sometimes can enter data manually about these parameters. PDA "takes all this in" and "puts it all together" to reproduce information for patients. This "meaning making" (the taking all this in and putting it all together) is a "wow" moment, every time patient "understand" what PDA is saying. The patient will hold new beliefs, make decisions, and develop new relationships, with PDA. It builds trust with a conversational agent.

The changes brought about by conversation have lasting value to the participants in this "effective conversation" interaction. Referred to evolving relationships. Converge on agreement means the confirmation by PDA that it understands the patient correctly. On receipt of such messages, the patient attempts to make sense of PDA formulation and compares it with her original intention. It may lead to further exchanges. When both patient and PDA judge that the concepts match sufficiently, they have reached "agreement over understanding."

The last section of conversation is acted or transact. Sometimes one or more of the participants agree to act because of, and beyond, the conversation that has taken place. For example, they may agree to decide on recipes' with low calories together or enter into a relationship (where patient just drop a message to PDA to remind her to have frequent walks at the party).

2.4 Related Work

This section details about the literature found on related work of mHealth self-management applications, gamification techniques in the non-gamification field, data visualization and summary of related work. Last section details about systematic review and meta-analysis.

2.4.1 Self- Management Applications

With the emergence of mHealth platforms and the necessity to make gestational diabetes logs more accessible, several forms of applications have been developed in the field of health care. These range from a straight translation of conventional paper logs into an electronic form, to unique designs that strive to achieve positive health behavior changes in patients (Goyal, et al., 2017).

While reviewing for mHealth/telemedicine solutions, two main types of solutions were identified: medical data transfer/sharing systems and phone consultations that were in the form of short message service (Franc, et al., 2011); the reason is the easily usable technology. The review concluded that successful gestational systems should incorporate an easy to use a system that facilitates easy interaction with the care team, and provides timely feedback of blood glucose readings and related questions.

In the study of usage log analysis of MoDD (a web-based application with integrated short message service) (Mamykina, et al., 2015), participants logged diabetic parameters twice per week and set two behavioral goals. The study shows that individuals used MoDD to follow the steps of the problem-solving process, from identifying problematic blood glucose patterns to exploring behavioral triggers contributing to these patterns, to selecting alternative behaviors, to implementing these behaviors while monitoring for improvements in glycemic control.

This study concludes that informatics interventions for reflection and problem solving can provide structured scaffolding for facilitating maintained key parameters of gestational diabetes by guiding users through the different steps of the problem-solving process and by providing them with context-sensitive evidence and practice-based knowledge related to gestational diabetes self-management on each step. This study suggests that to have successful PregDia tool, it is important that PregDia advisor engage individuals in self-monitoring, reflection, and problem-solving

In another study, a mobile food record for assessing dietary intake was evaluated (Daugherty, et al., 2012). The goal of the study was to gage user capabilities and perceptions towards the food record. Users noted that the software was easy to use. However, not everyone agreed that taking pictures before and after meals would be easy to take. It may have been due to a requirement of the study for a fiducial marker to be included in each picture, which meant that each user had to carry an item in addition to the mobile phone.

The usability concern of carrying multiple devices is a common theme among diabetes patients because they already need to carry several items on a daily basis (i.e., glucometer, BG test strips, medication, logbook, etc.). Therefore, it is important, if a photography log feature is included in the PregDia application; it should be integrated into the design and does not require the support of any external devices. Whereas in another study limited supporting evidence was found in image-based dietary records (Rollo, Ash, Lyons-Wall, & Russell, 2015). The study shows that the inability to go back in time to capture a photo of what was consumed earlier in the day underreport the dietary intake using Nutricam (Refer figure 6) versus the paper log.
It highlights a particular design need of usability for PregDia that is to ensure that patients should have the flexibility, with the photography feature, to go back and add in notes about what was consumed earlier in the day. The Same methodology should be followed for other parameters like blood glucose levels and activity.

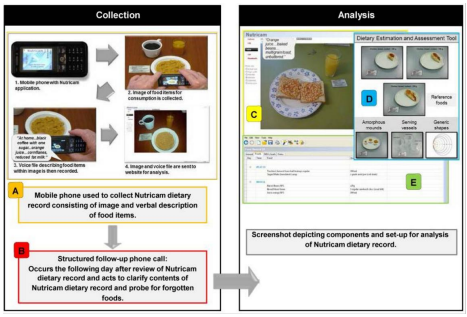


Figure 7: NutriCam

A multi-method study by (Oinas-Kukkonen S. L., 2012) explored the impact of reminders on the effectiveness of information systems that aim to facilitate behavior change. The study explicitly focused on reminders as a key persuasive software feature that was employed to support behavior change A prototype was designed aiming to encourage people to reduce soda/fizzy drinks consumption gradually. A multi-method 14-day pilot study was conducted, composed of statistical analysis followed by a qualitative focus group. Statistical analysis shows that participants consumed less fizzy drinks in the second half of the study, and feedback from the focus group study indicates that reminders successfully persuaded participants to keep a log of their fizzy drink consumption. This study supports the claim that persuasive reminders have extraordinary potential for helping people change their behavior's. The details of all these studies are summarized in Table 1 below. All involve some form of mobile self-management technology.

Table 1: Literature Description and Key findings

Researchers	Interventions	Description	Key Findings
(Franc, et al., 2011)	Smartphones, e-mail, texting or phone calls	- Smartphone loaded with application to apply physicians' prescriptions, - Data stored in the smartphone transmitted to authorized caregivers, enabling remote monitoring and even teleconsultation. - systems combining the healthcare provider and the patient by e-mail, texting or phone calls	- System provide immediate assistance to the patient - Better control of patients' blood glucose levels through accurate adjustment of insulin doses -Provide motivational support as well.
(Mamykina, et al., 2015)	MoDD App Mobile Diabetes Detective	-Participants logged glucose levels twice a day -Set two goals Usability tested regarding self-management while monitoring for improvements in glycemic control.	-Guided users through the different steps of the problem-solving process -Provided users context-sensitive evidence and practice-based knowledge related to diabetes self-management on each step
(Rollo, Ash, Lyons-Wall, & Russell, 2015)	NuDAM App Nutricam Dietary Assessment Method	- A mobile phone is used to capture the Nutricam image-based dietary record - Combined with information collected via a phone call - Analysis consisted of the identifying and quantifying food items contained in each Nutricam dietary record entry	- The software was well received by users favoring the Nutricam method over pen and paper -Intake was significantly underreported using nutricam over the written log book -Some modifications to the NuDAM could improve efficiency and evaluation in a larger group
(Daugherty, et al., 2012)	Mobile Telephone Food Record	-Images of food were captured before and after eating -A fiducial marker was to be included in each photo -Usability tested with different set of users to determine skills and user preferences	-Users did not completely agree that capturing pictures before and after eating were easy
(Kari, Piippo, Frank, & Moilanen, 2016)	App Sunnto Movescount	- App reward points for getting active and tracking fitness activity -User experience tested for concept of gamification in selected application -Study to find motivation and behavior change by gamification	-Interview results were positive - Results show that rewards encourage and motivated users to do exercise through mobile application
(Cafazzo, Casselman, Katzman, & Palmert, 2012)	Bant App	-Analysis of the concept of gamification by routine behavior change -Actions were rewarded in the form of iTunes music and apps.	-Positive behavior change for rewards -Actions rewarded in the form of iTunes music
(Oinas-Kukkonen S. L., 2012)	Fizzy drink	-Aim to encourage behavior change - System sent reminders to users for less consumption of fizzy drinks	- Persuasive reminders change behavior

In the following section, the implementation of gamification in design and how will that encourage patients to use a mobile app to support their self-management.

2.4.2 Gamification and Data Visualization

In the context of self-management in pregnant women with gestational diabetes, gamified design can be used to encourage patients to adhere to their structured lifestyle. Gamification is an informal term used to describe how game-design features are applied in non-gaming contexts (Johnsona, et al., 2016).

The study was done by Cafazzo, in which users were awarded points for loading blood glucose values from a Bluetooth connected glucometer. Once a sufficient number of points were accumulated, the user was able to redeem the points for an iTunes reward. The pilot evaluation of study showed that the daily average frequency of blood glucose measurement increased 50% (Cafazzo, Casselman, Katzman, & Palmert, 2012). User satisfaction was high, with 88% (14/16 participants). The results were positive, as the number of blood glucose readings significantly increased. This study supports that the concept of gamification can be implemented in this thesis project, whereby routine behaviors and actions can be rewarded to patients. In a paper that discussed games for health, a couple of applications were analyzed to find out if to gamify or not. This empirical study (Kari, Piippo, Frank, & Moilanen, 2016) on the usage of selected exercise application Sunnto Movescount shows that the use of an application enhances the awareness of one's physical activity and progress, and in most cases, it increased one's motivation to be physically active. In this study, gamification was found to have a potential impact on motivating the users to exercise. Study details about positive user experience results but lacked to provide details on the usability of the applications. Regarding having efficient application for gestational diabetes, it is important to consider the usability of the application along with user experience.

Another research (Daniela, Danilo, Federica, Mario, & Ester, 2017) shows that the structured lifestyle enhances positive diabetes self-management behaviors such as controlling carbohydrate intake, weight, exercise, and controlling blood glucose. In gestational diabetes data collected for an individual patient can be massive and difficult to interpret (Bellazzi & Abu-Hanna, 2009). However, it is important for patients and their healthcare providers to regularly survey this data to maintain a good understanding of how the disease is being managed. The paper records, although helpful with tracking data, does not provide the patient with useful information at a glance when filled out. Electronic tools can provide a means for turning this data into rich visualizations. Harris (2010) has assessed the feasibility and acceptability of using mobile phones by extending an existing web-based system to a mobile platform and tested tabular and graphical feedback of blood glucose meter uploads for desirability. Mobile glucose meter uploads combined with graphical and tabular data feedback were the most desirable system features tested. Participants had a mixture of positive and negative reactions to an automated and tailored messaging feedback system for self-management support. Participants saw value in the mobile system as an adjunct to the Web-based program and traditional office-based care (Harris, et al., 2010).

Data visualization feature can make a wide range of mHealth applications more intuitive and productive. However, the mobility context and technical limitations will raise few challenges (Chittaro, 2006). Presently diasend is a system, which uploads patient’s blood glucose meter readings and displays them in a clear format to help pick up patterns. Doctors and Patients review blood glucose results using Diasend data at clinics or home on computers or laptops.

2.4.3 Summary of Related Work

Gestational diabetic patients are encouraged to collect a significant amount of data from the day they are diagnosed. This information has typically been recorded in a paper logbook or kept stored in a glucose meter and is reviewed when prompted by their care team. With the increasing popularity of mobile devices (Statista, 2017), the next logical step would be to develop mobile applications that can help support patients in their gestational diabetes data collecting endeavors and also utilize persuasive technology to provide useful feedback.

In this chapter, several mobile applications were reviewed with a focus on exploring specific design features. There has been some benefit demonstrated in studies that have attempted to include like form of photographic log for carbohydrate calculation and option to go back and enter glucose level, activity data, carbohydrate count data manually in mobile self-management tool. However, users may need to be more encouraged to enter data and follow structured lifestyle as required in gestational diabetes. Gamification techniques like rewards, reminders may be the solution to continue user engagement. They can be considered in the design, as they work best to meet certain goals. Visualizing the collected data was found to be useful, but there is a need to create designs. Finally, the introduction of conversational agents is seen as the medium to traverse persuasive technology to motivate and change the behavior of patients.

2.5 Systematic Review and Meta-Analysis

Systematic literature review (Unertl, Novak, Johnson, & Lorenzi, 2010) for digital support for gestational diabetes, peak to the need for more studies on patient interaction, system usability and self-management in the field of mHealth. This systematic review and meta-analysis were conducted following the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement (Moher, Liberati, Tetzlaff, & Altman, 2009).

To establish rigor in the review process, firstly, it was necessary to determine and follow a search strategy (Kitchenham, 2004). A literature search with no language restriction was performed using PubMed, MEDLINE, ACM Library, Google Scholar, Research Gate, etc. databases to identify relevant studies published until Sep 2017. The review included the study of the prevalence of gestational diabetes, monitoring techniques of GD, controlling GD and conversational agents followed by analysis of mobile health monitoring services, service design frameworks and surveys on gestational diabetic patients in Bergen Norway was done. The systematic literature review helped in analyzing the limitations of the existing system and GD patient challenges. As an initial step, combinations of the following MeSH terms and keywords were used (but not limited to) to search the different databases. These includes “gestational diabetes”, “glycemic control”, “self-management”, “Human computer interaction”, “Data visualization”, “self-monitoring”,”conversational agents”, “smartphone”, “mobile applications”,“Mobile health”, “Gestational diabetes”, “Norway health”, “mobile interventions”, “self-motivation”, “Behavior change”, “mobile app for diabetes”, “gamification”, “persuasive systems”, “HCI and design and conversational agents”, Design Science Research methodology, “mHealth and Gestational diabetes”, “diabetes and HCI”.

Preliminary searches aimed at both identifying existing systematic reviews and assessing the volume of potentially relevant studies. Then, selection of articles was based on few predefined criteria like, would be peer-reviewed, would be in English language only, would have smartphones as a mode of communication throughout the intervention, would include mobile applications based interventions on Gestational diabetes.

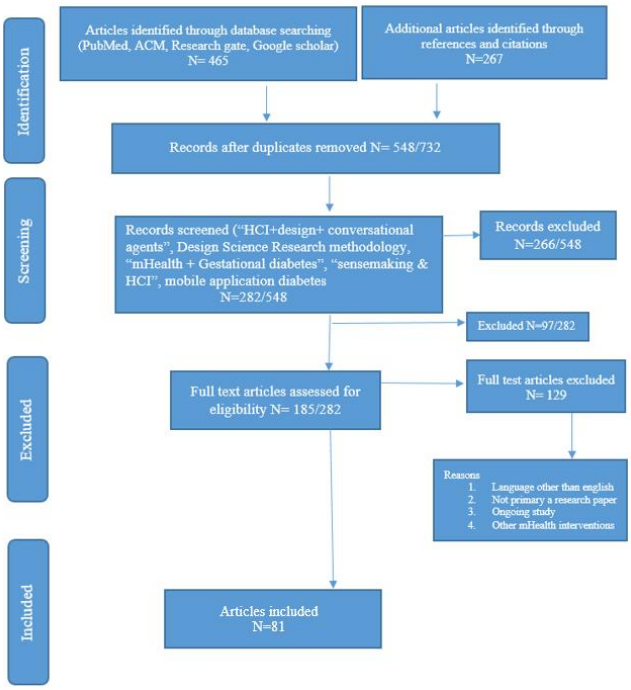


Figure 8: Systematic Review and Meta-Analyses

Few of the inclusion criteria for the mobile app were like support for blood glucose monitoring as a minimum requirement, the patient as the intended primary user of the application, and the application to be used as an enabler for diabetes self-management by supporting one or more of the self-management tasks. Exclusion criteria's included duplicate applications, applications where the sole purpose is to educate the patient about the disease, applications without an English-language user interface, and applications intended exclusively for healthcare professionals.

Figure 8, elaborate the complete process of literature review for my thesis work whereas table 1 (refer section 2.4.3 above) details the literature related to various application related to same field of research. According to the literature review, currently, there are thousands of applications in the online stores, which are associated with mHealth. Virtually the 95% of the applications are concerning diabetes (not gestational diabetes), but only 1/5 of these essentially help in the self-management of the diabetes disease. Furthermore, at this point in time, there are not any strict quality control criteria for all these applications.

None of the mobile application for Gestational diabetes patients was found with integration to conversational agents. Only a few studies were carried out in different countries.
Most of the studies had self-monitoring. Some major gaps identified in the literature review include:

1. None of the studies includes a system framework or design component for sense-making.
2. None of the studies was on the use of conversational agents for gestational diabetes patients.
3. None of the studies includes user acceptance tests of Gestational Diabetic patients for diabetes management.

Chapter 3: Methodology

For this study, the following research question was outlined:

1. *How to design mHealth application for gestational diabetic patients that can guide the user towards attainable goals?*

2. *How to introduce conversational agents in such designs and how will users perceive these designs?*

This chapter presents an overview of the methods and techniques used to design a prototype as an answer to the stated research question. The focus of this chapter is to give a justification of choices made in regards to research design, methods, and techniques used for designing PregDia.

3.1 Design Science Research

Design science research (Vaishnavi, 2015) refers to the overall strategy that is chosen to integrate the different components of the study coherently and logically, thereby, ensuring the research problem is addressed effectively.

The purpose of research is seen as the production of knowledge that can be used by others in different areas other than the problem area on which the producer of knowledge is working on. Whereas the purpose of design is the creation of a specific solution to be applied in the world (Giaccardi, 2017). Nevertheless, some differences are often noted (refer table 2):

Table 2: Research and Design

	Research	**Design**
Purpose	General knowledge	Specific solution
Result	Abstracted	Situated
Orientation	Long-term	Short-term
Outcome	Theory	Realization

In general, the terms research and design carry different connotations. Despite such differences, design and research activities are surprisingly similar as both aim to create something new, building on what was known before. These are referred as “Research For Design” and “Research Through Design (RtD),” respectively (Giaccardi, 2017).

This thesis study uses research through design (RtD) as a framework for guiding the research process to scientifically construct a prototype and produce knowledge from the said prototype.

3.2 Research through design

This section will explain the methodological framework for my master thesis project.

The term research through design (Stappers, Visser, & Keller, 2014) indicate studies in which knowledge is generated on a phenomenon by conducting a design action that is the prototype(see chapter 5), and evaluation (see chapter 6) of the design results in practice.

