Investigating usability issues of mHealth apps for elderly people

A case study approach

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ABSTRACT

Context. The evolution of information communication technology (ICT) has led to rapidly increasing integration of smartphones in the daily routine of individuals. Due to their support and enhancement of mobility and connectivity as well as local adaptability and personalization, applications developed for smartphones are able to address more specifically the needs of patients, doctors or healthcare providers in the healthcare domain, a development which is termed as mHealth. The purpose of mHealth applications is to deliver healthcare services to the patients irrespective of the place.

Objectives. In this thesis, usability issues in mHealth applications are explored and identified by studying and testing an application intended for elderly patients with type 2 diabetes (T2D).

Methods. For this purpose, the author has conducted a literature review and a case study with a prototype application from an ongoing research project, the Health in Hand project. Usability evaluation for that prototype application was conducted. The main source for evaluating the usability of the mobile application is users and their interaction with the mHealth application. In this thesis, two categories of user were taken i.e. elderly people and younger people and both their perspectives on usability issues were investigated and compared.

Results. The results showed overall satisfaction with the application but some usability issues were identified. Functionality and services provided via the mHealth application’s interface were evaluated by using think-aloud technique which is a common usability testing method. Moreover, recommendations for improvement of the mHealth application concerning usability aspects have been collected during the case study and are presented in the thesis.

Conclusions. Usability problems were identified when the participants interacted with the user interface of the selected mHealth application. The observed usability problems provide input for the Health in Hand project where they will be helpful for designing efficient mobile applications in the future.

Keywords: mHealth, usability, mobile, healthcare, type 2 diabetes, elderly people
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# List of acronyms

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<thead>
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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>HCI</td>
<td>Human computer interaction</td>
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<tr>
<td>ICT</td>
<td>Information communication technology</td>
</tr>
<tr>
<td>mHealth</td>
<td>Mobile health</td>
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<tr>
<td>NFC</td>
<td>Near field communication</td>
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<td>OS</td>
<td>Operating system</td>
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<tr>
<td>PACMAD</td>
<td>People at the Centre of Mobile Application Development</td>
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<tr>
<td>PDA</td>
<td>Personal digital assistant</td>
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<tr>
<td>T2D</td>
<td>Type 2 diabetes</td>
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<td>UX</td>
<td>User Experience</td>
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# INTRODUCTION

The topic of this thesis is usability evaluation of mHealth applications. The case study within which the usability evaluation has been carried out concerns the development of a mHealth application for supporting elderly patients with type 2 diabetes (T2D) in living a healthy life and managing their diabetes. The thesis project makes a contribution to an on-going research and development project, *Health in Hand – Transforming Healthcare Delivery with Innovative Mobile Technologies for Health Promotion and Disease Prevention*, at Blekinge Institute of Technology. In the following paragraph, a brief background concerning the problem area is presented.

In recent years, the evolution of information communication technology (ICT) has led to considerable changes in the field of healthcare. The recent advancements in technologies like smartphones, sensor networks, and social networks have led to a new branch in eHealth called mHealth (mobile health). Mobile technologies have become pervasive and are integrated into our daily life [1]. With this advent, many mobile applications have been developed that are now contributing to transforming healthcare delivery. Doctors are able to treat their patients remotely. Not only doctors, but patients are able to manage their health by themselves by using the applications.

This thesis has focused on a mobile application for supporting patients with a chronic condition called diabetes where the patient has to take continuous medical treatment. Diabetes is a disease caused due to deficiency of endogenous insulin. There are two types of diabetes, type 1 and type 2. Type 1 diabetes is caused due to the insufficient production of insulin and type 2 diabetes is caused due to insulin resistance i.e. improper response to insulin. This study mainly focuses on T2D. In T2D, cells do not respond properly to insulin and cells would not get sugar from the blood [2]. People who are above 45 years or obese or who do not indulge in physical activity are prone to get T2D. If T2D is not managed well and controlled, it increases the risk of heart disease, retinopathy (a disease of the retina which results in impairment or loss of vision), kidney damage, poor blood circulation and nerve damage [2].

Usability is considered a crucial issue concerning ICT in and for the health domain. Usability is usually understood as an issue that needs to be addressed for all web and mobile applications where end users come in direct contact with the interface. Irrespective of whether it is a web application or mobile application, usability problems continue to exist, despite available tools and guidelines for how to design for better usability [3][4].