Zimmerman, et al (2007) has sought to differentiate design practice from design research. They have proposed a model of how to conduct HCI research, they emphasize how interaction

designer work to create the “right thing”: “a product that transforms the world from its current state to a preferred state” whereas industry practitioners of design focus on making commercially successful products.

3.2.1 Problem Identification

Wicked problems are central to RtD. This problem refers to that class of problems, where there are many clients (patients, doctors, nutritionist, etc.) and where the ramifications of the whole system are thoroughly confusing. (Churchman, 1967).

To address such wicked problems in design research, the RtD framework postulates that interaction designers should Integrate the true knowledge (the models and theories from the behavioral scientist) with the how knowledge (the technical opportunities demonstrated by engineers). Design researchers ground their explorations in real knowledge produced by anthropologists and by design researchers performing the upfront research for a design project. (Zimmerman, Forlizzi, & Evenson, 2007).

In the case of this study, the “wicked problem” tamed was by using persuasive system design model (see section 2.3.1) for developing conversational agents (see section 2.3.1) in the mHealth application. mHealth application will solve the problem of gestational diabetic patients by use of conversational agent and persuasive technology for self-management (see chapter 5).

To define a problem space for this challenge I have participated in workshops, observations, conducted interviews and surveys (see section 4.1) organized in close coordination with Helse Bergen for project “GraviDia.” Participants were from various fields ranging from researchers, doctors, patients, dieticians, design professionals and expert users. In the workshop, all met together to discuss and share ideas that cumulated in self-management with conversational agent technology for addressing the previously mentioned problem.

3.2.2 Evaluation of Design

In any research paradigm, there is the need for criteria to evaluate what is sound research. Zimmerman et al. (2007) set out some guiding principles for evaluating prototypes in regards to providing the scientific community with the knowledge that can be built upon. These principles are Processes, Invention, Relevance, and Extensibility.

The first principle is processed, which is considered as one of the critical elements for judging the quality of an interaction design research contribution. Interaction design research cannot be reproduced, as artifacts of design research are unique and reproducing a project’s process may not provide same results. Therefore quality can be judged by analyzing if the research was applied with rigor, what was the rationale for choosing methods and decision on design choices. Additionally, the novelty of a design process is critical (Zimmerman, Forlizzi, & Evenson, 2007).

An artifact created through research must explain the significant invention, which is the second principle. That can be achieved through a thorough literature review that can demonstrate the community that how the contribution advances the research community (see section 2.4.3). As mentioned earlier, there can be no expectation that two designers given the same problem will come up with identical artifacts. It is important that instead of applying this criterion of validity that is central to behavioral sciences, design research should argue for its relevance, which is

the third principle. That is, how the process is framed concerning the real world, and why it is an important problem to solve by design research.

The last principle is Extensibility that is the ability to build on the resulting outcomes of the interaction design research. It could be by either employing the process in a future design problem, or understanding and leveraging the knowledge created by the resulting artifacts (Zimmerman, Forlizzi, & Evenson, 2007). That means a research through design study could result in design considerations or design implication, which future research could build upon.

Concluding this thesis, a thorough discussion of what was found in the construction (see chapter 5) and evaluation (see chapter 6) of the proposed design is presented in chapter 7. From this discussion, some design principles for further work in this field is proposed for other design researchers to apply when tackling similar challenges.

3.3 User-Centered Design

Human-computer interaction research and practice have focused on designing human-centered technologies that fit into the everyday needs and routines of the people who use them, often referred to as a user-centered design. As mentioned in section 2.1, the term 'user-centered design' originated in the 1980s (Norman & Draper, 1985) when HCI proposed the focus to involving users at early stages of interaction design.

In the development of products, there is a huge need for the projects to have a user-friendly interface, as it can determine the success of the product (Bannon, 1991). Involving users in design in one way or another has been shown to lead to developing more usable satisfying designs. A case study on the actual use of User Centered Design (UCD) investigates that UCD tends to improve product's technology, usefulness, and usability by giving prime attention to key areas such as user experience, end user involvement (Vredenburg, Mao, Smith, & Carey, 2002).

Whereas a multi-method study on reminders (Oinas-Kukkonen S. L., 2012) shows that user involvement in the design, implementation, and evaluation of persuasive information systems could highlight insights that are rather hard to obtain from statistical data alone (McGee-Lennon, Wolters, & Brewster, 2011). In this research project, the common techniques of UCD employed to guide and evaluate the design process were personas and scenarios.

Personas

As defined by Cooper, a persona is a fictitious, specific and concrete representation of target users (Cooper, 2004). The goal of persona is to help the product teams better understand the users and thus improve their products. The user-centered design approach is about making users the center point for all research, concepts and design choices. Here users refer to the end target audience who will use the product/service (Abras, Maloney-Krichmar, & Preece, 2004). For this study, personas were used primarily for communicating an archetype of a possible user (see section 5.1.1). Personas were elicited from workshops held with potential users and stakeholders at Helse Bergen (see section 4.1.2).

Scenarios

Scenarios are narratives, usually in written form, that describe how users use the conceived product to perform a certain task. Rosson and Carroll mention that scenario descriptions can be very useful in managing the tradeoffs of usability engineering (Rosson & Carroll, 2002). For

example, scenarios are both concrete and flexible. The concrete and flexible character of scenarios address the tension between wanting to make progress quickly but at the same time keeping the design space open for further changes. To achieve this, the scenario should not be too abstract and should not omit details concerning history, motivation, and personality of users. It makes them less engaging than real stories, and it makes it more difficult to identify with the main characters. There is, therefore, need to write more personal scenarios (see section 5.1.2)

3.4 Prototyping

RtD indicates a study in which knowledge is generated on a phenomenon by conducting a design action, drawing in support knowledge from different disciplines, and reflecting on both the design action, an evaluation of the design result (Usability) in practice (Stappers, Visser, & Keller, 2014).

About this thesis work, prototyping is an initial instantiation of a concept as part of the product development process and is an essential part of evaluating design ideas. Preece, Sharp, and Rogers say that prototypes are "manifestation of a design that allows stakeholders to interact with it and to explore its suitability if it is limited in that, a prototype will usually emphasize one set of product characteristics and de-emphasize others" (Preece, Sharp, & Rogers, 2015).

In designing for interaction, it is important to distinguish between three main types of prototypes: low fidelity, medium, and high fidelity prototypes. Fidelity describes how well prototype resembles the final product. A low fidelity prototype differs from the final product in things like interaction, visual expression or level of detail (Miriam Walker, 2002). Such a prototype can, for example, be made out of paper rather than screens on a computer.

Medium fidelity prototype refers to "visualization of design ideas" as a depiction of concepts, design alternatives, and screen layouts." Prototypes of this modality are limited in function and interaction. Common for these is the necessity of a facilitator for the demonstration of testing of the prototype. Mockups, paper prototype (Justin, 2012) and wireframes are concepts that fall into this category.

High-fidelity prototyping, on the other hand, should have the complete functionality and interactivity of the intended final design (Rudd, Stern, & Isensee, 1996). They look and act like the future product. Due to their high fidelity, they are commonly used to make detailed prototypes. There is a risk that the prototype is experienced as final, at which it may become difficult to generate new design proposals.

Comparison between high fidelity prototypes and low fidelity prototypes made of paper and made on computer show only small differences in the kinds of usability issues raised. (Johansson & Arvola, 2007) A case study concludes that one should choose a prototyping technique according to what is most practical for the situation and it is impractical to implement a working product for evaluating emerging technologies especially when one cannot decide what architecture or platform will be used for implementation (Youn-kyung Lim, 2006).

For a detailed comparison of low, medium and high fidelity modalities of prototyping refer Table 3.

Table 3: Differences between low, medium and high fidelity prototype

	Advantages	Disadvantages
Low Fidelity Prototype	Low development cost Evaluate multiple design concept Useful communication device Address screen layout Issues Useful for identifying requirements	Facilitator driven Limited utility after requirement gathering Navigational and flow limitation Poorly detailed specification of code
Medium Fidelity Static Prototype	Low development cost Evaluate multiple design concept Useful communication device Address screen layout Issues Useful for identifying requirements Complete functionality User Driven	Facilitator driven Poor detailed specification to code
High Fidelity Dynamic Prototype	Complete functionality Fully Interactive User Driven Clear definition of navigation Look and feel of final product	More expensive to develop Time-consuming to create Not effective for requirement gathering

3.5 Usability Evaluation

In research through the design process, once the prototype is designed it needs to be evaluated in real-world settings to gather data on how proposed design choices are perceived by potential users and domain experts (Gaver, 2012). Evaluation data received from these iterations, form the basis for a rationale and defines the design choices in next iteration.

For the design process that resulted in PregDia, presented in this thesis, each iteration's contribution was evaluated to determine how to iterate the design process further. Cognitive walkthrough evaluation was conducted to give a group of domain experts, clinicians, and patients, a sense of where PregDia was headed. Their continued feedback shaped the design process. Table 4 gives an overview of the conducted evaluations throughout the design process.

Table 4: Overview of design evaluation presented in Thesis

Design Phase	**Evaluation Type**	**Participants**	**Section**
Iteration 1 Conceptual design	Domain expert evaluation	1	5.1.4
Iteration 2 Story Boards	Domain expert evaluation	1	5.2.3
Iteration 3 Low-fidelity prototype	Cognitive Walkthrough	5	5.3.3
Medium fidelity Static prototype	Think-Aloud protocol	4	6.0

3.5.1 Cognitive Walkthrough

A cognitive walkthrough is a usability inspection method that emphasis on completion of the task. By using this technique users' goals can be identified, how they attempt these tasks in the interface, then very thoroughly identify problems users would have as they use an interface.

For each action a user has to complete a task, a reviewer needs to describe the user's immediate goal and answer pre-defined questions. It may come as no surprise that one of the biggest

complaints about using the cognitive walkthrough method is how long it takes to answer each question (Wharton, Bradford, Jeffries, & Franzke, 1992).

Spencer mentions that this issue can be resolved by streamlining cognitive walkthrough technique in which you evaluator ask only two questions at each user action (Spencer, 2000). That summarizes that by reducing the number of questions and setting up guidelines for the evaluation team cognitive walkthrough can overcome this issue.

3.5.2 Think-Aloud Protocol

Usability testing methodology used for final iteration was Think-aloud, a recommendation from Nielsen (Nielsen, 1993). It states that in thinking aloud test, test participant is asked to use the system while continuously thinking aloud, that is, simply verbalizing their thoughts as they move through the user interface.

> *"Simply" ought to be in quotes, because it is not that simple for most people to keep up a running monologue. The test facilitator typically has to prompt users to keep them talking.*
>
> - (Nielson, 2012).

As recommended by Nilsen (Nielsen, 1993), three main requirements must be prioritized to run a basic thinking aloud usability study; First, recruit representative users, Second, give them representative tasks to perform, and Third is let the users do the talking. According to the recommendations by Nielsen, 3-5 users should able to identify about 85% of all usability problems. Once participants are selected, it is important to develop a plan for the test.

(Joe, Chaudhuri, Le, Thompson, & Demiris, 2015) A study done by to evaluate the usability of a multifunctional wellness tool was accomplished with a think-aloud protocol, states that as users are asked to verbalize their thoughts while they complete various tasks, investigators should gain insight on participants' thought processes about the interface and task (Jeffrey Rubin, 2008). Sessions in think aloud include a single participant and a facilitator and designated note-taker, who observed and took notes as the participant worked through the various tasks. Joe et al (2015) also mentioned that a good facilitator must make sure not to cut off or intervene the participant too early, as this may cause users to give up earlier in the subsequent tasks, or encourage them to look to the facilitator for help in completing the tasks.

One of the major reason for choosing this methodology was the flexibility it offers to ease the test participants while testing. Krahmer and Ummelen (2004) mention about this in the study of "think aloud protocol" testing by two different type of verbal protocols on navigation problems for a highly nonstandard website "Mulisch." First type protocol did not allow the experimenter to interact with the subject, except for a keep talking reminder when a subject falls silent. Whereas second protocol was different as the experimenter gave "mm-hmm" tokens as feedback and as reminders to continue verbalization. Study results (Krahmer & Ummelen, 2004) shows that the process of thinking aloud did not seem to be affected by the type of approach that was used. In the two conditions, subjects used equal numbers of words and equal numbers of clicks as well. Table 5 briefs few more advantages think aloud protocol as mentioned by (Nielson, 2012).

Table 5: Advantages of Think-Aloud protocol for usability testing

Advantages	Description
Cheap	No special equipment is needed
Robust	Get reasonably good findings, even if a study run is poorly
Flexible	Method can be used at any stage in the development lifecycle
Convincing	The most hard-boiled developers, arrogant designers, and tight-fisted executives usually soften up when they get direct exposure to how customers think about their work/product
Easy to learn	Can be learned in a day or two

3.5.3 Usability Measurement

There isn't any direct usability measurement tool to find the usability of an application. Instead, evaluation relies on the impact of good and bad usability results to assess the quality of the user experience. (Sauro, 2011) Has recommended 10 metrics that can be used in any usability evaluation. These are task completion rate, usability problems (UI problems), task time, task level satisfaction, test level satisfaction, errors, expectations, clicks, conversion and single usability matrix. All of these were considered in analysis evaluation results (refer chapter 6). Whereas scenarios & questionnaires are used as supporting tools to conduct the usability test of a prototype.

(Mifsud, 2012) mentions that paper prototyping is a simple technique that has been effectively used since the 1980s for usability testing and is likely to continue to be used with a guaranteed degree of success for many more years to come (Mifsud, 2012). (Thomas, 2015) Recommends using questionnaire both before and after the usability test to evaluate the usability of the test. He also explains while using system usability scale (SUS) use ten usability related statements, half of which are positively written and the other half negatively written, to measure usability of the design.

These tools and techniques are used in chapter 6 while evaluating the results of usability.

3.6 Chapter Summary

This chapter detailed the research design of the study presented in this thesis.

Research through design-framework was applied to find answers that are extensible to other research projects. To develop this research project the principles and common techniques of User-Centered Design were employed to guide and evaluate the design process. Later, evaluation techniques and methods for usability in the design process were described, and evaluation methods for researching empirical evidence of the use of the constructed prototype are detailed in chapter 6.

Chapter 4: Requirement Gathering and Analysis

Qualitative research was carried out to develop a deeper understanding of Gestational diabetic patients. The main goal was to understand their challenges and to generate a theory about what their requirements would be from a mobile self-management support application. Since the focus of this stage was to understand the gestational diabetic patients, an ethnographic research approach was taken for the requirements analysis. (Jackson & Verberg, 2006) summarized the ethnographic research activities into three phases: pre-field, fieldwork, and post-field.

4.1 Requirement Gathering

In this thesis, ethnographic methods complemented with the user center design were used to develop an understanding of the user, their tasks, and their environment. Figure 9 below depicts the relationship between ethnography and UCD. A literature review from a pre-field method has been discussed in section 2.3 and section 2.4.

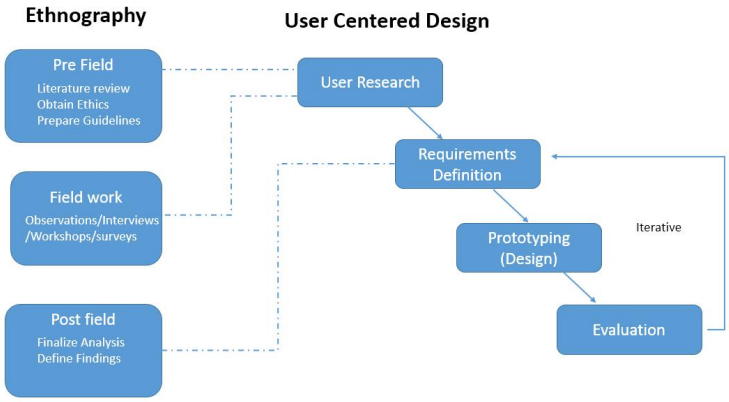


Figure 9: Ethnography and User-Centered Design

Fieldwork started with an initial meeting with the project manager from Helse Bergen about project "GraviDia." This meeting was to make myself familiar with the existing material around the project, as well as the basis for the idea at the Innovation Camp 2015. At innovation camp 2015, Women's clinic Bergen Norway, wants to investigate the need for digital tools that can help to improve the user experience for pregnant women with diabetes and gestational diabetes. Project manager introduced me to Knowit team, who was responsible for prestudy for Helse Bergen. This initial meeting concluded-

Problem statement "Self-management of Gestational Diabetes" is true, and various research sectors like healthcare (at Haukeland) and ICT experts (at Helse Bergen) are looking for solutions.

The main components of fieldwork utilized in this research were surveys, observations, workshops and semi-structured interviews. Brainstorming was also included in this phase as the results from this activity contributed to defining themes and design ideas used to guide the development of questions for the semi-structured interviews. Figure 10 below depicts the overall approach taken to solve the design problem.

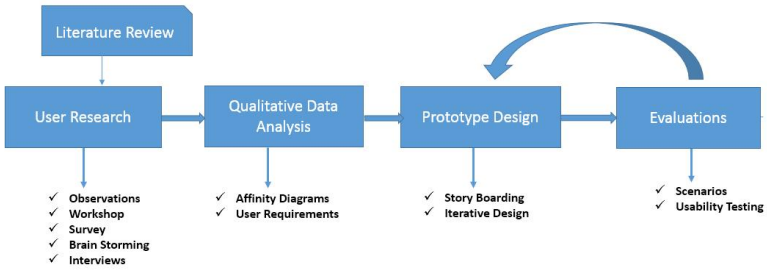


Figure 10: Design Approach

The following sections describe the methodologies and subsequent analysis in detail.

4.1.1 Observations

This phase focused on understanding the current patient flow focusing on challenges and potential. It was achieved with simple tasks and observations of applications, systems and physical space around the patient and health care providers at KK. This was achieved by joining the Knowit interaction design experts that were interviewing the process participants. It included interviews of:

- One midwife from clinic
- One midwife from KK
- Three pregnant women with gestational diabetes
- Two senior consultants from the maternity clinic / KK
- One nutritionist
- One doctor internist

Other than that observed facebook group “svangerskap diabetes” for 4 months. Observation on Facebook group gave me an insight, how patients can give emotional support to one another. Most importantly how they exchange advice, tips and information (e.g., about snacks or recipes, events and initiatives, interesting books or articles and so on).

4.1.2 Workshop

Helse Bergen and Knowit organized this workshop. It consisted of a four-hour workshop with participants that included former patients, the project team and stakeholders of Innovation Camp 2015 at Helse Bergen. Participants were given a presentation of the key findings and the opportunity to discuss among themselves what was the most revealing insights in the form of group assignments focusing on empathy and user needs. Attending this workshop was an important part of the mapping of the desired patient care also focusing on a better and closer collaboration between health professionals.

Exercises like “putting yourself in patient’s shoes” were of great use. At the workshop, the discussion was done by the experts. It outlined the problems faced by patients and doctors at Kvinne Klinikken. The objectives of this study were:

- To understand barriers that impact lifestyle modifications by women with GD
- To gain an understanding of the ongoing prenatal and postpartum needs of women with GD
- To discuss implications for best practices, health policies and future concerning Gestational diabetes prevention in “at risk” women

Overall, the main point of discussion observed was on the different type of patients in a different type of situations struggling to manage the blood glucose, diet, etc. How best they regulate and keep it within the target range, also, a lot of emphases was placed on the carbohydrate measurement. Figure 11 below summarizes the common factors discussed that contribute to fluctuations in blood glucose.

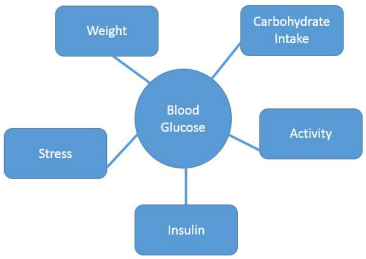


Figure 11: Common factors that affect blood glucose

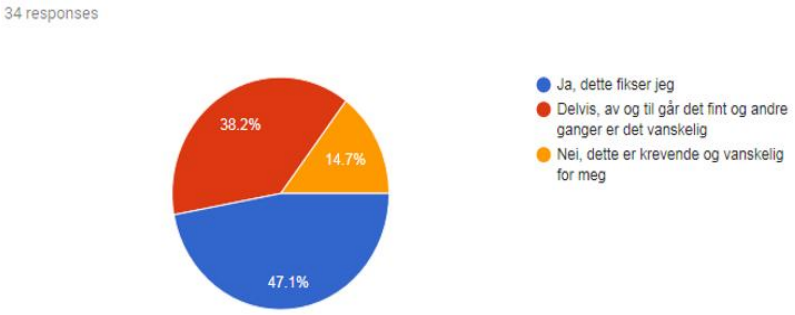
Another important factor that came from the workshop was the ethnicity of patients. Dietician and other doctors mentioned food habits and language of different ethnicity sometimes create hindrance in the treatment process. Literature research also shows that (Stene, Strøm, & Gulseth, 2017) many immigrants from South Asia, are at higher risk of gestational diabetes than ethnic Norwegian women.

This observational study of patients at the Kvinne Klinikken Hospital Gestational diabetic patients was extremely helpful in developing a deeper understanding of patients, situation and self-management requirements at home care. This understanding helped in formation of Personas (see section 5.1.1) and Scenarios (see section 5.1.2). It was valuable to observe and learn more about what was expected of them from a self-management perspective.

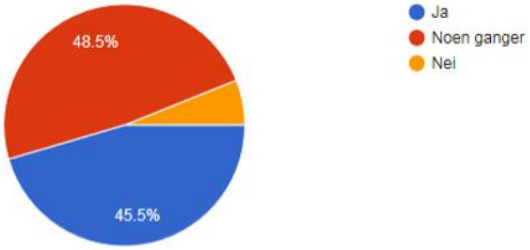
4.1.3 Surveys

The questionnaire was made in close coordination with ICT and health care experts at a working meeting in Helse Bergen. Google forms questionnaire with multiple options was mailed to facebook groups “svangerskapdiabetes” and “diabetes før svangerskap .“ The identity of users was completely confidential. Purpose of this survey was to determine how much knowledge patients at present have about the problem, are they getting enough health care support on time, how to these patients currently diagnose and manage gestational diabetes and what is there approach towards mHealth technology.

55 responses were received. 34 responses received from svangerskapdiabetes are considered in this study and can be found in annexures attached. Feedbacks from “diabetes før svangerskap” were excluded, as I was not able to reach any user for evaluation, who have diabetes before pregnancy. For a detailed overview of survey questions refer, and results refer appendix 1. Figure 12 shows that only more than 50% patients feel that they don’t have enough knowledge about diabetes. Whereas same results were found on health care service availability. More than 50% patients reported that they are not able to reach health care personnel when they need them (refer figure 12).



Figur 12: Percentage of people feel they have enough knowledge about the disease



Figur 13: Percentage of people feel healthcare specialists are available when they need them

45.5 % of patients agreed to use mobile application for gestational diabetes whereas more 50% patients reported that they are confused, or they do not need (refer figure 13). Survey results also find that few patients are using mobile applications that they found themselves (refer figure 14) but wish to have an application that is from health personnel (refer figure 15).

Figure 14: Percentage of users with a mobile application for gestational diabetes

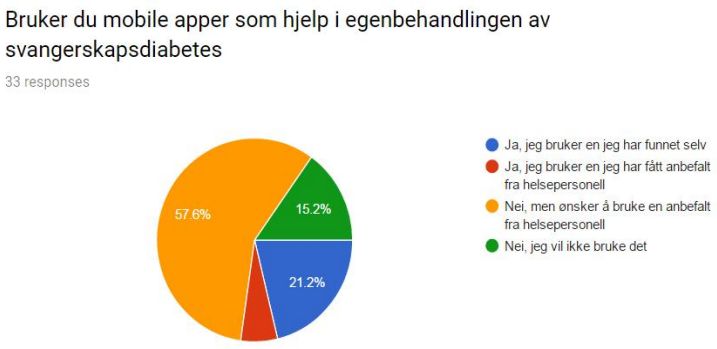


Figure 15: Percentage of patients wish to use mobile application for managing GD

Survey results show only 6/34 patients feel that presently the information received is motivating (refer appendix 2). More than 50% patients are not sure about the information in next appointment. It is a critical factor (refer appendix 2).

As patients have to sometime spend 3-4 hours for diagnoses at doctor's clinic, it makes them more stressed. For few tests patients have to starve for a longer time, it becomes difficult for them to manage if they arrive at the clinic without preparation. Survey also shows that once diagnosed with GD; patients reach a different set of service providers (refer appendix 2) for, e.g., few consulted a General practitioner, few gynecologist, and few approached midwives.

It shows lack of awareness. As doctors and midwives cannot be available all the time to support or guide patients, for information patients reach different sources other than consulting doctors/midwives like internet, books. Unfortunately, one cannot completely rely on the information received from these sources.

These survey results show a great need to support the gestational diabetic patient with home health care. For detailed survey results refer appendix 2.

4.1.4 Brain Storming

Although brainstorming is not typically considered a means for collecting and defining user requirements, it is an effective tool to develop and collect many design ideas in a group setting. The session was approximately an hour in duration at Helse Bergen. Following a brief review of the findings from innovation camp, previous workshops, and survey results, any and all ideas were welcomed. As a result of the session, the following four design features were listed as 'most wanted':

Conversational Agent: That should be available to support patient whenever needed. The purpose of the agent would be to introduce a competitive element to the mobile app with the goal of motivating users to update data and adhere to standard parameters.

Statistic: A statistic would display how well the targets are achieved by performing as a whole concerning blood glucose readings. In other words, this feature would display the average blood glucose whenever a user is uploading her reading.

Progress Bar: The purpose of this feature would be to display information regarding a user's overall 'status' for the day. In addition, since the application leverages points to encourage certain behaviors, letting the user know how far they are from achieving their next reward is important.

Encouragement Algorithm: The purpose for this to encourage user for uploading a reading and reward them for positive behaviors such as loading a reading within range or resolving a negative trend.

Appointments: This feature will detail about next appointment. The benefit of this feature is that patient can prepare for next appointment questions and answers.

The discussion of these features was a good starting point for beginning to map out and visualize the app. It also helped guide the questions for the semi-structured interviews regarding whether specific design features would be appropriate for all users or not.

4.1.5 Semi-Structured Interviews

The next stage of requirements gathering involved conducting interviews with Gestational diabetic patients. The recruitment inclusion criteria were, English speaking and who had been diagnosed with Gestational Diabetes. A total of 6 participants were recruited. Interviews were conducted at the location's agreed with patients one-hour each in duration. Data collected through the literature review, workshops, observational research, and brainstorming session helped to guide the development of the semi-structured interview questions (refer table 6).

Participants were asked to fill pre-interview questionnaire (refer appendix 3), followed by an interview. Particular areas of interest included effective data monitoring and visualization, Social Support, and sources of motivation. In addition to being asked questions, participants were shown and encouraged to provide feedback on rough paper sketches please refer to appendix 4. These were simple sketches drawn by hand, the purpose of this activity was to collect preliminary design feedback and to determine which design features, is most appreciated by users. The following section outlines the analysis performed on the data collected from these patient interviews.

Table 6: Interview questions

Category	**Questions**
Social Support	1. Who do you typically share your blood glucose information with? When do you share? How frequently you share and why? 2. What type of information do you typically share and with whom? What motivates you to share that information with others? 3. How often do you talk about your diabetes with others? 4. How does sharing information help you? 5. Overall, what do you like most about your current information sharing practices? What would you like to improve or change?
Data Visualization	1. How do you currently track and record information related to your diabetes management? 2. What information do you record and why? How often? 3. How and when do you review and interpret your blood glucose results? 4. What tools do you employ? 5. Do you ever look back through your logs? If so, how far back do you go and why? 6. When you do make changes to your routine, what do you base your decisions on and why? 7. Overall, what works well in your current information capture and review practices? What would you like to change?
Motivation	1. What keeps you motivated to stay on track with your self-management practices? 2. Do you ever set goals relating to your self-management practices or overall health? If so, how do you set out to achieve them? 3. Do you currently use any mobile apps? If so, what keeps you interested in the app?

4.2 Qualitative Data Analysis

This was a qualitative study with the aim of deeper understanding and exploring women's experiences of gestational diabetes and their perceived needs, using a conventional content analysis approach. Data were analyzed using the conventional content analysis method. The qualitative content analysis is one of the classical procedures for analyzing textual material,

no matter where this content comes from – ranging from interview data, surveys to online material (refer section 4.1).

Data collected was in the form of notes, photographs, sketches, and tasks (refer appendix 5) from the interviews. Each of the six participant interviews was transcribed while keeping them anonymous (refer appendix 3), participant statements were printed, and highlights were mounted onto cards (label making) for easy grouping. The next step involved organizing the information into groups. The content was classified by interview category: information sharing, data visualization, design elements (comments on preliminary sketches), and motivation ideas. The statements could have been categorized one level further into answers for each question; however, to allow original ideas to diverge, the cards remained in the larger groups of categories. The resulting data from the grouping activity are outlined below in the table 7.

Table 7: Data Analysis (semi-structured interviews)

Information Sharing	Data Visualization	Design elements and Motivation
1. Motivation: The motivation behind sharing diabetes-related information with others. 2. Online: Opinions and behavior are towards online information sharing practices. 3. Recipient (who): The individuals who are likely to be the recipient of the information shared. 4. Content: A cross-section of the type of information that patients choose to share. 5. Frequency: The frequency of which information is shared with others. 6. Social: Participation in diabetes communities either online or in person. 7. Questions: How to handle diabetes-related questions between clinic visits.	1. History: How far back patients look through data collected. 2. Data Loads (Frequency): The frequency with which BG readings and other information is recorded or loaded. 3. Data Tracked: The information that is tracked. 4. Tools Used: A summary of the various tools used to assist with data tracking. 5. Making Decisions: Insights into how decisions related to diabetes self-management are made. 6. Making Changes (Frequency): How often changes are made to self-management routines.	1. Desired Features: Features that participant looks for in a mobile application. 2. Data Organization: The preferred way to view data. 3. Color Meaning: Color's associated with high and low BG readings

4.3 User Requirements

With the data from the interviews organized into category and sub-category, the next stage of the process was to translate the groupings into user requirements. This data analysis concluded the problem space of gestational diabetic patients and gave an overview of their expectations from PregDia.

Borrowing aspects of persuasive design model (refer section 2.3.1) findings identified from qualitative data analysis was related to design principles that were used to the guide prototype development.

Table 8: Mapping user requirement and Design principle (Borrowing aspects from PSD Model (Oinas-Kukkonen & Harjumaa, 2009))

Category	Findings	Design Principle
Information Sharing	1. Patients share diabetes-related information with close family members, few friends, doctor, dietician, and midwives. 2. Patients are not interested in sharing with an open online community. 3. Sharing information helps patients and friends to better understand gestational diabetic condition 4. The majority of patients have an online presence (i.e., Facebook, etc.), but only a few of them use them as a means to discuss GD.	1. The app should provide users with a means to share information related to their diabetes with close family and doctors 2. The app should not link to a pre-existing online social community. 3. Send information to doctor and close family member if out of threshold for 3 consecutive readings
Data Visualization	1. Patients most frequently track and record the following information: carbohydrates, blood glucose, weight, and activities. 2. Patients make adjustments to their self-management routine based on how they are feeling (physically/emotionally), BG lows and highs, as well as on insulin and carbohydrate intake. 3. Logs are reviewed every day. 4. Recording information is time consuming. 5. Patients associate the color green with being in range. However, there is no consensus on a color code for low and high readings (blue, orange, yellow, red were few of the options).	1. The app should present data in one-week increments as far back as nine months. 2. The act of recording data into the the app should be fast, easy, and straightforward. 3. The app should allow users to keep track of and review their physical and emotional well being. This data should be displayed with other recorded data. 4. The app should allow users to record and track their blood glucose, carbohydrate intake, weight, and activities fast and in easy way. 5. The color green should be used to indicate in range readings and red to indicate out of range readings regardless of whether the values are high or low (as red is commonly known to represent 'danger'). In general, app should follow color guidelines
Design Elements	1. Being aware of average blood glucose and the percent of readings in and out of range is helpful to know. 2. Reviewing a summary of data by day (time on the x-axis) is more clear and valuable than seeing data summarized by context.	1. The app should clearly display the users average BG and the percent of readings that are in and out of range. 2. The app should provide a summary of collected data by day.
Rewards/ Motivation	1. Fear of future GD related complications motivate patients to stay on track. 2. General good health and feeling well motivates patients to stay on track with self-management practices. 3. Patients set a goal to achieve or maintain an in-range reading and also set goals related to general health.	1. The app should highlight or emphasize the use of good health and feeling well to motivate them user to stay on track. 2. The app should have a place where users can track and review their A1C for goal setting purposes.

4.4 Chapter Summary

Data analysis shows that current care in gestational diabetes includes giving information about a healthy diet, physical activity and monitoring of blood glucose levels and observing the fetus through ultrasound. Information on health care at present is given verbally in a small appointment session at KK. Most of the time information is not sufficient and practically cannot be used when needed. A dietician cannot provide detailed information about non-western food items in different languages. During the restricted time of clinic visits, information about healthy eating and physical activity competes with other components of care and other information.

Most of the patients wish for a system, preferably a mobile app that is easily and constantly available. Information available on new system should be from trustworthy source. 24/7 availability of system, adaptability, consistency, open, unobstructed, useful and easy to use
The system is required.

Chapter 5: Development of Prototype

A prototype is what Zimmerman et al. (2006) refer to as the embodiment of the right thing (as detailed in section 3.4) when constructed by design researchers. A total of four design iterations were completed to produce the current state of PregDia. While the project started out as a making of the simple text-based conversational agent (chatbot) for self-management of gestational diabetes, it evolved to consider a more general sense of behavior change and persuasiveness.

PregDia reflects a team effort to design a persuasive conversational agent for patients with Gestational Diabetes. The team includes colleagues from the "GraviDia" research project team Helse Bergen, which includes possible future users, domain experts, and interaction design experts. The design was greatly influenced by their feedbacks in the first, second and third iteration. Before detailing each iteration, a summary of each iteration is presented below.

First iteration: Presents personas and scenarios. A conceptual design was articulated and evaluated by a domain expert.

Second iteration: Presents sketches and storyboards of interactional flow and low fidelity prototype. Study of Diasend Glucometer. Evaluation of low-fidelity prototype.

Third iteration: Design for a persuasive conversational agent, historical data, ease of use and social support. Further design and evaluation of low fidelity prototype.

Fourth iteration: Further design explorations, and an implementation of a fully functional persuasive conversational agent.

5.1 First Iteration

First iteration briefs about building personas and scenarios. This iteration derived the problem statement and made a basis for concept phase development.

5.1.1 Personas

The results from the study (LeRougea, Mab, Sneha, & KristinTolled, 2013) show that personas are a valuable methodological approach in capturing the conceptual model and informing the design and development decisions into the design of software interfaces targeted for users with specific health care needs.