There are many mHealth apps available in the app store (app store is a type of digital distribution platform for mobile apps). For this usability study, the author has selected the application which was chosen to be used as a prototype in the *Health in Hand* project, which focuses on diabetes care. The mobile application is a cloud-based application which collects data regarding the glucose levels of the patient and this data is accessible to the healthcare professionals or doctors if the patient gives access to them by providing the clinic ID. The web application of the company that is involved in the *Health in Hand* project is available for 15 countries and has gained tremendous response from users. However, the company is going to launch a mobile app and it is presently in its initial stages. To study the usability issues we have selected this mobile application for this study.

The primary objective of this study is to explore the usability issues of the selected mHealth application concerning the aim to efficiently support patients with T2D. In addition, strategies for improving the usability of the mHealth application were investigated.
2 BACKGROUND

2.1 Problem definition

A recent survey has shown that European countries have favorable conditions for mHealth [5]. Due to the penetration of personal digital assistants (PDA) like smartphones, tablets, etc. mHealth has a broad scope and uptake in the European countries. Sweden is one among the top 3 countries when it comes to use, acceptance and uptake of mHealth [5].

With the broader scope of uptake and use of mHealth applications, app developers have to take measures such that their mobile healthcare application is accepted by both healthcare professionals and the patients and other end-users who use it. Developers while developing an application may overlook a functionality which is important which not only leads to defaming of the application but also might cost lives. So developers often use a user centered design (UCD) approach to address this issue. When combining two fields i.e. information technology and health care, one has to take necessary actions to minimize the errors caused by the application. In case of chronic diseases, continuous care has to be taken to prevent health of the patient from deterioration. One such chronic condition that the author focused in this study is diabetes. mHealth applications have during recent years been developed which offer different functionalities such as glucometer reading, insulin/medication tracking, diet tracking etc. for supporting health monitoring and self-management for diabetes patients [6].

During a meeting with nurses at Landstinget Blekinge hospital (Karlskrona, Sweden), they gave the input that most elderly people hesitate to self-manage their diabetes and they often visit the hospital to check their diabetes. This implies that elderly people think that applications are not usable. To mitigate this issue, the author has conducted a usability test of a mobile application that focuses on diabetes. Through this, usability problems that prevent elderly people from using the application are identified. These usability problems act as an input for the Health in Hand project.

This thesis is a part of, and aims to contribute to, the Health in Hand project which deals with usability issues that threaten the effective implementation of mHealth in healthcare and disease prevention[7]. The Health in Hand project includes an on-going Swedish case study which focuses on usability issues of mHealth applications for elderly people with diabetes. An investigation of mobile based applications for supporting T2D has been conducted, and the focus has been mainly on the mobile interface used by elderly patients. Elderly patients are here defined as patients who are 65 years old or older.

2.2 Human Computer interaction (HCI)

HCI is a multi-disciplinary area of research which includes disciplines such as human factors, computer science, information systems, physiology, sociology and visual design. HCI mainly deals with how humans interact with machines. HCI researchers mainly focus on the technologies that can be designed to make human computer interaction easier [8]. The design approach that is often considered by HCI researchers is the user centered approach which aims to give a detailed understanding of usability, usefulness and capability of technology to be integrated into the daily life of humans[9].
2.3 Mobile health (mHealth)

According to Eysenbach, ehealth is defined as “an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology”[10].

The recent advancements in technologies like smartphones, sensor networks, and social networks have led to a new branch in eHealth called mHealth (mobile health). mHealth is defined as “Medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices”[11]. mHealth is thus a multidisciplinary area of research which involves biomedical engineering, healthcare and Information Technology (IT) with a special focus on mobile information and communication technologies[1].

The applications that have previously worked on desktop computers have now come to mobile devices. Mobile devices typically include PDA, smart mobile phones and tablets. Though PDAs were used in the early 2000s, with the advent of the computational power of smartphones the features of PDAs have been incorporated into the smart phones[12][13]. Mobile health care applications, usually called mHealth apps, provide health services to the patients remotely i.e. deliver health services to patients anywhere/anytime [14]. mHealth changes healthcare provision as it supports healthcare professionals for monitoring patients remotely and it helps patients lead a healthy life. The increased advancements in mobile networks and applications are currently transforming healthcare delivery on a global level[1].