In this thesis project, personas tap into the conceptual models of the targeted gestational diabetic patients reflecting their challenges, preferences, capabilities, and attitudes towards using technology in self-management care. By using personas, insight into the behavioral model of the patients has been shown to inform later stages of user-centered development (e.g., the creation of prototypes and usability testing) as well as implementation and adoption strategies. 4.1.2

Two personas Meera and Arrey were created (refer figure 16 and 17) and that guided this and future iterations of PregDia. It was inspired by user-centered design methodology literature presented in section 3.3 and 4.1. Considering facts detailed in section 4.1.2, it was important to

consider two different ethnicities to thoroughly understand the challenges faced by a different type of users.

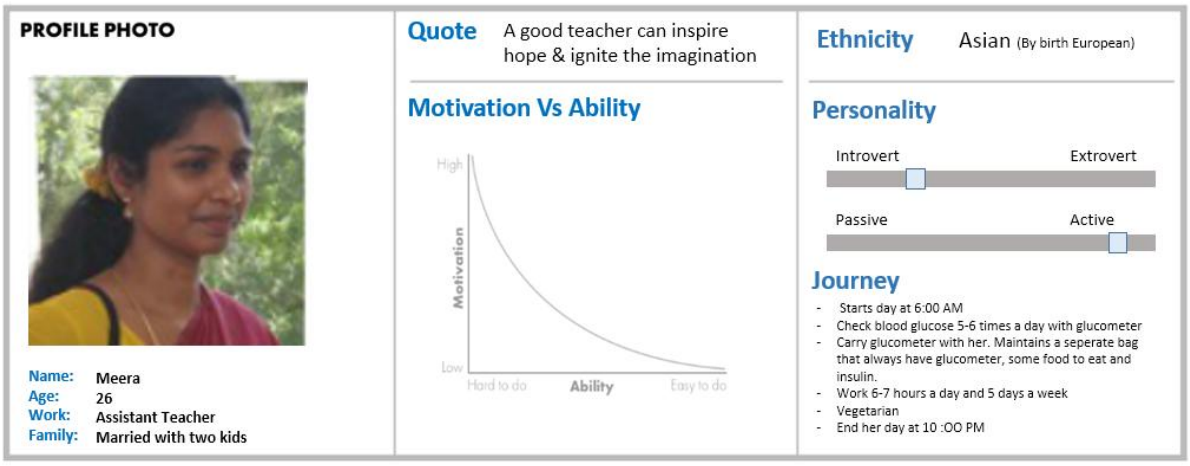


Figure 16: Persona illustrating the typical user for PregDia (Non-European)

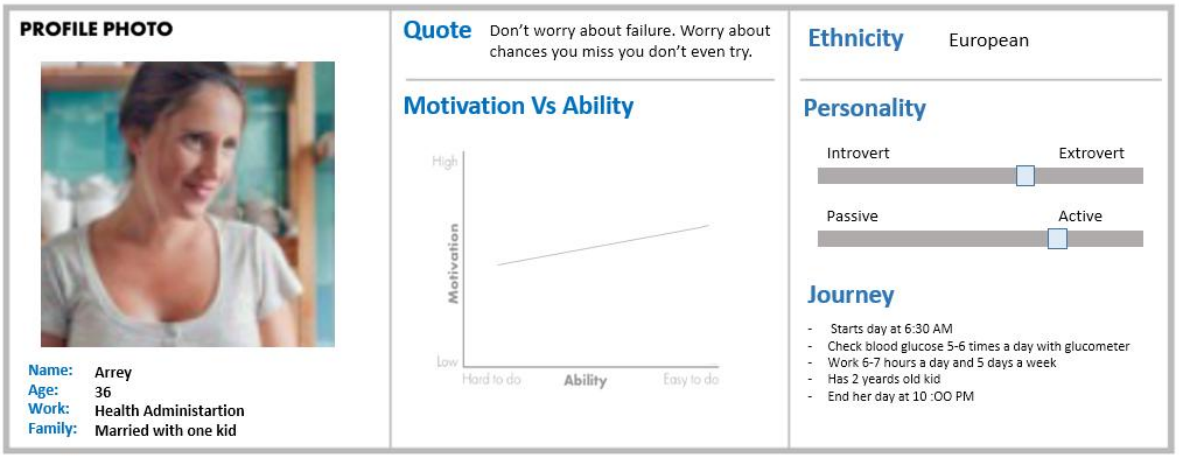


Figure 17: Figure 18: Persona illustrating the typical user for PregDia (European)

5.1.2 Scenarios

The scenario that accompanies the above persona was created to emulate a sense of the potential user's everyday challenges and needs associated with self-management of gestational diabetes. In this thesis, scenarios were used as the method to guide the user through the paper prototype. They were developed using the user requirements identified in section 4.3.

The idea was that these scenarios should represent the actual self-management tasks that a gestational diabetic patient would want to complete using PregDia mobile application. Figure 19 details about the scenario used to request help from a conversational agent or patient can direct explore the app to find other solution.

Section 6 details about the use of multiple scenarios in think-aloud usability evaluation. While making scenarios, it was considered that scenarios are ordered in such a way so that it makes sense to the user and give an overview how these scenarios will occur in real life. For example, reviewing data make no sense until the user has recorded some data.

Now, after establishing a target user in terms typical of user-centered design projects, design work was started.

Arrey, mom of 2 year old kid and is now pregnant with 5 months of gestational diabetes. She is highly motivated to maintain her parameters in required limits. She is back to home from office at 4:30 p.m., as she reach home she checks up blood glucose levels before dinner. After that, she drops her younger kid to birthday party at 5:00 pm and kid has to be picked up at 6:30 p.m. She reach home back at 5:15 p.m. and is extremely tired. She has no other support at home. She has to now prepare meal for her. As she has just 1 hour in between to prepare and eat meal, she is struggling now what to eat? What is easy to cook and equally healthy?

Figure 19: Scenario for searching recipe

5.1.3 Conceptual Design

This section briefs about the proposed persuasive system design for GD patients. Drawing on the findings on problem space (in section 4.3), a concept of a proposed solution "*PregDia*" is presented here:

> *PregDia: A mHealth solution that can manage, monitor, analyze and assist the gestational diabetic patient. When the measured intensity of self-management parameters exceeds the individual threshold, the PregDia advisor (conversational agent) performs an intervention (that is persuasive) for the user. In that way, the system suggests the user through some steps necessary to maintain the critical diabetic parameters in control. These persuasive parameters help to relieve the stress and guide to take corrective action.*

5.1.4 Evaluation – Conceptual Design

As the concept for PregDia was articulated, it was necessary to evaluate the feasibility of such a project concerning adaptability and usefulness in a clinical context. The idea was presented to project manager at Helse Bergen, with rough sketches (refer appendix 4).

The domain expert appreciated the conceptual design of the project and gave suggestions about designing next iteration with storyboards. As storyboards will give a better understanding of proposed features in a real-world setting. She also suggested that storyboards should present understanding how conversational agent will provide support to patients in self-management
Now, the next challenge was to build the knowledge base for a conversational agent. As the results from workshop session shows (refer section 4.1.2), most of the treatment depends on the data related to blood glucose levels, so next step was to capture and integrate this data to the application. A smartphone itself cannot measure the blood glucose level, so there was a need to find another tool that captures this data.

5.2 Second Iteration

Continuing the design of PregDia, establishing some system requirements of the design was necessary. The research was done to discern existing glucose test kits and technologies for measuring blood sugar levels. Diasend was chosen for this study as the data produced by diasend is used by clinics for treatment advice to patients.

5.2.1 Establishing Requirements

From the conceptual model (presented in the previous section), and evaluations, some requirements of the system were determined (see section 4.3). The system must provide the user with:

1. Blood Glucose Readings
2. Can record historical data

Technical Requisites

To achieve the requirements mentioned above, glucose test kit was necessary to do the feasibility study of data integration. Abbott was acquired for this purpose. Some other devices were also considered as candidate technologies for PregDia. Furthermore, Abbott is compatible with Diasend, a program that is used by doctors at clinics for checking the blood glucose pattern recorded in glucose test kit. Diasend achieves this by installing a program on the computer, which is used to upload patients meter readings (from Abbott). Once results are uploaded to Diasend, patients/doctors analyze and take effective actions.

5.2.2 Further Design and Prototyping

To explain, the interactional flow of blood glucose data for PregDia, a Business Process Model and Notation representation of its components was modeled (SaraAguilar-Savén, 2004). The purpose of this model was to map out the distinct features of persuasiveness and behavior change in proposed self-management application and identify gaps in the flow of interaction.

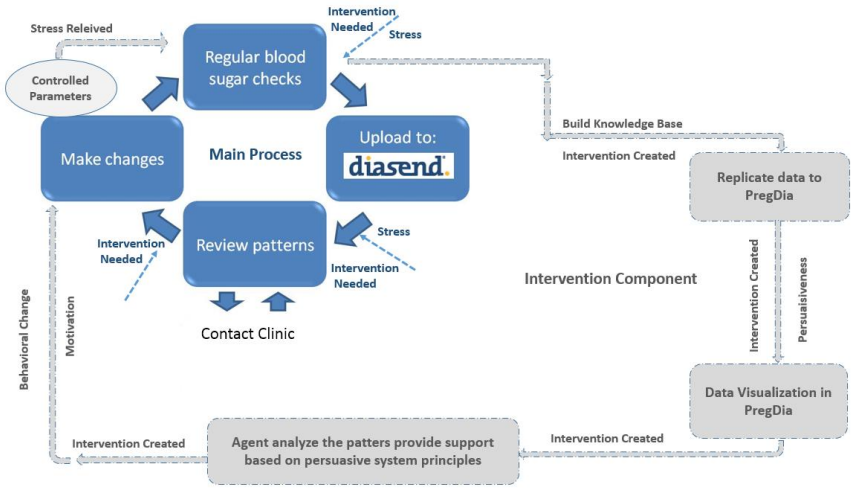


Figure 20: Proposed blood sugar level Intervention Process Model

Figure 20, details on how the conversational agent will use this data for data visualization and social support to the patient. The patient will appraise the situation, feel motivated and will manage to bring change in the situation, resulting in controlled parameters and stress with either remove or decrease.

Storyboards (Figure 21) were made to communicate the concept of PregDia to audiences at Helse Bergen. Storyboarding is a technique in which series of sketches shows how a user may interact with the system or progress through a task or process (Mou1, Jeng, & Chen, 2013). While these are visually simple, but they demonstrate how the effective self-management is achieved by a behavioral intervention that empowers patients with the ability to self-monitor, understand the impact of lifestyle behaviors on glucose level control, and adjust their self-care based on data visualization or suggestions by a conversational agent.

Figure 21: Storyboard Left (Conversational agent provide reminder to update) Right (Data Visualization)

5.2.3 Evaluation – Story Boards

Storyboards were used with scenarios to bring a more detail and context. The major benefit of using storyboards was that they made us think through the process that how some features can be used. For more storyboards refer Appendix 6.

Table 9: Feedback

Sr. No.	Suggestions
1.	Features should be easy, and straightforward.
2.	The app should allow users to keep track, and review their physical and emotional well-being.
3.	The app should allow users to record and track their blood glucose, carbohydrate intake, weight, and activities.
4.	The app should provide a summary of collected data for Glucose test, exercise and carbohydrates intake in the form of Graph
5.	The app should review data entered by the patient. Verify if any mandatory entries are missing.
6.	The app should present as of recent entry as far back as patient started using the data.
7.	The app should clearly display the users average glucose level, weight and the percent of readings that are in and out of range.
8.	The app should provide users with a means to occasionally share information related to their diabetes with doctors, midwives, partner, close family, and friends.
9.	Users can share videos, images, and links to other websites
10.	The app should highlight or emphasize the use of good health and feel well to motivate the user to stay on track.
11.	The app should have a place where users can track and review their goals achieved
12.	App should promptly remind user if required parameters are missing
13.	App should send some good or encouraging thoughts to patients when needed
14.	App design should consider color blindness patients

In this case, storyboarding was used to identify what tasks patient with gestational diabetes will attempt to complete using the mobile application and what the expected system response would be to accommodate the action. Inputs received are summarized below, and most importantly they gave some guidelines on how to move forward with the development of Prototype. Summary of these discussions is provided in table 9 above.

5.3 Third Iteration

Continuing the design of PregDia, the previous iteration's prototype was further designed to incorporate what was found in the evaluation in the second iteration.

5.3.1 Refining Refinements

Taking into account what was found in the evaluation of the second iteration of the prototype (refer section 5.2.2), business process model (refer section 5.2.2) and borrowing aspects from PSD model recommended by (Oinas-Kukkonen & Harjumaa, 2009) (detailed in section 2.3.1) four design principles were created. These are primary task support, dialogue support, system credibility support, and social support, detailed in Table 10.

Table 10: System Design Principles (Borrowing aspects from Oinas-Kukkonen and Harjumaa)

System Design Principle	Requirement Description
Primary Task Support	PregDia should be able to make the task easier for patients. Design should be simple.
(Reduction, Tunneling, personalization, self-monitoring, and simulation)	The system should guide the users throughout the behavioral change process. It should provide messages, regular updates, progress tracking and suggestions as per change in behavior.
	The system should offer personalized content and services for its users.
	The system should provide personalized content for the user based on his profile or individual health information. Tailored information should be more persuasive.
	The system should provide an option for each user to self-monitor his/her progress. It will provide statistics and track reports for instantly monitoring their progress.
	Users should be able to gauge the outcome of the system such as when should glucose levels be normal, or time required to lose weight according to their current schedule of physical activity or diet control.
Dialogue Support	Giving the user's clues about behavior before they take action
(User Clues, Reminder, Praise, Linking)	The system should push regular reminders to the user.
	Based on user behavior, change system will generate inspiring messages or notifications for her attempt. It helps to motivate the user to change behavior towards right direction further.
	The system should have an appealing look and feel
Social Support	The system should help users to help others or get help/suggestion from their fellow users whenever they are craving for or food or help compare physical activity.
(cooperation, social learning, social facilitation, normative influence, social comparison, recognition)	The system should provide a snapshot of the diet recipe shared by other users with fewer carbs and healthy for GD patients.
	The system should allow users to see the cumulative progress of other users.
	Instant chat support of the system should allow users to be motivated by their peers and thus should be more likely to adopt target behavior faster.
	The user can compare her performance concerning that of other users. However, personal information about other users should not be visible to any user.
	The system should provide recognition to the user depending on her progress. Other users should be able to see the top performers and can give their feedback or ask for suggestions from these users.
System Credibility	All the information provided through the system should have options to be verified.
(Verifiability, system response)	Take into consideration the system feedback and response time
	Integration of glucose test kit data. It should also be integrated into systems like DIPS and Natun used by midwives and doctors at KK.
	The system should also target to fetch health card details from another application named "Health Care" that is in the process of development at Hauk eland.

Upon review of these design principles, it is evident that the main purpose of the application is to make a self-management system that can help and guide patients reach their goals. Another important point is that app should record and analyze information. Without collecting day-to-day details for blood glucose level, activity, and carbohydrate intake, the app will not be able to provide the user with a representation of recent or historical data.

After having a detailed understanding of design principles, next was to create low-fidelity porotype.

5.3.2 Low-fidelity prototype

This information refined in the previous section will help to drive the prototyping process in this iteration.

5.3.2.1 Designing Persuasive conversation agent for Behavior Change

Persuasive conversational Agent, named as PregDia Advisor (PDA) is a technology that will make the interaction between man and machine (mobile) by using natural language in the form of text. In this thesis, an architectural design of a PregDia Advisor will function as virtual diabetes physician/doctor/midwife/dietician/trainer. This PregDia Advisor will allow diabetic patients to have a diabetes control/management advice without the need to go to the hospital.

Onboarding feature was used as a starting point to guide the design with the expectation that it would iterate and change as the prototyping process moved forward. Once user downloads the app. PregDia Advisor welcomes the user to the app and assist her in registering. The further design was done by following the design principles concluded in table 11 above.

Initiate the conversation and introduce itself

At the start of a conversation, the PDA introduces itself with a short description, as the user might not be familiar with the PDA or its working. The description will explain the purpose of PDA and prompt the user to take the first action. In figure 22 PregDia Advisor onboard the patient after the app is downloaded.

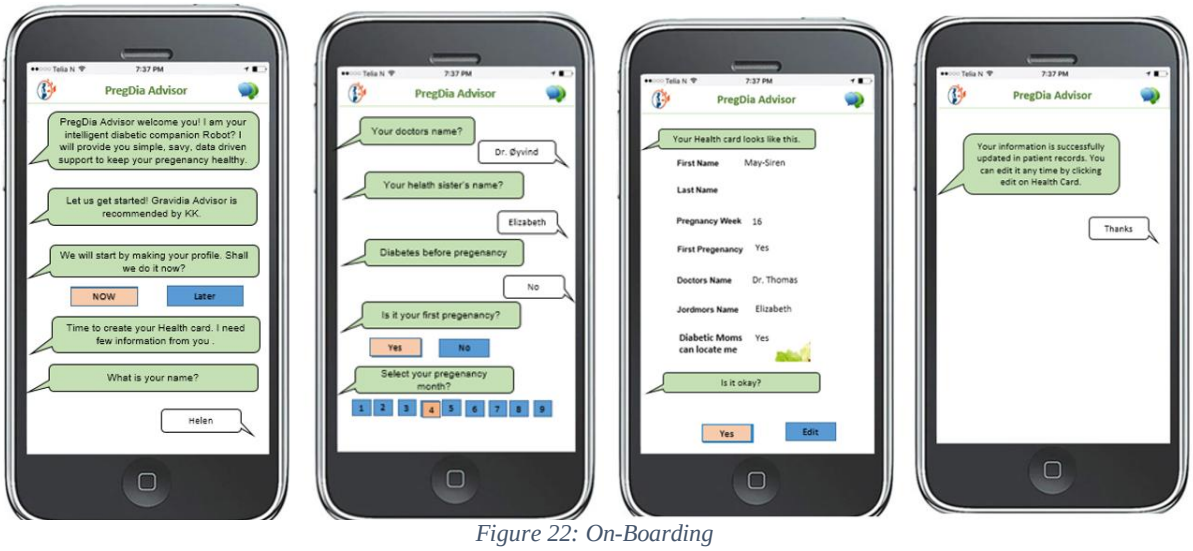


Figure 22: On-Boarding

Appropriate options to guide the user

It was made sure that PDA does not burden the user with too much information quickly. Information overload may misguide, making the patient lose focus. Along with that, it was also made sure that conversation does not become stagnant, so it is equally important to take actions and keep giving the user necessary options. Following "Authorization" design principle from the PSD model, after introducing itself, PDA authorize patient to decide if she wishes to create the profile "Now" or "Later" (in figure 22). These principles state that authorization makes the design persuasive.

Provide direction to conversation

It was made sure that buttons are used with multiple options instead of asking open-ended questions. These possible options provide direction to the conversation and prevent them from possible dead ends, as there are many directions available for the conversation to head forward. By limiting functionality, PDA can guide users towards a specific path within the program. It will allow the user to choose one answer, rather than type in something which may not fit with the script.

Short interactions with gradual learning curve

Next, was about creating the length of interactions. To have better readability on mobile, it was important to keep the messages, short, sweet and straight to the point. Long texts can confuse the patient and can even make conversations boring.

More texts and fewer graphics

PDAs goal is to bring a hybrid experience of messaging and GUI at one place. Thus combining structured content and images into the conversation, opens up multiple interaction possibilities, but information balance is needed. It was noticed that excessive use of structured messages made the conversation look little artificial (refer figure 22) and it was losing human element.

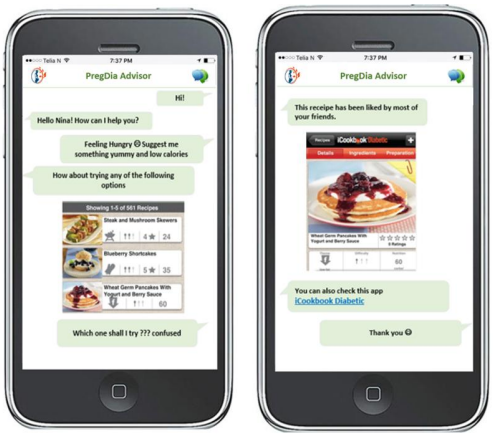


Figure 23: Conversational agent giving suggestion and references to other sites

Following "Real World feel" principle from PSD model, in next iteration of PregDia conversations, it was taken care by streamlining the conversations. It was achieved by creating a strong balance of GUI inside the interaction (refer figure 23) while giving user details about food options the information was balanced between messaging and GUI. It makes the conversation flow look natural.

Success

For the success of PDA, it is important that patients get acquainted with it. This was achieved in by introducing expert features in bits to users. In figure 23, while giving more options to users about picking the recipes, links to other website was shared. This shows to the user that PDA has the strong knowledge base and can help the user with two type of data, data entered by the user and open data available on the web.

Following "Normative influence" Principle for behavior change from PSD model (refer table 11), which states that System should provide means to observe other users who are performing their target behaviors and seeing the outcomes of their behavior. In Figure 23, PDA provides information to the patient about the recipes liked by other users. This influences the behavior of the patient, and can influence to select the recipe. Whereas in figure 24 PregDia Advisor help the user by sharing videos. It also shows that PregDia Advisor Reminds Patient if it found some required parameters missing in its database.

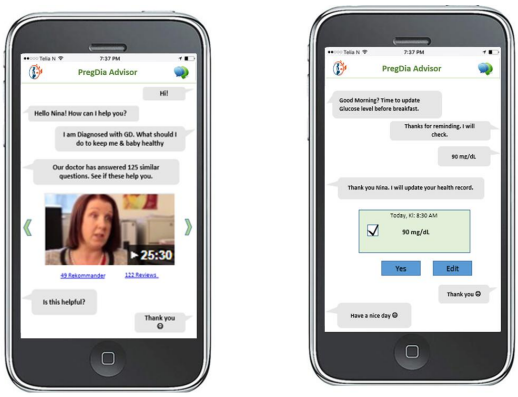


Figure 24: Conversational agent supporting user

5.3.2.2 Designing for Historical Data and visualization

For implementing design principle "self-assessment" and "self-monitoring," data visualization was introduced in the app. As mentioned in section 2.4.2 data visualization make a wide range of mHealth applications more intuitive and productive. Figure 25 (first screen) below depicts the main screen design. The main screen was divided into two sections. The middle portion and bottom navigation bar. The first section that is the middle part of the screen allows the user to access the basic options such as profile, appointments, friends group or library among others by clicking on the icons. The second part of the screen is the bottom navigation bar that has direct links to important feature tabs Health card, PregDia Advisor, favorites, and appointments.

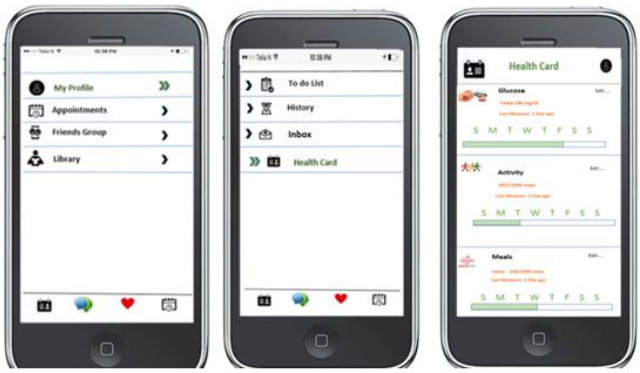


Figure 25: Home Screen, Health card, Logbook for parameters

The main interaction interface comprehends the Health Card screen (3rd screen in figure 25), which covers most important information for the user to know about monitoring, the screen

where the user can view glucose level, activity and carbohydrates details for the current day. It also shows that when was the last measure taken. The act of logging a reading occurs within the health card or by texting message to PDA (as mentioned in section 5.3.2). Edit option (third screen in figure 26), on the right side of the middle screen, gives an option to manually enter/edit monitoring parameters of activity like a number of minutes of walk, weight, distance, and steps. This feature acts as a log book that summarizes the data collected throughout the day and it is the gateway for users to enter self-measured data manually in the case doesn't replicate automatically from glucose test kit to PD mobile app. The lower portion of the screen (refer figure 26) shows the graphical representation of glucose levels for a day and activity while in process.

Figure 26: (a) Activity parameters, (b) Walking target status and (c) Glucose level status

The manual edit feature was introduced due to the usability concern found in a study of Nutricam app versus the paper log (refer section 2.4.2), where the inability to go back in time to capture a photo of what was consumed earlier in the day underreport the dietary intake using Nutricam versus the paper log. This highlighted a particular design need of usability for PregDia that is to ensure that patients should have the flexibility to update data manually. Not only with the photography feature for carbohydrate intake but with other parameters of tracking like blood glucose, activity, etc., to go back and add in notes about what was consumed earlier in the day, what activity was done or what was blood glucose readings.

Another reason for manual update feature is provided for a situation when the patient does not carry the mobile while performing activity these parameters can be entered manually later. For automatically capturing the status of activity a person can click the walk icon on right side of the screen (Figure 26). As a result, the third screen in figure 26 will keep updating the patient about the status of target achieved. Whereas the second screen gives an option for tracking weight. Weight tracker allows the user to follow up her own weight by manually registering it into the app. When the weight is registered, the user can check her progress by checking the weekly and monthly graphs.

5.3.2.3 Designing for Social Support

Friends Group

This feature (refer Figure 27(a)) allows the user to communicate and stay in touch with her midwife, doctors, and other gestational diabetic patients. The patient can also add new contacts to their family members or friends. This feature is one of the key features because unlike other apps, by using friends group, the user can receive feedback in real time from trusted sources instead of taking suggestions or guidance from other online websites. As doctors, midwives and

PregDia advisor is also part of the friend's group; the patient can always ask them to confirm the suggestion if she is not convinced by the suggestions made my other friends.

Figur 27: Left to Right (a) Friends Group; (b) Appointments; (c &d) Library

Appointment

The appointment feature (Figure 27(b)) is one of the most important section of the application. It can be accessed by clicking on the big icon appointment inside the main screen. It shows a weekly calendar in which the user can see not only the appointments planned for today but also the future appointments.

Progress Bar

As shown in figue 25, health card shows the progress of patient on achieving keyparameter data. The main purpose of this feature would be to display information regarding a user's overall 'status' for the day. In addition, since the application leverages points to encourage certain behaviors, letting the user know how far they are from achieving their next reward is important. This feature of self-assesment is a techniques from gamification (refer section 2.4.2) that will bring change behavior of patients to take corrective action for self-management.

PregDia Library

This feature allows user to find any information about PregDia app, Gestational diabetes or recipes' for gestational diabetic patients. The user can save the selected recipes to favorites and use the information offline. This feature of support will encourage patient to have healthy lifestyle as quick advice and material related to gestational diabetes is available at a click of a button.

Main Screen

In an early evaluation of this design, it became clear that the tabular representation of the data in the middle portion of the screen would not quickly convey useful information to the user. When the application is first launched, it opens to the main screen as shown in figure 28 as option1. Feedback was received from users, and option two was preferred as the main screen by most users.

My Profile

In 'My Profile' (refer figure 28), the user should be able to edit all the personal details and information that she has entered when registering in the app. These details include name, email, password, and information regarding the age, height, weight, and goals among others.

Figur 28: (a) My Profile (b) Different views of the main screen

5.3.3 Cognitive Walkthrough Evaluation

To evaluate the third iteration of a prototype a cognitive walkthrough evaluation was done with colleagues of Helse Bergen "GraviDia" project team. In attendance were doctors, midwife, expert users, and interaction design professionals.

The group showed interest in the prototype and was positive to the design decisions that had been made so far. Conversational agent supporting patients by use of motivational text, videos, and links to other websites was positively received by those with clinical experience; they found that it leverages the user as an active participant in the process of home care self-management and will build trust in patients. Historical data visualizations were also considered a motivating factor for behavior change through self-assessment.

Whereas few areas were also discovered for improvement. It was mentioned to have the detailed view of the appointments. Moreover, in each of the appointments, the user should be able to see a summary of the checkups to be done by doctors or midwives. App and PregDia advisor should provide the option to send the list of questions to doctors and midwives in advance. It should also work as a personal diary where the user should be able to do follow up on their progress and be reminded about future planned appointments. Another discussion point was some reminders; there were suggestions to provide the feature to control the number of reminders or enable/disable option for reminders.

Whereas the midwife argued "friends group," as the suggestions provided to patients will be by nonexperts. Discussions and advice by other experts concluded that color differentiation could be used to highlight health care professional comments and other. Some confusions were noticed in data recording options. Few user scenarios and questionnaires were also used to invoke more discussion. The major high light of discussion was the working of the conversational agent while the user is not cooperating. Whereas, all participants proactively took "onboarding screen exercise" and "feature priority," this exercise gave an insight into the most favorable feature in the application (refer table 11).

Table 11: Priority of features

Feature	Description	Priority
PregDia Advisor	A messaging system that can answer any question raised by user. Information can be provided in the form of text, image, video or links.	Very high
Reminders	System should send reminders for glucose level, appointments, etc	Very High
Sharing Recipes or links	The system should provide a medium to share recipes or links or any other information with other users.	High
Dashboard	To manage activity, carbohydrates and glucose level. It should show information from the last update back until the first update.	High
Motivational	The system should be motivating the patient.	Very High
News	System should share news regarding new medications, seminars or special meetings for GD patients	Low
Health Card	Contains information about the patient. It should detail about next appointment. Details about what is expected in next appointment. Provide tips to the patient about what to ask the doctor in next appointment.	Very high
Library	Provides informational videos, images, links to other websites	High
Fetus Growth	New feature	High

5.4 Fourth Iteration

In the fourth and final iteration of this design project, a fully functional persuasive self-management application was designed. This section documents the final development phase of PregDia for this thesis.

Table 12: Revised design principles for PregDia

System Design Principle	Description
Primary Task Support	**Reduction** -Conversational Agent (CA), -Revised main screen, Carbohydrate update Manually, Glucose level manually
	Tunneling -Reminders and suggestion's by CA to update key parameters -Manual data visualization turns into self-assessment and behavior change
	Personalization - CA referring patient by name - CA showing growth charts promptly to patients
	Self-monitoring Data view of key parameter readings
	Simulation Integrating data from Diasend resulting in instant view on patient's information, resulting in quick action by CA to remind patient for corrective action. As an action by patient, she can gauge her parameters.
Dialogue Support	**Reminder** CA push regular reminders to the user.
	Praise Based on data recorded CA inspire the patient to upload data. As a result, patient gets motivated to change further result.
	Linking System has appealing an appealing look
Social Support	**Cooperation** CA support the patient with text message about advice, appointment details. CA supports patient with features like library to provide manual support
	Social learning CA provides to patient with snapshot of diet like by other patients. Friends group is a place to have general health discussions
	Social Facilitation CA encourages the patient by sharing the recipe like by most of her friends
	Normative influence All time support of CA has motivated the users to adhere to self-management parameters
System Credibility	**Verifiability** Proposed but not tested
	System response Proposed. Assumptions for testing are made that system is already connected and fetching data for glucose level readings.

5.4.1 Incorporating Feedback from Previous Iterations

Having had a constructive walkthrough evaluation of the third iteration of prototype, several design elements needed to be reworked and some new features to be designed to meet the new requirements of PregDia. In this section, requirements were again refined by revisiting the design principles in section 5.3.1 and are displayed in table 12 in detail.

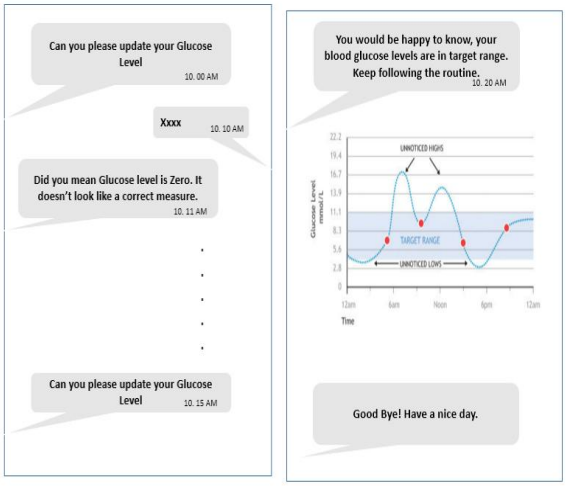
5.4.1.1 Redesigning for complex conversations

The scenarios discussed in section 5.3.2.1 works fine in ideal solution until user cooperates with PDA, what if the patient leaves the conversation in-between.

Leading the conversation

As mentioned in literature review these challenges can be overcome by fixing the utterance and response fire rule (refer section 2.3.1). The solution found to this was to make sure that PDA leads the conversation and should develop the conversation naturally by moderating whenever it deviates its goal. It is an awkward situation if the communication is going off the script and can make the system fail. A good option for PDA is to use suggestions in such a way that the PDA help the user to skip unwanted systematic instructions, and efficiently end the interaction to the user's satisfaction.

Design in figure 3 represents the concept of dialogue management (Lokman & Zain, 2010) explained in section 2.3.1 and by following conversational process guidelines explained in 2.3.3. It shows that the PDA opens the conversation to collect glucose levels from the patient, the patient did not provide a logical reply. Here even after human intervention, the task is not completed, but PDA does not leave the user hanging without losing effectiveness. As shown in figure 30, firstly, PDA did not record incorrect data. Secondly, PDA tries to lead the discussion again by messaging, "*if reading is zero*." Third, an attempt by PDA is to show historical user data, to encourage user. Still, user does not respond. PDA says good bye and closes the conversation. It is important to close the conversation with user's satisfaction rather than questioning the PDA's effectiveness.



Figur 29

Figure 30: Off the track conversation

5.4.1.2. Redesigning for Data Recording & Data Visualization

In the evaluation of iteration 3, few concerns were found regarding the usability of "updating glucose details manually." Usability issued not having enough clarity leading to ambiguity. It was redesigned following the design guideline as presented in the third screen in figure 31. In this design, carbohydrate data was entered by use of scale rather than text.

Figur 31: Revised Data Recording screens and data visualization screen

Whereas better visibility was provided for graphs in the daily representation of the blood glucose measurements taken throughout the day with the time on the x-axis and glucose on the y-axis. The light blue band through the middle indicates the target blood glucose range.

For removing the complexity in carbohydrate tracker feature, an additional feature of registering food picture was allowed with share option to her dietician/friends with each of the meals that she has eaten during the day. This way, the user can receive personalized feedback about how healthy or not she is eating directly by her dietician as shown in the second screen of figure 31.