2.4 Related work

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 [15]. A systematic literature review conducted by Fiordelli et al. (2013) has showed that the most common chronic condition addressed between 2002 and 2012 is diabetes[15]. Diabetes is a chronic condition where the patient needs to take continuous care for his/her health. With the help of mHealth applications, the patients are able to 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 (ICT) has made the use of mobile phones a common way of communication [16]. ICT has influenced the healthcare field by offering different mobile technologies. In 2009, Stavroula et al. have focused on mobile applications that support self-management of type 1 diabetes. They have evaluated a single Windows(OS) based mobile application that supports the transmission of data between mobile phones and hospitals [17]. In a systematic literature review conducted by Hamine et al. (2015), the effectiveness of the mHealth applications that support
chronic disease management of diabetes, cardiovascular disease and chronic lung disease has been studied. Results showed that there is difficulty in using mobile applications by the users and they also exhibited technical issues like problems with inputting the values, errors etc. when working with the application [18] [19].

Though the applications are meant for everyone, Qiuhi (2008) observed that elderly people often had difficulty in understanding the functionality of the interface and most of the elderly studied were comfortable with basic tasks such as dialing a number but they were not comfortable with complex applications [20]. A participatory design study conducted by Davidson et al. (2013) with elderly people above 65 years old has resulted in identifying the health metrics such as health appointments, rest tracking, stress relief activities that are often not considered by the designers. Interviews, group sketching and questionnaire methods were used to identify the health metrics [21].

No matter how many technologies or applications are developed, they will lose their significance if they are not used by anyone. This has led to research on usability. Usability in simple terms is the ease of use of technical artifact used by the users to fulfill an objective [22], [23]. Usability is considered a crucial part of design and development of apps for mHealth as it aims to reduce the risk of users having difficulty in using the application [22] and it is one of the attributes that regulate the success of the app in the market [24]. Generic usability guidelines exist for desktop applications, but when it comes to mobile applications, the usability guidelines are still largely lacking [25]. In recent years, in the field of HCI research, there has been an increase in interest in mobile usability studies. This may partly be due to the rapid increase in mHealth applications on the market. Usability studies have their origins in the 1970s, but since that time the focus has gradually shifted from isolated and strictly monitored experiments in usability laboratories to context of use for usability. Several scholars have proposed context of use theory which showed that there are extra variables that effect usability [26] [27] [28]. Traditional usability evaluation proved insufficient, or even inappropriate, when usability issues were addressed in situational contexts of everyday use. Mobile applications can be developed for different contexts.

To address the usability needs when it comes to mobile phones, traditional HCI researchers have opted for a new paradigm that considers environmental issues and context of use as important factors [29] [30].

Baharuddin et al. (2013) have conducted a review where they proposed a model prioritizing usability dimensions identified from previous studies [24]. A recent systematic literature review conducted by Arnhold et al. (2014) on mHealth applications which focuses on diabetes for older adults has shown that the applications which are offering a small range of functions are performing better than the ones that are broadly multi-functional [31]. Wildbenbos et al. (2014) have designed a framework for evaluating a mHealth application which focuses on elderly people. They found usability issues through cognitive walkthrough approach where one or more evaluators worked on the application to find usability problems [32]. But in the end, usability issues faced by end users often differ from what is normally high-lighted when using a cognitive approach.

According to a review paper by Belén Cruz et al. (2015), empirical user testing and usability inspection, usability evaluation methods were the most common classification among the several taxonomies. Real world end users were the participants in user testing whereas experts or designers were the participants in usability inspection [33].

In this thesis, the author has focused on the end users and used think-aloud technique for the usability evaluation. The author has focused on an application for supporting patients with T2D in managing their health, and investigates the issues and barriers that make mHealth solutions difficult to use for elderly users.
2.4.1 Contribution

Within the framework of the *Health in Hand* project, the study contributes with a first closer look at usability issues concerning the prototype being tested in this project. The usability issues concerning the application and recommendations, which were collected from participants, were documented in order to help developers when they develop an application for elderly people with T2D. This documentation of usability issues and recommendations also can be seen as a contribution for startup organizations where the resources are limited i.e. organizations which cannot afford employing usability experts and UX designers in their initial stages, but where insights from usability studies can serve to inform design of mobile applications that are suitable for elderly people.

2.5 Mobile application architecture

The mobile application in this study was provided by a company participating in the *Health in Hand project*. Since the company’s name is confidential, the author has given a brief, anonymized overview of the application. Figure 1 below depicts how the application works. Glucose values are measured with a glucometer by taking a blood sample from the patient. The measured glucose values are sent to the mobile application through near field communication (NFC) technology. Through the application, the glucose values are uploaded in the cloud which can be accessed by the healthcare providers. Only healthcare providers who are explicitly given access by users can access the details of the users. Figure 1 shows the architecture of the mobile application.