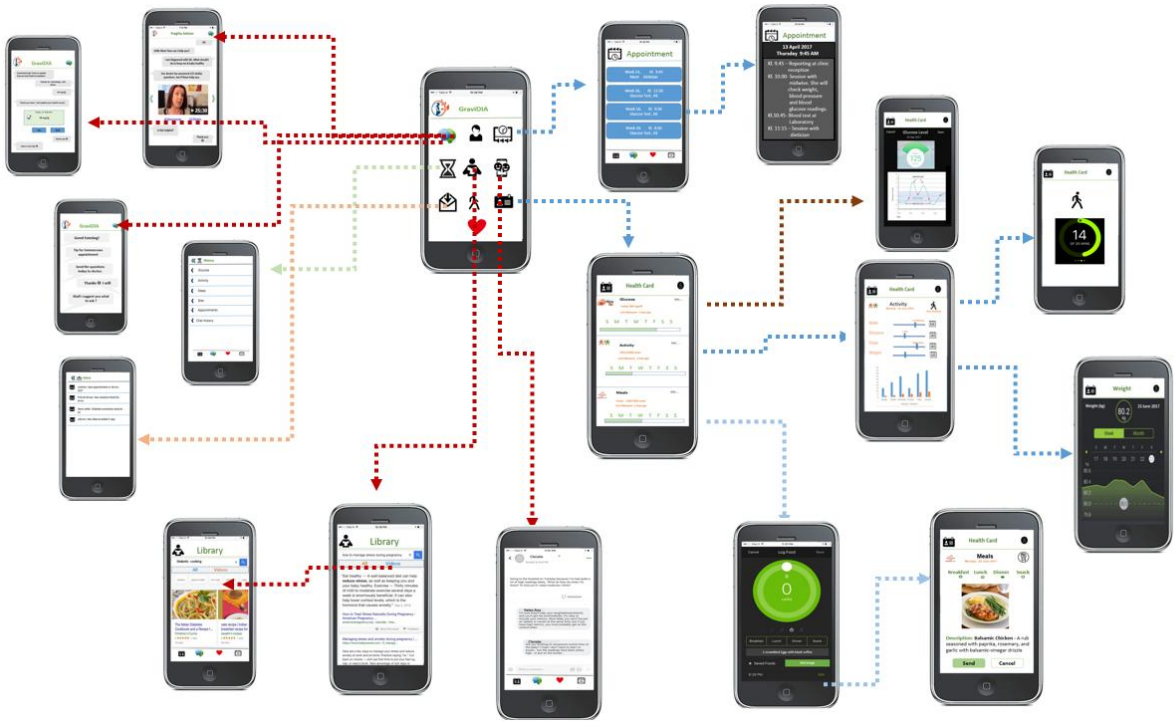
5.4.2 Final Prototype

The medium fedility static prototype was finalized for usability testing was feature rich with an emphasis on data visualization, self-management, and social support. It had a total of eight main sections, three of which are directly related to key parameter readings and different methods of representing the collected data. The information architecture of the final prototype has been drawn below (refer figure 32).

The arrows stemming from the menu bar indicate how the screens are linked together and demonstrate how a user could navigate through the application. Different colors represent the navigation of different feature.

The goal was to keep the flow as straightforward as possible; this was accomplished by minimizing the depth to which a user can navigate within each section. The number of screens was limited to maximum three tabs to reach the target screen. Whereas conversational agent can follow the flow of text message while chatting with the patient.

The next goal was to collect opinions through testing regarding how useful these features would be to potential users. In the next phase of this research, usability tests were conducted using this finalized prototype. The goals, methodology, and results from testing are outlined in Chapter 6.



Figur 32: Final Prototype

5.5 Chapter Summary

By using research through design as a research framework, PregDia was designed as a fully functional self-management system with PregDia Advisor as an inbuilt conversational agent. Diasend is a system used to provide the application with glucose level data. PregDia Advisor analyses the data and suggest the patient with corrective actions to keep the diabetic parameters in control. Expert feedback and Cognitive walkthrough were used to evaluate first three iteration and fourth iteration will be evalued by use of talk out aloud protocol, that is detailed in chapter 6.

Chapter 6: Evaluation

In user-centered designs, Usability Testing (UT) has an important role. It helps in validating the good design features and is capable of uncovering the design flaws. This section will detail about how the users perceived the proposed design regarding usability and the evaluation methods used to measure them. Later section details about the summary of results.

The usability testing of prototype included three participant categories, i.e., users, observer, and facilitator. According to the recommendations by (Nielsen, 1993), 3-5 users should be able to identify about 85% of all usability problems. As usability test was planned with a paper prototype, it required thorough planning. Few guidelines were defined for this phase (refer table 13).

Table 13: Guideline for usability testing inspired by (Nielsen, 1993)

Guideline	Guideline Description
1	During the tests, the users interact with the paper prototypes of the interface to be tested. Additionally, users will be interviewed about their impressions and experiences.
2	The facilitator is responsible for explaining the objectives, plan of the test to the user, and provide the users with tasks to perform the test and ensure that everything runs smoothly in the process.
3	The observer has to watch the behavior of the users and their actions, interpret the interactions with the prototype and write down any important observations or comments. As an observer, a main ethic clause to be followed was to not to communicate with the users, and only perform the role of taking feedback.
4	Paper Prototypes has to be prepared for the usability testing. Since this was testing of mobile interfaces, all the templates created has to be on phone screen.
5	Keep few blank templates, so that facilitator can use them for directly making changes according to the feedback and test the new changes with the same users.

6.1 Methodology

This section will details about the methodology followed for usability evaluation and, how scenarios and questionnaires were used to complete usability testing.

6.1.1 Think-aloud Protocol

Usability testing methodology used was talk-out loud, a recommendation from (Nielson, 2012). Nielsen defines that in thinking aloud test; test participants are asked to use the system while continuously thinking out loud — that is, simply verbalizing their thoughts as they move through the user interface. Nielson mentions - *"Simply" ought to be in quotes, it is not that simple for most people to keep up a running monologue. The test facilitator typically has to prompt users to keep them talking.*

As recommended by Nielson, three requirements were prioritized to run a basic thinking aloud usability study, i.e., selection of representative users, tasks for users to perform and let the user talk without any interference. Following the first step, participant's recruited for usability testing were actual future application users or were similar to application users. Nielson has recommended 3 to 5 participants for a talk-out loud study. Six participants were reached for usability testing but were able to conduct a usability test with 4 participants. Selection of participants was by their interest to use a new system. One of the criteria for selection of participants was fluency in English so that participants can comfortably understand the scenarios and provide feedback on questionnaires. Major preference given was to patients who were diagnosed with gestational diabetes for few months. These preferences criteria's (like language, patients with GD and level of interest) were selected to ensure that patients were reasonably comfortable with their self-management routine.

The second step was to plan a test. Time planned for the test was 1 hour and on arrival of patients for a usability test, first had a casual talk with users to make them feel comfortable. Then participants were provided with a copy of the consent form and were briefed about the session and PregDia application. Later they were asked to have a walk through the document, and then they were asked to do five minutes of group discussion. Whereas as per recommendation by (Thomas, 2015) participants were also asked to fill pre-test questionnaire form (refer Appendix 7.1), as to gather background information. Participants were given 20-25 minutes to walk through the scenarios; 5-10 minutes were given for clarification and asking questions about study/testing. Upon completion, participants were briefed on the testing method and the prototype

Third was to conduct design evaluation, I played a role as a computer and placed the layouts on a table near the user but not in her line of sight. As the user taps with the finger on the screen layout, I picked up the modular part, representing the response and placed it in front of the user. "Me" as a computer could be referred as the user interface during the test session. As a computer, I indicated to the users when "it" has finished working and the user can proceed with the next interaction. This was done by using a designated gesture, e.g., hands folded in front of the user represented as the "computer" has finished working. As a facilitator, it was also kept in mind that not to over explain the design elements before starting the test.

6.1.2 Scenarios as methods

Scenarios (refer table 14 below) were used as the method to guide the user through the paper prototype. The idea was that these scenarios should represent actual tasks that a gestational diabetic patient would want to complete using a mobile application that supports them with their self-management routine. Therefore, the scenarios were sequenced in such a way, that it makes sense to the user and give an overview of how these scenarios will occur in real life. For example, reviewing data make no sense until the user has recorded some data.

As participants worked through completing each scenario, they were asked to 'talk out loud' and voice any opinions they have on the design or scenario, and share their thought process regarding their navigation choices. If an issue was encountered, or the participant was stuck, the scenario was ended and the session proceeded to the following scenario. As participants worked through each scenario, the number of 'clicks' off the critical path and overall task success were recorded. Once a participant had completed the usability test, they were asked to fill in three questionnaires after which they were debriefed on any screens and scenarios they had trouble with.

Table 14: Scenarios

Feature	Scenario	To do List
Boarding Screen	**SC1**- Arrey had doctor's visit earlier in the day. The doctor has briefed her about this app. She has a little overview. She downloads the app, as the doctor says it is mandatory to use. Its dinnertime (7 pm) on Sep 3, 2017. A message pop up from PregDia app.	Action: Open the message and follow the chat with PregDia advisor.
Record Data	**SC2** - It is breakfast (8pm) on Sep 4, 2017.	Action: Open the app and record blood glucose before breakfast in PregDia Advisor. Info to record: BG – 6.0 mmol/l, Carb Count – 20 grams, Activity – Yoga Emotion – Happy
Review Recent Data	**SC3** - Since it is the end of the day, Arrey wants to have a look through her carbs, glucose level, activity, and how are monitoring graphs throughout the month.	Action: Traverse the interface and check your glucose level for month
Reading Data	**SC 4** - Meera have an urge for food she has never had before; Have a look through the app for suggestions and carbohydrates estimate for this new dish.	Action: Explore the app how to achieve that.
Review Historical Data	**SC 5** - It is the first day of October and Meera want to see how her blood sugars looked the month before (September). Have a look through PregDia dashboard to see how you did. In particular, you want to see what happened on September 25th. You have made a mental note that your readings before breakfast have been a bit out of range lately. You are curious what your average blood glucose at breakfast has been for the past few week. Use the PregDia app to find out.	Action: Now that you have had a glance through what your readings looked like for the past week, you want to know the percent of times you have been in and out of range,
Data Visualization	**SC 6** - Explore the prototype to find different data visualizations. The prototype has four different ways of representing information: on the home page, dashboard, bottom bar, and PregDia advisor.	Action: Explore the app how to achieve that.
Share Data	**SC 7**- Meera remembers she wanted to share some information with her dietician since she has been bugging you for updates lately.	Action: Explore the app how to achieve that.
Look for Motivation	**SC8 –** You are in mid of the day doing your office work. PDA sends a message to upload glucose level.	Action: Follow the chat

6.1.3 Questionnaires

Participants were presented with questionnaires at the beginning and end of the usability testing session. The purpose of the pre-test questionnaire was to collect background information on participants regarding their routine and level of comfort interacting with mobile devices. There were three post-test questionnaires all focused around measuring the usability of the design; the system usability scale (refer appendix 7.2.1) was issued first, followed by a general post-session questionnaire (refer appendix 7.2.2 & 7.2.3). The SUS (Thomas, 2015) consists of ten usability related statements, half of which were positively written and the other half negatively written. Using a 5-point Likert scale, participants were asked whether they agreed or disagreed with the system.

The score is calculated by following these steps:

1. For positive items (1, 3, 5, 7, 9), take the scale position minus 1
2. For negative items (2, 4, 6, 8, 10), take 5 minus the scale position (reversing the score)
3. Sum all scores
4. Multiply the total by 2.5 resulting in a SUS score out of 100

The SUS score provided a usability measure of the mobile application as a whole but does not provide feedback for specific design features. Therefore, an additional two post-test questionnaire was created.

6.1.4 Participant Demographics

A total of six participants were recruited for usability evaluation. Participants had varying levels of comfort with mobile devices, and less than half had used diabetes-related mobile applications in the past. Of those that participated, two were not able to participate due to personal reasons. As a result, the analysis was conducted using a total of four participants.

Table 15 summarizes the demographic profile of the participants where the in the fourth point comfort with mobile devices scale was represented as follows: NC – Not comfortable, SC – Somewhat comfortable, C – Comfortable, VC – Very comfortable.

Table 15: Usability Study- Participant demographics

Questions	Participant 1	Participant 2	Participant 3	Participant 4
Age	25-30	30-35	30-35	35-40
First Pregenancy	Yes	No	No	No
Glucose Management kit	Yes	Yes	Yes	Yes
Comfort with Mobile	VC	VC	C	VC
Uses Diabetes App	No	No	No	Yes
Use Social media for GD	No	Yes	No	No
Carbohydrate Tracking	-	-	-	-

One participant that used social media to find help/support had listed it out in her questionnaire.

6.2 Evaluation Results

The data collected from usability testing was analyzed in detail, beginning with assessing how participant performed overall by scenario and assessed feedback collected for each design feature.

6.2.1 By Task

While users were working through each scenario, two main metrics were recorded, namely success of task, and level of success.

Success of task

It was measured in terms of task success rate to complete the scenario. Time was ignored, as participants were encouraged to talk aloud which directly influences this metric. Figure 33 below depicts the percent of participants who successfully completed each scenario.

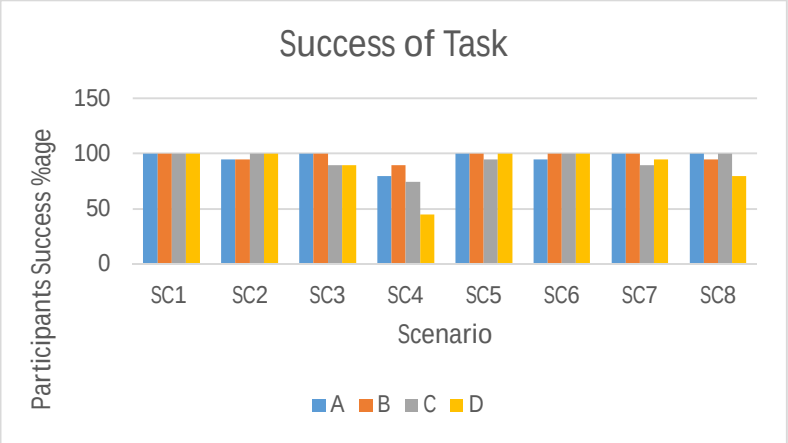


Figure 33: Success of Task

From above chart, it is apparent that users struggled with scenario "SC3", "SC4" and "SC8". Whereas participants struggled a lot with scenarios "SC4". To provide context, scenario SC4 was related to carbohydrate details and upload of food picture. This feature was included in the prototype but was not fully functional. In the scenarios outlined in table 14 (refer scenario 4), participants were encouraged to log their carbohydrate intake, but any additional functionality such as uploading a photo of the food was not included. The purpose of including scenario was to encourage discussion, gauge interest, and determine whether it would be an area for future research.

Figur 34: Representation of Scenario 4

The failures for scenario three (refer figure 35) was attributed to a minor design flaw in the Health Card screen. Some participants failed to read the edit tab on the right to reach the graph. For a future iteration of this design, it would be recommended that some shortcut should reach directly to monthly progress.

Figur 35: representation of scenario 3

Level of success

Level of success was measured in terms of percentage of gestures and taps (clicks) were off the track. Figure 36 shows that users struggled with scenario SC3, the reason was same as mentioned above, users were not able to locate the icon because of its size or clarity of use (Refer figure 35) resulting in more number of tabs and confusing facial expressions.

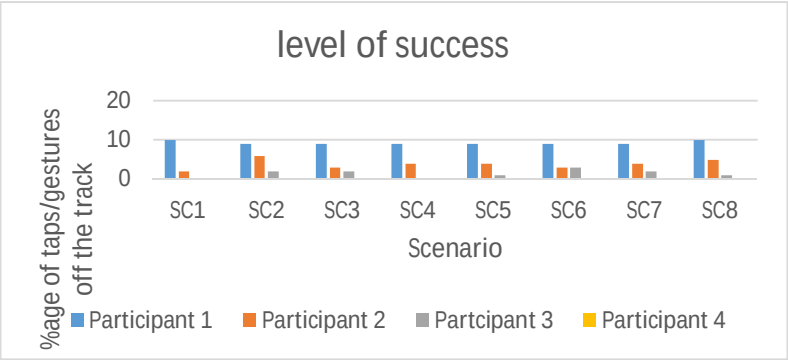


Figure 36: Level of Success

6.2.2 By Feature - Ease of Use

In the post-test questionnaire (refer appendix 7.2.1), participants were asked whether they would use this application for self-management routine. Of the four participants, three indicated that they were 'very likely' to use the app, while the remaining one said that they would "likely" use the application.

In addition, the SUS scores for each participant were generally quite high, with scores 80 or higher. Average satisfaction scores are typically between 65 and 70 meaning participants were highly satisfied with the usability of the mobile application.

	P1	**P2**	**P3**	**P4**
SUS Score	80.2	81.7	83	80

Figur 37: SUS Score

Overall, this was a positive feedback, but in order to determine why the majority of the participants were not entirely convinced to use the application, each feature was examined in further detail. As part of the questionnaire, participants were asked to indicate how easy it was to use or understand each major feature of the mobile application (refer appendix 7.2.2). Figure 38 below summarizes the average rating by the feature of all participants: 1 - very difficult to 5 - very easy. It is clear that the "sending food details" features were the most difficult to use/ understand.

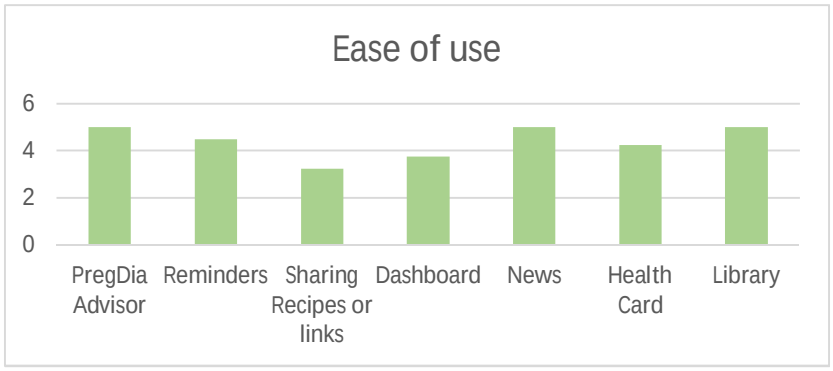


Figure 38: Ease of use design feature

6.2.3 By Scenario Relevancy

The last section of the post-test questionnaire two (refer appendix 7.2.2) was asking the participants to rank how realistic/relevant the scenarios were to them on a scale of one to five: 1 - not realistic and 5 - very realistic. Figure 39 below summarizes the results with realistic to very realistic.