![Figure 1. Architecture of the mobile application for T2D patients](image)
3 METHOD

3.1 Aims and objectives

The main aim of this thesis is to identify usability issues that could cause problems for elderly people with T2D when using a mHealth application to manage their T2D. For achieving this, the author has chosen a mobile application that targets diabetic patients. The results of the project are intended to support developers in understanding the needs and requirements of elderly people when it comes to mHealth applications for managing chronic disease. The results are also intended to contribute to the Swedish case study in the Health in Hand project, and to inform the continued design and development of the specific mobile application which has been studied. The objectives of this thesis are

- To identify and map usability problems that occur in a mHealth application prototype.
- To understand the user’s behavior when using a mHealth app.
- To evaluate mHealth application.
- To explore how usability testing results can be presented in order to efficiently inform and enhance the design of mHealth applications.
- To investigate interaction design solution suitable for elderly people.

3.2 Research questions

RQ1: What role does usability evaluation play during mHealth application design?
Motivation: This research question elicits the importance of usability evaluation in the field of mobile healthcare. To answer this question, the author has conducted a literature review.

RQ2: What are the usability issues (problems) involved when developing a mHealth solution for elderly T2D patients?
Motivation: This research question helps in identifying the usability problems that occur when using the mHealth application. The identified usability problems can be further explored and the knowledge developed in this way can be helpful in improving the mobile application. By taking care of the usability problems, the communication between the healthcare providers and patients can be improved.

RQ3: What could be the strategies for improving the usability of a mHealth application?
Motivation: This research question was intended to provide recommendations to mHealth application developers, in order to overcome the usability issues faced by elderly people. This question is answered from the results of the usability test and interviews with elderly people who are experienced in using the mHealth applications.

3.3 Research design:

The author has followed a mixed method approach in this thesis. A literature review and case study methods were used. Since the main aim of the thesis was to identify usability issues in an mHealth application as a way of exploring and gaining a better understanding of usability issues in design and development of mHealth solutions, the literature review was chosen as a sufficient way of collecting basic information regarding usability issues and which usability evaluation method should be selected for evaluating the usability of the mHealth application. An alternative method, Systematic
literature review (SLR), could have been used. SLR usually involves in-depth analysis of the literature. The author has selected a literature review rather than SLR because this thesis focuses on understanding usability issues and why these issues prevent users from using the mobile application. Thus, the author has selected a case study research method for this thesis, which includes a lab experiment with students for the usability evaluation. After the usability evaluation with students, an additional usability evaluation has been carried out with elderly users. An alternative method to a case study could have been a more focused lab experiment. This method was however rejected, as the author has selected a particular prototype of a mobile application for diabetic patients. In this context, the aim is to evaluate the usability of mHealth in an everyday context as close to the patients’ normal everyday life as possible, which is easier to do in a case study than in a lab experiment.

The following diagram shows the research design followed in this thesis.

![Figure 2. Overview of the research design of the master thesis project](image-url)

Figure 2. Overview of the research design of the master thesis project
3.3.1 Literature review

The initial step was to conduct a literature review in order to get an overview of methods for usability evaluation and how these are used in the design and development of mobile applications for mHealth. A literature review helps to define the topic and position the thesis project within the chosen topic area. It also helps determine and delimit the scope of the study [34]. In the later stage of the study, the literature review will also be helpful for designing a usability test and presenting the results of the test in ways that can efficiently inform interaction design when a mobile application is developed.

The guidelines provided by Creswell’s “research design” book were used to conduct the literature review [34]. To begin with, the author identified the keywords related to this thesis topic. The author has used keywords such as mHealth, eHealth, usability, usability evaluation methods, mobile application. With the identified keywords, the author has searched different databases like Scopus, INSPEC, Google Scholar and ACM. From the results obtained from the databases, the author has selected relevant articles, journals, books and review articles to read and work further with.

3.3.2 Case study

A case study is defined as an in-depth study of a particular situation or case [35]. The main aim of this study was to find out the usability issues faced by elderly people with T2D when using a mobile based application for managing their T2D. In this thesis project, an existing prototype obtained from a company which is involved in the Health in Hand project was used to study usability issues involved when developing an application. In this case study, the case was about the mobile application that targets diabetic patients and the unit of analysis was the interaction between users and the mobile application. To identify usability issues, a usability test was conducted with a small selection of BTH students with a computer science background and elderly people who were the main target of this study. The original plan was to combine a small usability test with elderly people with a large-scale web based questionnaire targeting people all over Sweden who are living with T2D. The web based questionnaire was intended to focus on user expectations and experiences and perceived usability issues of mHealth apps for managing T2D. The questionnaire was to be distributed via a national portal for mobile apps for managing diabetes, diabetesappar.se, the designer of which has also taken an active part in the Health in Hand project. However, this part of the project has been repeatedly delayed and could therefore not be included in the master thesis project, which had a tighter time frame than the Health in Hand project.

T2D can in fact develop even in young people, although it is considered to be a disease that mainly afflicts elderly people. There may thus be students at BTH as well as elderly people who are living with T2D and who have firsthand experience of monitoring and managing T2D in their everyday life. But in the usability test conducted with students in this study, the assumption was that the participants did not have firsthand experience of diabetes, and that the usability test was carried out as a simulated “as if” test where the participants were asked to test the mHealth application “as if” they were expected to use it themselves and “as if” they had T2D. In this case, the usability test could be seen as both a way of exploring usability issues concerning the specific mHealth prototype that was being tested, and a way of exploring and reflecting on usability issues and methods for evaluating the usability of mHealth applications more generally. The usability test conducted was a non-invasive usability test (that is, not actually taking blood tests and reporting glucose levels in the mHealth app) meant that it was not necessary to apply for formal ethical approval of the case study, a procedure that can take a number of months and costs quite a bit of money.
During the usability test, data was collected through think-aloud technique where individuals explain aloud what they think of the application as they carry out a set of tasks in the application. This technique is carried out in two stages. The first stage is the collection of observations through think-aloud protocol and the second stage is to analyze the observed human behavior while the participant is dealing with the assigned tasks [18]. The observations were documented and recorded (audio) with the participating individual’s consent.

Informal discussion means sharing of information. Informal discussions with the supervisor directed the author in taking the next steps for doing the usability evaluation. Questionnaire with the participants at the end of the usability test added to the results of the usability evaluation, but also, on a more general level, provided valuable information for enhancing mHealth application developers’ understanding of perceived usability issues concerning this type of applications.

Research questions are answered in chapter 4 (RQ1), 5(RQ2) and 5.8(RQ 3).
4 THEORETICAL WORK

4.1 Usability

According to the International Organization for Standardization (ISO) standard ISO-9241, usability is defined as “the effectiveness, efficiency and satisfaction with which a specified user can achieve the specified goals in a particular environment” [36][37]. Usability is a key factor in mHealth applications, especially for elderly people who may find it difficult to interact with smartphones, PDAs etc.

The five quality components (criteria) that define usability according to Jacob Nielsen are [38]

1. Learnability: Learnability is about learning and getting used to the interface of the system to get maximum benefits from using it. How easy is it for users to accomplish basic tasks the first time they encounter the design?
2. Efficiency: A system is said to be efficient if the usage of the system is expected to have a good level of productivity.
3. Memorability: If the users who have experience with the system but have not used it for some time are able to return to the system and use it successfully then the system is said to be memorable.
4. Low error rate: Whenever the users fail to perform a task, the user gets an error. The system should be able to withstand errors. The users may give up on the system if they encounter too many errors or if errors are managed badly. This quality component is not only about number of errors, but also about severity of errors and how easy it is for users and the system to recover from errors.
5. Satisfaction: The satisfaction of the users plays an important role regarding the usability of the product. A user is satisfied if he/she is able to get expected benefits from the system and if the design is perceived as pleasant to use.

According to Shneiderman (2000), key usability attributes are time to learn, speed of performance, time taken to recover from errors, error rate by the users and satisfaction [39]. According to the ISO 9241-11 standard, usability is defined as the target accomplished by the user in the terms of effectiveness, efficiency and satisfaction[37]. Table 1 gives a high-level comparative overview of the usability quality components proposed according to Nielsen, Schneider, and ISO 9241-11.

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<td><strong>Efficiency</strong></td>
<td>Speed of performance</td>
<td>Efficiency</td>
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<td><strong>Learnability</strong></td>
<td>Time to learn</td>
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<td><strong>Memorability</strong></td>
<td>Retention over time</td>
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<td><strong>Satisfaction</strong></td>
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The Nielsen Norman Group (NN/g) is an HCI and user experience (UX) consulting firm which was founded in 1998 by Jacob Nielsen, Donald Norman and Bruce Tognazzini and which has done influential work in usability testing, in recent years also concerning user experience of mobile devices, including iPads [41]. Therefore, the author has decided to select the quality components proposed by Nielsen.