Relevancy	U1	U2	U3	U4
SC1	5	4	4	4
SC2	5	5	4	5
SC3	5	4	5	5
SC4	5	5	3	5
SC5	4	5	4	4
SC6	5	5	5	4
SC7	5	5	5	5
SC8	4	4	5	5

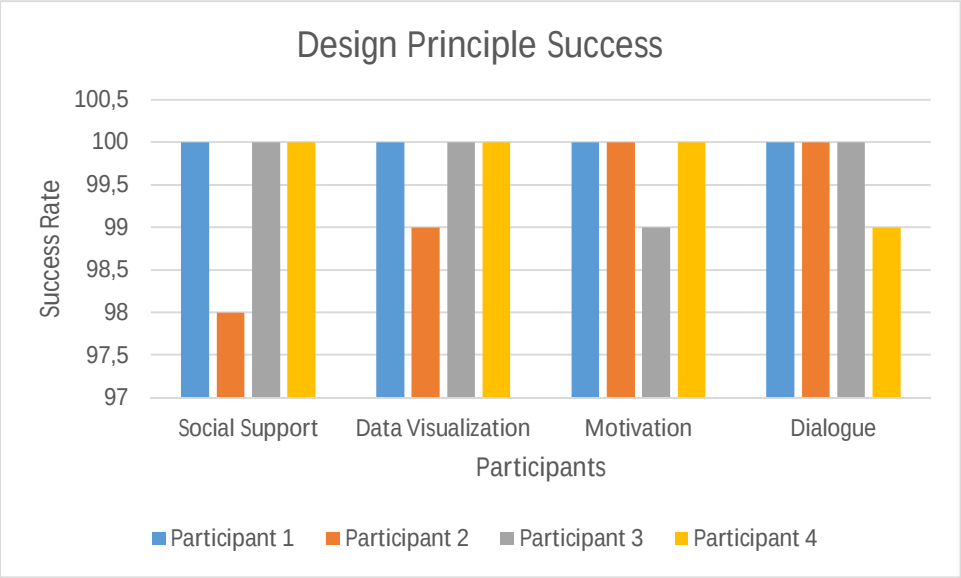
Figure 39: Scenario relevancy

The purpose of this piece was to confirm what aspects of the design, a gestational diabetic patient might be most interested in using. Overall all scenarios more realistic as they were scaled more than 4, further analysis shows that the most realistic scenario for all participants was data sharing to a dietician.

6.2.4 By Functionality Relevancy

The third questionnaire was to find out the effectiveness of each functionality that was measured in terms of design principle success in evaluation by different scenarios. In this evaluation users were asked to answer five questions in each category of design principle and were asked to rate the success of each task. They were asked to rate on a scale of 0 to 5, how supportive the prototype was for the success of completion of each design principle. This test was similar to usability test by task, but in that case the results were based on usability test observation. Whereas in this result is based on the answers found in questionnaire.

These results shows that design is persuasive and has motivated the users to change their behavior to self-management parameters of gestational diabetes. Although few suggestions are received for further improvement and are discussed in chapter 7. Analysis shows that as compared to other design principles more improvement is needed in social support. Further analysis shows that is due the carbohydrate details sharing feature. Figure 40 details about design principle success rate.



Figur 40: Design principle success rate

6.3 Summary of chapter

This chapter presents an evaluation of PregDia by using the think-aloud protocol as usability testing method. Results detail how PregDia was used and experienced by four participants over eight scenarios. Most participants experienced a benefit to maintain structured lifestyle by asking advice from a conversational agent, PDA.

Performance of PregDia measured is in terms of the amount and the consistency of the added content. Results show that patients responded to almost all the suggestions and reminders. Evaluation results also shows that persuasive mHealth solution has involved motivation, resulting in behavior change of patients. PregDia specifically designed to support the development of self-management tool for GD patients. It was achieved by proactive responses by PDA to the added content by the patient in a social fashion (in the form of text conversations). This gave the feeling of care and stress relief to patients.

Based on the results, users found PD is easy to use and useful.

Chapter 7: Discussions

This section details about the discussion on few open points from this research work. These discussion points are build mainly around the feedbacks received in the post-test questionnaires of usability Evaluation

Literature review shows that Gestational diabetes is a complex disease that requires constant monitoring and active patient participation in the development and maintenance of their daily self-management routine. As each patient is unique and has different needs which makes designing a mHealth solution to provide support to these individuals a challenging project. As very few applications are designed specially for gestational diabetes so this research involved exploring existing diabetes (any type of diabetes) mobile applications and design features, developing a better understanding of user requirements, translating those requirements into a medium fidelity static paper prototype, and collecting feedback on the final design. Evaluation of final design has shown that the application has motivated the users towards achieving self-management goals. Regular follow ups and suggestions by PDA are main success factors of success. But there were few open questions and the solution for them can be designed in next iterations. These open points include:

Text Based Conversational Agent

The primary contribution of this research is the text-based conversational agent designed to support patient by invoking self-management, this is achieved by providing data visualization to patients about status of goals (i.e. if the parameters are in or out of threshold). Users felt motivated on viewing the targets achieved. The main area of discussion in conversational agents is data integration to glucose kit data.

For success of PregDia it is important to have data integrated with glucose kit. Business process model is recommended in section (5.2.2). In this usability evaluation it was assumed that conversational agent PDA is integrated to blood glucose data. Imagining a scenario when patient does not text the details to PDA, as a result PDA will not be in a situation to give any advice to patient for corrective actions. To overcome such situations it is recommended to have both options, first patient can send data to PDA manually in form of text message to PDA and second data should be fetched from integrated device. In further design it is recommended to have a comparison chart on the readings from device and manually entered by patient. More research is needed in area on managing conversational process (Følstad & Brandtzaeg, 2017), this is already an area of concern in field of HCI . Persuasive design principles formed by borrowing aspects from (Oinas-Kukkonen & Harjumaa, 2009) can be used for further research in this areas (refer section 5.3.1). These design principles were achieved by refining the requirements in each iteration. These design principles were evaluated in section 6.2.4.

Carbohydrate count

In the results from usability evaluation, it was noticed that users are most interested to record and share carbohydrate information but due to design challenges they were not able to use the functionality completed. As mentioned earlier, in this research this feature was not complete but was put in scenario to invoke discussion. Results were as expected, can be seen from evaluation results (refer section 6.2). Idea here is to upload the picture with food and description of food. Dietician can calculate the carbohydrate intake using this data for further treatment. Users mentioned this data log is equally important for them, as they can learn from these logs which recepies make the sugar levels go high or low.

It is recommended to consider this functionality in next iteration and should be tested with high fidelity prototype.

Fetus growth
This feature was requested by users and clinic experts. It is presumed that the visualization of the growth of baby will keep the patient motivated to adhere to structured life style and self-management. Due to lack of time this feature was not designed in this prototype but can be considered in future work.

Social Support
At present, all users are on social media but less than 10% use social media for gestational diabetes support. Interview results shows that mostly all patients reach at least one more person other than health care providers for help. That could be mother, father, sister, partner or a friend but since the person reached has not faced this disease there suggestions cannot be considered for treatment. This was also mentioned by midwive at one of the sessions. So social support feature should be explored further for support.

To summarize, throughout the user-centred design process, copious user feedback were collected which contributed to the understanding of gestational diabetes patients and helped guide the design of novel data visualizations, historical data and motivations in self-management techniques. These were tested and validated by the user. The feedback was positive and overall, the patients enjoyed the experience of using the mobile app. The hope is that applications like this can help to lower the burden of care on gestational diabetes patients.

Chapter 8: Conclusions

The research work concludes and details that PregDia designed on persuasive design principles can invoke behavior change in the self-management process for gestational diabetic (GD) patients by using text-based conversational agent technology. This research proposes a set of persuasive design principles (Refer section 5.4, table 12) for self-management, data visualization of historical data, motivation and social support for application development of gestational diabetic patients.

This constructive research provides overview of existing mHealth applications for diabetes with design features, provides an understanding of user requirements, translates those requirements into a prototype, and provides the evaluation of final design (refer chapter 6). Research is referred as constructive due to the development of design-rationale and iterative development of a self-monitoring persuasive system for women with gestational diabetes. This includes a selection of methods for constructing such a system(chapter 5), as well as establishing user requirements (chapter 4). The main contribution of this research is the produced knowledge about how to design for self-management of gestational diabetes and how to design persuasive conversational agents for gestational diabetic patients. Whereas empirical view of this research provides an investigation of characteristics of usability and experience from using the constructed prototype, PregDia.

Through conducting requirements analysis and usability evaluation with gestational diabetic patients, this research helped to develop a deeper understanding of the patient issues and their expectations and attitudes towards mobile applications. In the design and development stage, the persuasive design principles were translated into a prototypical implementation that built the foundation for subsequent rounds of demonstration and evaluation of the artifact. The artifact built was thus theory-ingrained and embedded the research contribution in its design through demonstration and evaluation (refer chapter 6), that shows the feasibility of the proposed design.

Furthermore, this thesis seeks to communicate the findings of this study in a way that is extensible to future research in the field of HCI, mHealth, behavioral change, persuasiveness and text based conversational agent.

Chapter 9: Future Research

This research is the first iteration of an ongoing design process. The feedback collected from participants could now be used as a basis for future work in this area. Future research should include another iteration of design making changes using the feedback collected from usability evaluation (refer chapter 7). More specifically, changes should be made to account for issues users faced when interacting with the paper prototype.

This application design focused mainly on patients, but future design can consider the way healthcare providers will use this application. Features such as the uploading images and scrolling the video recommendations should be tested using a high fidelity dynamic prototype where the interaction would mimic what it would actually be like using a mobile device. In addition, the food database portion of the app was not fully developed. Usability evaluation shows that measuring and tracking carbohydrate intake is an onerous task for many gestational diabetic patients making this an area where creative research can be quite helpful.

To conclude, the need for creative solutions to help support gestational diabetics patients is endless. It is the hope that this research work can inspire new and fresh ideas for future researchers to build from.

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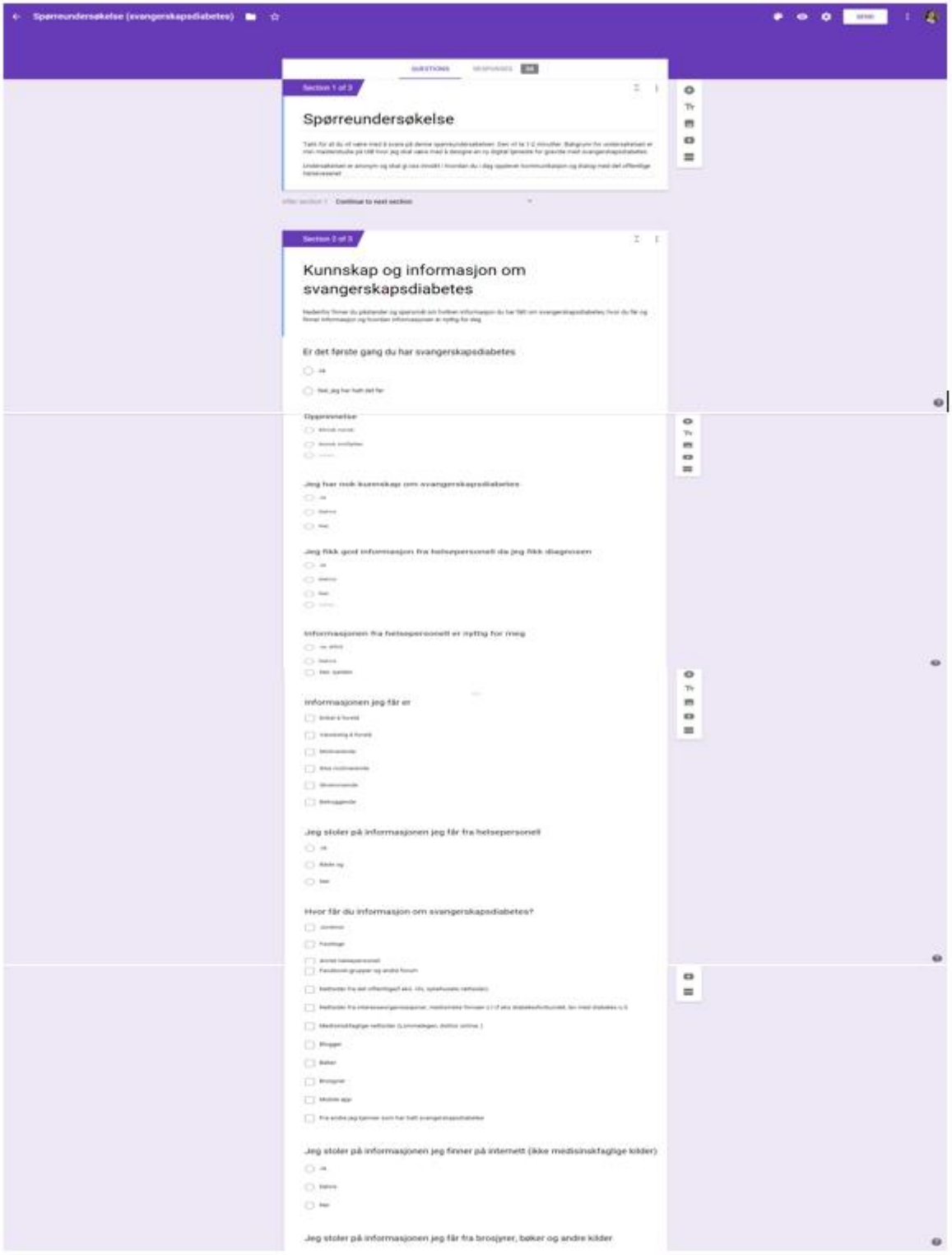
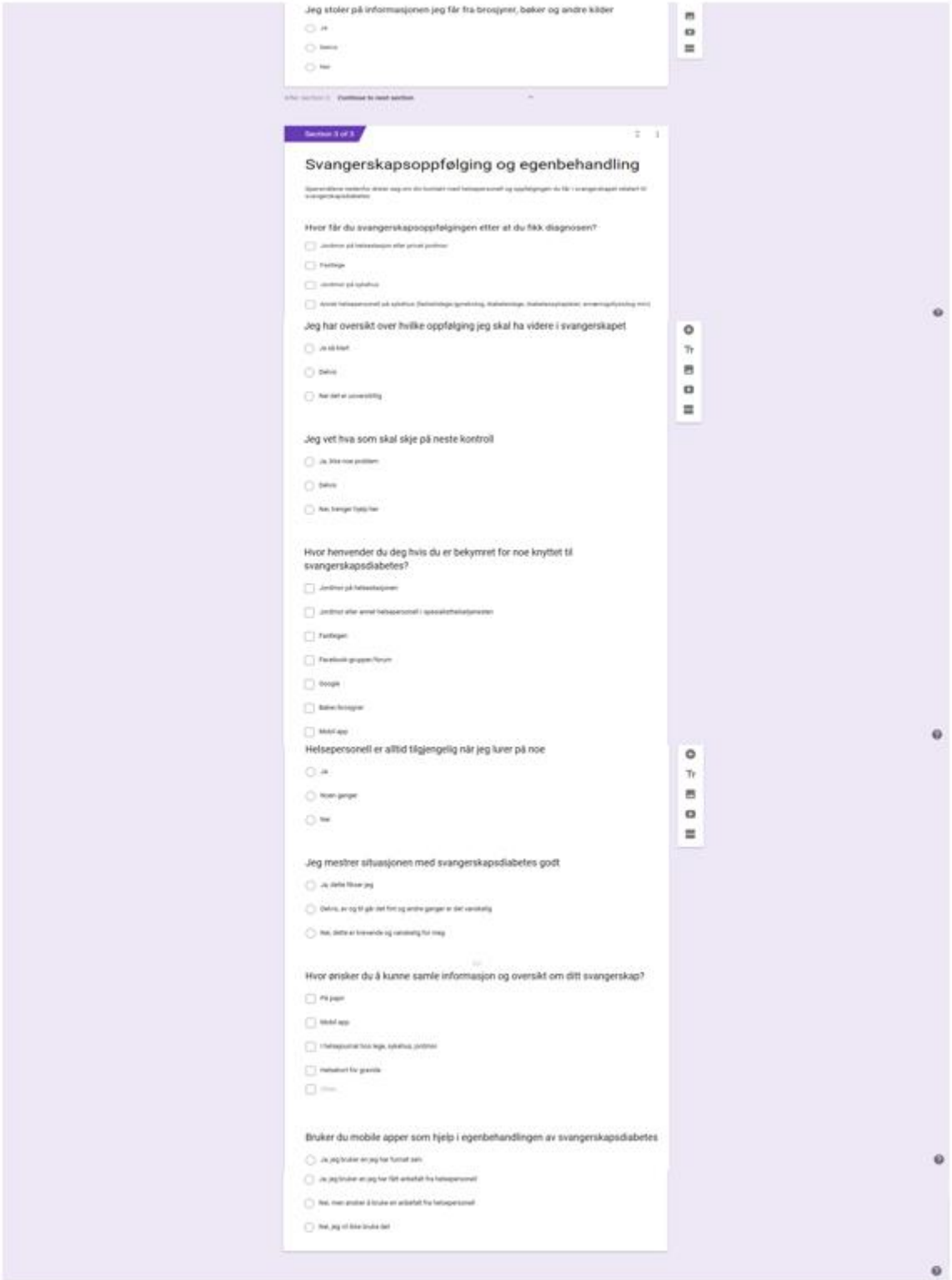
Appendix