4.2 Role of mobile applications in Healthcare

A mobile application is a piece of software that runs on handheld devices such as smartphones or tablets [42], that offers advanced communication and capability such as internet access and geo position system. Mobile devices which were previously used only for voice communication and text have changed to handheld computers with computing capabilities that include internet access and geo-positioning system [43]. The advantages offered by mobile applications in the field of healthcare appear to be almost boundless. mHealth application features available for healthcare professionals and patients are diagnostics, telemedicine, support for research and data collection, reference libraries, interventions, health promotion and behavior, sensors and peripherals, medical education, information sharing and drug reference and adherence[44][45]. According to statistics on mobile adoption and market share published by the web monitoring company (Super Monitoring) in 2013, 56% of the world’s population owned a smartphone, and users spent 80% of the time they were on their phone using mobile applications [46]. Although this type of market-oriented statistics would warrant further clarification concerning what the definition of a smartphone is, what is classified as ownership of a smartphone, what is defined as an app, and how the time spent on mobile phones inside apps versus outside apps is actually measured, the statistics do seem to indicate something about the scope, uptake and use of smartphones and mobile apps worldwide today.

With the pervasiveness of mobile devices in society, the impact of mHealth applications is considerable and includes improved patient involvement, enhanced data sharing and connection and communication between patient and providers [47]. With mHealth applications, patients are provided with a forum for goal setting, quick data sharing, self-tracking and observing capabilities which help them to become an active participant in their healthcare [48]. Through smartphones, healthcare providers are able to deliver their healthcare services to the patient’s home which also reduces the number of visits to the hospital. It also makes things easier for doctors to monitor remotely by observing the inputs from the patient. Efficient utilization of time can be observed when mHealth applications are used efficiently and to the full extent of their potential.

4.3 Importance of Usability for mobile applications

Usability mainly involves the design of the products or system as the user should be able to perform tasks with the system efficiently. Users wish to interact with interactive systems which are simple, interesting and satisfying. If they feel uncomfortable with the interface, it may lead to discard of the system or product, which on a large scale could lead to failure of the system or product on the market. Users do not show much interest in complex interfaces [38]. Involving users in the development process of a system with the ambition of developing a system according to their requirements is an area where usability has proved to be an efficient approach and tool. One example to show the importance of usability as a way of engaging users in design discussions is, a professor Frank reviewed 70 software products in different magazines and got 784 comments regarding the usability issues of the software[49].
Due to the fast growth in the usage of wireless devices and their ability to perform complex actions, many of the applications which were previously limited to desktop computers have now come to handheld devices. For people to get motivated to use these applications, usability of the applications must be taken into account from the start and measured during the development process to minimize usability problems when the applications reach the market. An application which is interactive will be successful, only if the users are able to perform the intended tasks successfully in an efficient manner. Even if the functionalities of the application perform well, but the users have issues with learnability and memorability of the application, feel dissatisfied and inefficient or face errors when using the application, then the mobile interface is not said to be good and usable. These issues have led developers and designers of applications to focus on usability and this has resulted in that usability has come to play a key role in developing an application. The success of an application is more feasible if the criteria for the usability evaluation are considered from the start in design and development.

In the limited literature found on usability of mobile phones, it is evident that the evaluation methods that are used for web are being used for mobiles also, i.e. there is an overlap between usability methods of web and mobile applications. However, in the case of mobile phones, usability explicitly involves context of use factors. The context of use includes task, environment, social and technical components [30].

To identify the usability issues of an application usability evaluation is performed. The reason for performing usability evaluation is to test the application to assure that it meets the needs of the users when they interact with it. Problems that occur during the development process and that affect the interaction design can be identified through iterative usability evaluation [50]. Usability evaluation aims to identify and solve problems that are related to the design which would be general, unique or task related [51].

According to the literature, Usability evaluation methods applied for mobile applications are categorized into:

a) Testing: With this method, interactions with the participants are observed by the evaluators to identify the usability problems.

b) Inspection: This method involves usability experts who to set up a list of criteria to identify usability problems.

c) Inquiry: This method involves exploring the perceptions, experiences, views and choices of the participants.

Testing:
Testing refers to the observation of user’s behavior when interacting with the application [38]. In testing, a set of tasks defined by the experimenter are performed by the users on either prototypes or a fully functioning system. The empirical data is collected by the experimenter when the user performs the assigned task. Data include time taken to perform the task, number of errors, user satisfaction etc [38][52]. In usability testing, think-aloud and co-discovery techniques have proven to be effective techniques[53]. Think-aloud technique is used to gain insight into the mental understanding of the users when they interact with the application. While interacting with the system, the users are allowed to verbalize their thoughts on the application, which helps the tester to identify the effectiveness of the application and the satisfaction or frustration of the users [38]. In co-discovery technique, the tester observes the tasks performed by a group of two participants. The two participants can discuss and help each other in completing a task with the provided application [52][54].

Inspection:
Inspection refers to a set of criteria evaluated by usability experts in identifying the usability problems related to the user interface. It is considered as a cheap alternative to testing. In the initial stages of the development process, inspection method proves to be
cost effective where the prototypes cannot be tested on users [38][52]. In usability inspection, cognitive walk through and heuristic evaluation technique are the most commonly used methods [55]. In heuristic evaluation technique, a group of usability testers compare an application against a list of heuristics (predefined usability principles) to identify the usability problems in a user interface design [56]. In cognitive walkthrough, the evaluators place themselves in the shoes of users and imagine how a user would interact with the application in their first encounter with it. Users’ goals are identified through exploration rather than referring to a manual. Users’ problems when interacting with the application are identified by evaluators [56][57].

**Inquiry:**

Inquiry refers to identifying the user requirements for the application when the evaluators get the information though observation and/or by communicating with the users [52]. The evaluation techniques used for inquiry are: field observations, focus groups, proactive field study, logging actual use, surveys. Field observations include the observation of how people interact with the application in the specified use context [38]. Focus groups refer to groups of people assembled informally to discuss on a specified topic or task. Users’ views and their understanding regarding a specific topic or task can be observed from this technique [38]. Proactive field study is done during the requirements or the initial stages of the software development. Evaluators go to the work or other everyday environments of the users to identify their requirements, tasks and problems [38]. Logging actual use means the device collects the statistical data without the need for manual intervention. The statistical data represents the actual work performed by the users [38]. Survey involves collecting the data manually on the results or to collect the data regarding the problems that are encountered with an application or device [58].

During the evaluation process, it is necessary to use appropriate techniques for investigation. The author has selected think-aloud, observation and questionnaire techniques to conduct the usability evaluation studies for this thesis. The author has selected think-aloud technique because the results obtained from this technique would be expected to be close to the user’s actual experience. The author also wants to collect the observations on ease of use of application individually.
5 **USABILITY TEST**

This chapter discusses about the planning and conducting of usability tests using think-aloud protocol.

5.1 **Selection of participants**

In the usability test, 15 students and 15 elderly people have participated. The students are from BTH and they were selected from a computer science background whereas elderly people were selected randomly. All students had experience in developing applications. To communicate better about the usability test and tasks, the author has chosen English as a mode of communication. Participants who were able to express themselves in English were selected so that the author would be able to collect the observations easily when spoken in English.

5.2 **Usability test planning**

The direct involvement of users has helped the author to collect information about the mHealth application. The evaluation of the mHealth application was conducted in an organized way. Usability testing guidelines were followed when conducting the usability test [59]. The participants were given a brief introduction to what they were going to perform and they were also provided details about the tasks that they had to perform at the start of the usability test. The usability test was conducted in two phases.

In the first phase, the author went through the mHealth application to get familiar with the application. After that the author selected tasks that should be performed during the usability test. The author thereafter conducted a pre-test with two students and two older people to ensure that the descriptions of the tasks to be carried out were understandable. Quantitative measurement parameters were defined based on the pre-test results.

In the second phase, the actual test was conducted where the participant’s interaction with the system was observed and noted down by the author. A total of 30 (15 students and 15 elderly people) participants participated in this test. Students were from computer science background. Among them, two persons have worked on the usability topic during their course work. All the students have experience of using smartphones and have been exposed to a number of mobile applications. Whereas in case of elderly people some of the people did not have experience in using mobile applications. Each individual was given five tasks and their interaction with the mobile application was noted down by the author.