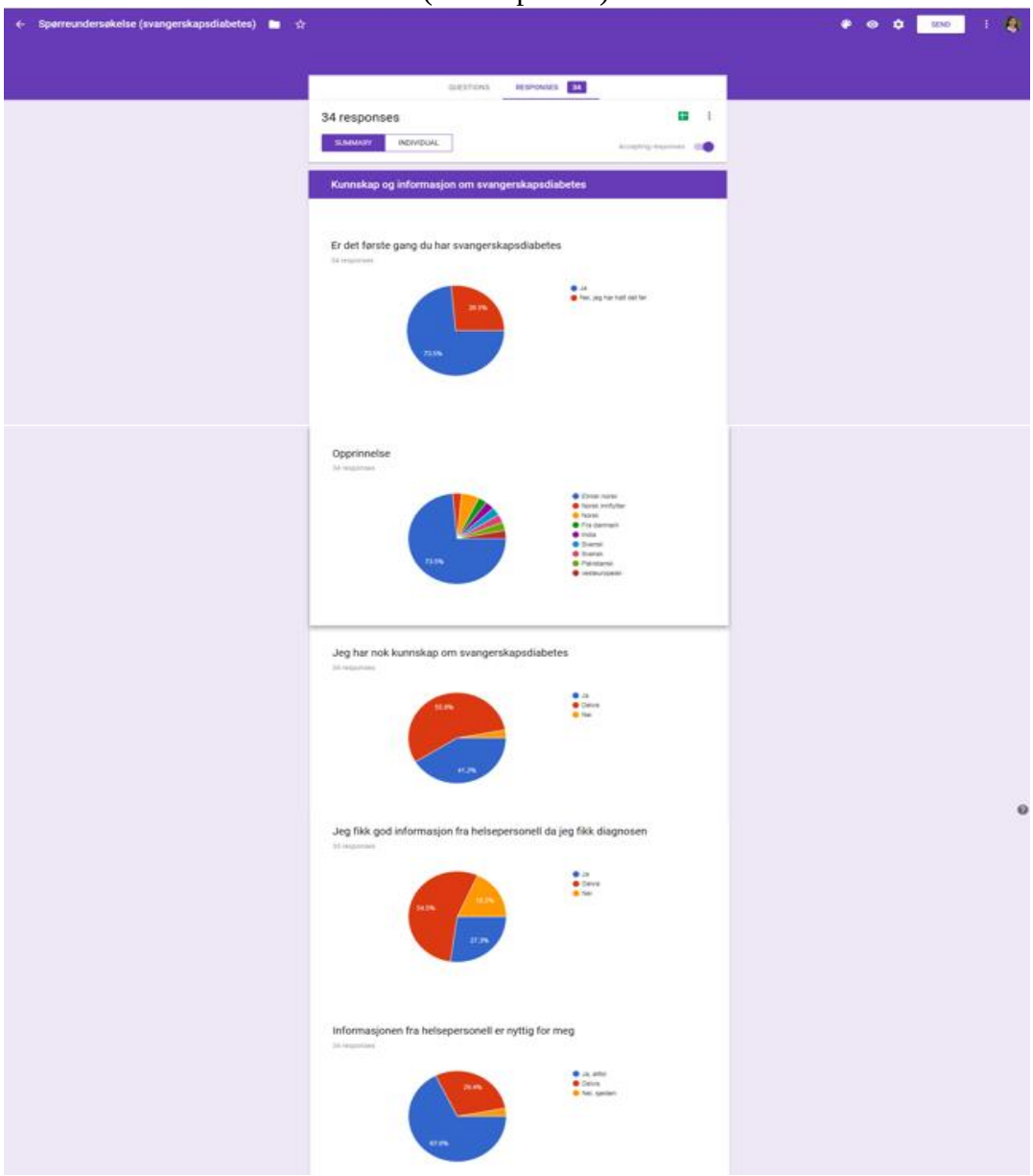
Appendix 1- Survey Questions (Google Form's)



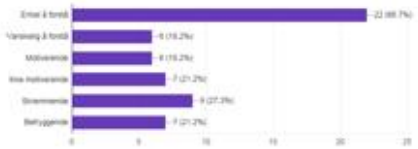

Jeg stoler på informasjonen jeg får fra brosjyrer, bøker og andre kilder
Section 3 of 3
Svangerskapsoppfølging og egenbehandling
Hvor får du svangerskapsoppfølgingen etter at du fikk diagnosen?
Jeg har oversikt over hvilke oppfølging jeg skal ha videre i svangerskapet
Jeg vet hva som skal skje på neste kontroll
Hvor henvender du deg hvis du er bekymret for noe knyttet til svangerskapsdiabetes?
Helsepersonell er alltid tilgjengelig når jeg lurer på noe
Jeg mestrer situasjonen med svangerskapsdiabetes godt
Hvor ønsker du å kunne samle informasjon og oversikt om ditt svangerskap?
Bruker du mobile apper som hjelp i egenbehandlingen av svangerskapsdiabetes

Appendix 2 - Survey Responses Anaylsis

(34 Responses)

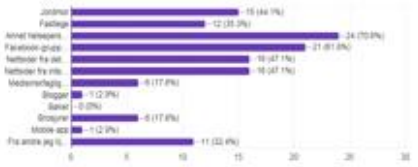


Informasjonen jeg får er

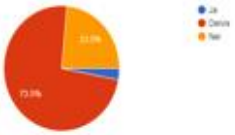


Jeg stoler på informasjonen jeg får fra helsepersonell

Hvor får du informasjon om svangerskapsdiabetes?



Jeg stoler på informasjonen jeg finner på internett (ikke medisinskfaglige kilder)



Jeg stoler på informasjonen jeg får fra brosjyrer, bøker og andre kilder

Svangerskapsoppfølging og egenbehandling

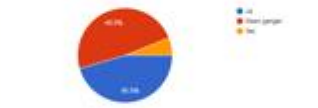
Hvor får du svangerskapsoppfølgingen etter at du fikk diagnosen?

Jeg har oversikt over hvilke oppfølging jeg skal ha videre i svangerskapet

Jeg vet hvis som skal skje på neste kontroll

Hvor henvender du deg hvis du er bekymret for noe knyttet til svangerskapsdiabetes?

Helsepersonell er alltid tilgjengelig når jeg lurer på noe



Jeg mestrer situasjonen med svangerskapsdiabetes godt

Hvor ønsker du å kunne samle informasjon og oversikt om ditt svangerskap?

Bruker du mobile apper som hjelp i egenbehandlingen av svangerskapsdiabetes

Appendix 3 - Pre-Interview Questionnaire Data

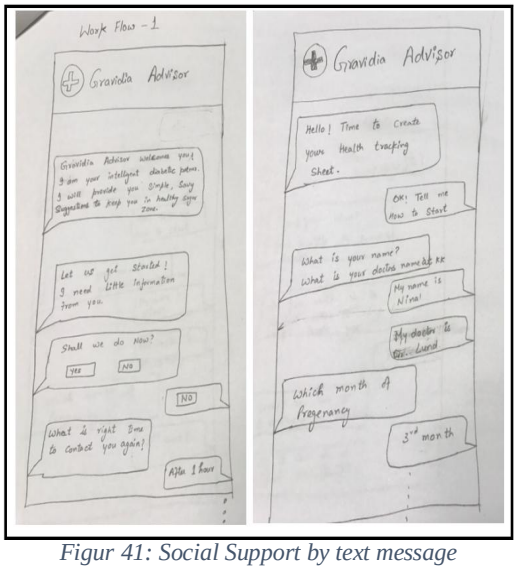
(Semi-structured interview before design)

Questions	**P 1**	**P2**	**P 3**	**P 4**	**P5**	**P6**
Age	25-30	30-35	30-35	35-40	30-35	25-30
First Pregenancy	Yes	No	No	No	Yes	No
Glucose Measuring Kit	Yes	Yes	Yes	Yes	Yes	Yes
Comfort with Mobile	VC	VC	C	VC	C	C
Uses Diabetes App	No	No	No	Yes	No	No
Use Social media for GD	No	Yes	No	No	No	No
Carbohydrate Tracking is easy	No	No	No	No	No	No
Share Diabetes Information (other than health care)	Partner	Mother	Partner, Mother	Partner, Parents	Partner, Sister	Partner
Does sharing information help?	Yes	Some time' s	Yes	Yes	Some time' s	Yes

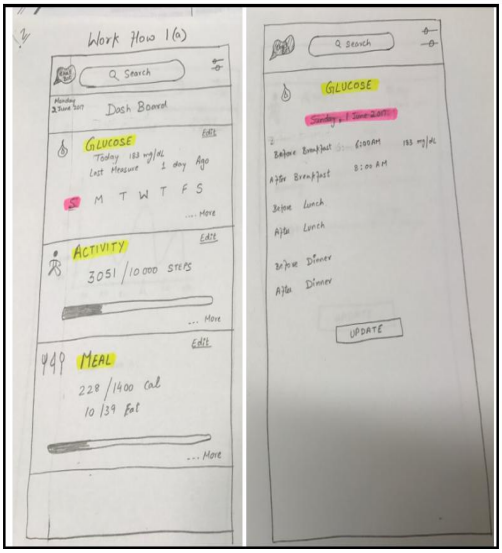
** VC- very comfortable
C - Comfortable

Appendix 4 - Sketches for Field Work -Semi Structured Interview

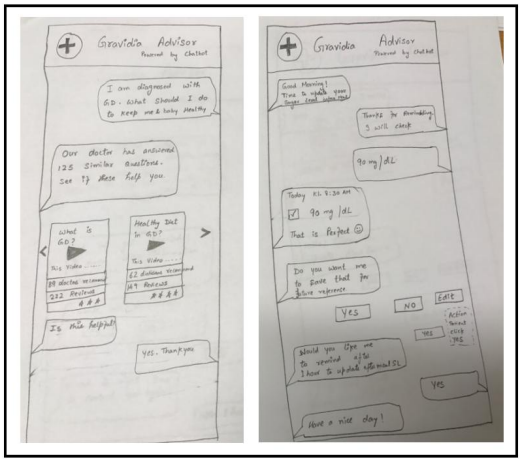
(Mobile application design for Gestational diabetes)



Figur 41: Social Support by text message

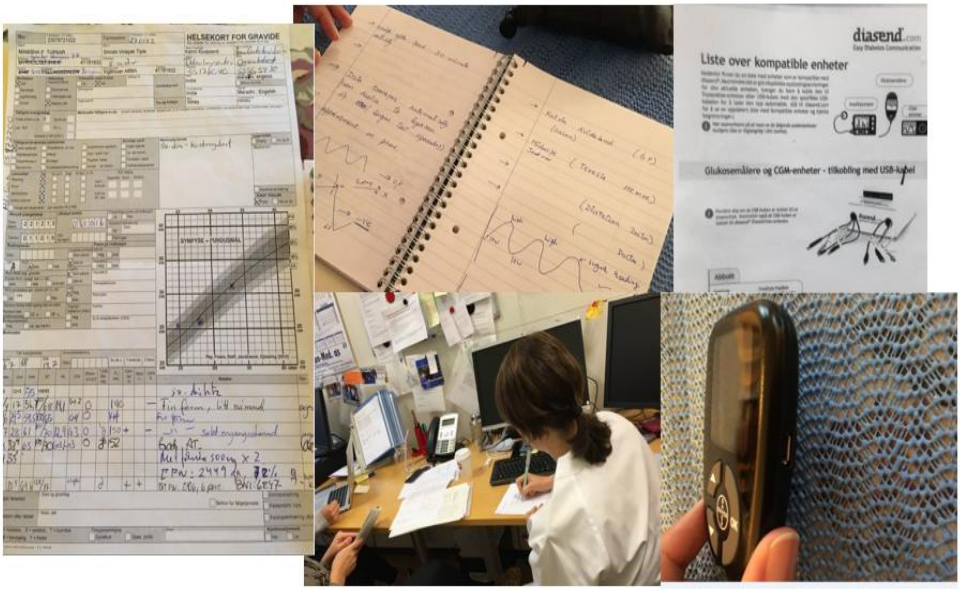


Figur 42: data monitoring

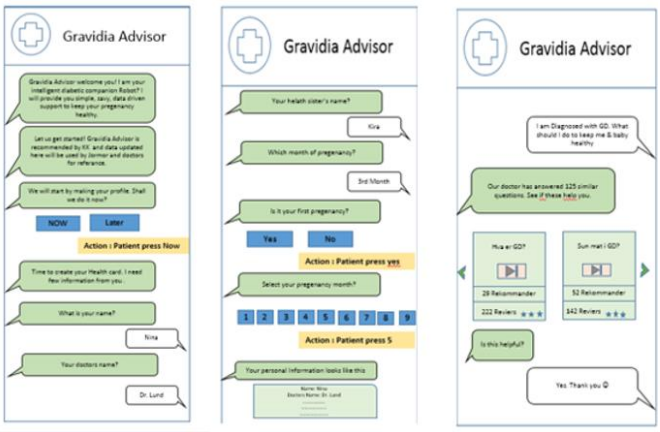


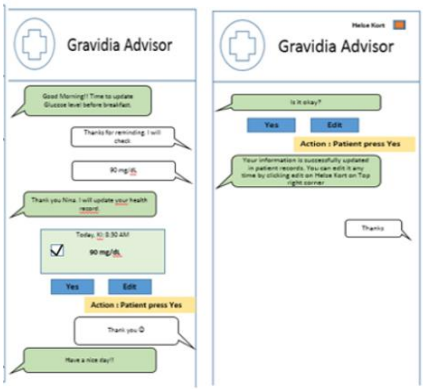
Figur 43: Motivation

Appendix 5- Pictures taken in requirement gathering phase



Appendix 6: Story Boards





Appendix 7 Questionnaire

7.1 Pre-Usability test Questionnaire

Pre-Usability test Questionnaire

1. In what age range do you belong?
   - o <25 years
   - o 25-30 years
   - o 30-35 years
   - o 35-40 years
   - o >45 years

2. Is it your first pregenancy?
   - o Yes
   - o No

3. Do you use glucose-testing kit?
   - o Yes
   - o No

   If yes name _____

4. How are you currently managing your diabetes?

   _____

5. How comfortable are you with using mobile devices and/or mobile applications?
   - o Very Comfortable
   - o Comfortable
   - o Not at all comfortable

6. Do you use any diabetes application?
   - o Yes
   - o No

   If yes, name _____

7. Do you use social media for diabetes?
   - o Yes
   - o No

   If yes, name _____

8. Do you track your carbohydrates?
   - o Difficult
   - o Easy
   - o Very Difficult

7.2Post Usability Questionnaires

7.2.1 Post Usability Evaluation Questionnaire 1- System Usability Scale

System Usability Scale

	Strongly Disagree				Strongly Agree
I think that I would like to use this system frequently	1	2	3	4	5
I found the system unnecessarily complex	1	2	3	4	5
I thought the system was easy to use	1	2	3	4	5
I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
I found the various functions in this system were well integrated	1	2	3	4	5
I thought there was too much inconsistency in this system	1	2	3	4	5
I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
I found the system very cumbersome to use	1	2	3	4	5
I felt very confident using the system	1	2	3	4	5
I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

7.2.2. Post Usability Test Questionnaire 2- Scenario relevancy and Feature Use

Post Usability Evaluation Questionnaire 2

1. Please scale (1 to 5) how easy it was to use/understand the following features of the mobile application:
   1-Very Difficult, 2- Difficult, 3-Easy, 4-Normal, 5-Very Easy

Feature	Scale
PregDia Advisor	
Reminders	
Sharing	
Dashboard / Data Visualization	
News	
Health Card	
Library	

2. Would you use this application to complement your daily self-management routine?
   - Not Likely
   - May be
   - Likely
   - Very Likely

3. Please list 3 things you liked most about the mobile application:

   _____
   _____
   _____

4. Please list 3 things you liked least (found most frustrating) about the mobile application:

   _____
   _____
   _____

5. Please rate the scenarios on a scale of 1 to 5 for how realistic they are to you.
   1- Not Realistic , 5- Very Realistic

Relevancy	Scale 1 to 5
Scenario 1	
Scenario 2	
Scenario 3	
Scenario 4	
Scenario 5	
Scenario 6	
Scenario 7	
Scenario 8	

6. Please share any other comments in the space provided below:

7.2.3 Post Usability Evaluation Questionnaire 3 – Design Principle Relevancy

Post Usability Evaluation Questionnaire 3

Sr. No.	Questions	Scale (0 to 5)
1	Did the PregDia application allow you to share information with others?	
2	Did you share any of your parameters for maintain gestational diabetes?	
3	Did PregDia advisor motivated you to share information?	
4	Did you reach any one for help in application?	
5	Did sharing information help you?	
6	Did you track information related to your gestational management?	
7	Did you record information related to your gestational diabetes?	
8	Did you review your blood glucose results?	
9	Did you ever look back to your logs?	
10	Did you made changes to your routine?	
11	Did you find any motivation to stay on track with your self-management practices?	
12	Did you set goals relating to your self-management practices?	
13	Did you receive any reminders for maintaining sugar parameters?	
14	Did you look back on your parameters? Does it help?	
15	Did you get motivated for next appointment?	
16	Did you link the suggestions by PregDia advisor?	
17	Did PregDia Advisor support you?	
18	Was PregDia Advisor good at communicating messages?	
19	Did you feel irritated by messages from PregDia?	
20	Did PregDia Advisor help you reach your goals?	
	0 - For Extremely Bad Support, 5- Very supportive	