5.3 **Equipment used in the test**

All the students have taken the test in a group room at BTH, whereas 4 elderly people have taken the test in a group room at BTH and 11 elderly people have taken the test at their respective homes. The test was conducted in an environment where the participant was free to move around in the room while using the application. The equipment used included a mobile phone, an audio recorder and a time calculating device.
5.4 Test conduction

The test was conducted at a convenient time for the participants. The tasks performed by the participants were observed and their interactions with the system were recorded. Duration of the test and time taken for each task by each individual was noted down by the author. See Table 2 below for a more detailed description of the tasks involved in the usability evaluation.

<table>
<thead>
<tr>
<th>Task 1: Open a user account in the mobile application</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Open the application</td>
</tr>
<tr>
<td>b) Create an account</td>
</tr>
<tr>
<td>c) Fill in your email address and a password in the text fields</td>
</tr>
<tr>
<td>d) Fill in the personal information in text fields provided.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 2: Find the help guidelines for observing the reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Navigate to the report page in the three tabs provided at the bottom of the screen</td>
</tr>
<tr>
<td>b) The two blocks in the report page have a help button each, when clicked this flips the block which gives the guidelines of what the graph in the block represents.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 3: Find the help guidelines to upload the glucose values</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Navigate to the upload data page in the three tabs provided at the bottom of the screen</td>
</tr>
<tr>
<td>b) At the top left of the application there is a bulb icon</td>
</tr>
<tr>
<td>c) By clicking it, a page drops down from the top which includes the guidelines to upload the glucose values</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 4: Share the scorecard results through email</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Navigate to the Scorecard page in the three tabs provided at the bottom of the screen</td>
</tr>
<tr>
<td>b) At the top right of the screen, there is a share button</td>
</tr>
<tr>
<td>c) By clicking on the share button, a page appears from the bottom where the user can select an application through which they share the results.</td>
</tr>
<tr>
<td>d) In our case, Gmail application is selected to share the scorecard.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task 5: Change the password for the account</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) In the Scorecard page, at the top right of the interface there is a person icon.</td>
</tr>
<tr>
<td>b) By clicking on the icon, a drop down page consisting of the page containing the details of the registered person is presented.</td>
</tr>
<tr>
<td>c) At the bottom, there is an option for changing the password.</td>
</tr>
<tr>
<td>d) After this a new page opens, that has three fields i.e. enter present password, enter new type password, re-enter to confirm the password.</td>
</tr>
</tbody>
</table>

After the usability test, the author has asked for recommendations from the participant to improve the mHealth application.

5.5 Analysis of Usability test

As stated in table above, each participant has performed five tasks. At the start of the usability test, each participant was given instructions to “think aloud” and provide comments and recommendations regarding the interface during the test.

The results obtained were categorized into qualitative and quantitative data. The collected data was analyzed and a conclusion was provided regarding the usability of the interface.
The measurements used when collecting the information are total time for completion, number of irrelevant touches for completing the task and time taken to complete each task.

5.5.1 Task 1:
The task is to create an account for the mobile application that was selected.
- Most of the participants were satisfied with the interface for creating an account. The steps to register were simple. All participants were able to create an account without any problem.
- To register for an account, the user has to go through three pages.
- In the first page, the participants draw attention to the labels in the text field. When they typed in the text fields, 3 participants have hitched a second. By placing the label outside text field, the users would be able to have a clearer understanding of the input text field when they want to change the values in the text field in the middle of doing it.
- In the second page, participants felt at ease when giving input to the text field. All participants admired the scrolling option for inputting the values of weight and height. However, they felt that it would have been better if there was an increase in the size of the font for the weight and height fields.
- The third page is about diabetes that a user has, starting year of diabetes and there are a few checkboxes such as insulin, oral diet and other option which refer to treatment that a user follows. Participants felt interactive about the drop down menu of the list of diabetes.

5.5.2 Task 2:
The task is to find the help guidelines for observing the reports.
- The author has observed that 22 (10 students + 12 elderly people) out of 30 participants find it difficult to identify the tabs at the bottom of the interface of the application. But they were able to find the tabs by multiple touches on the screen.
- Participants expressed difficulty when trying to find the help guidelines. They were not able to distinguish the information icon from the rest of the interface. 14 (6 students and 8 elderly people) out of 30 were not able to distinguish the information icon.
- While the participants perform this task, the author has also observed that there is an unnecessary icon on the top of the page which points to the guidelines to upload glucose values which should be in the next tab.
- The author observed that 4 students and most of the elder participants experienced difficulties in reading the contents of the help guidelines.

5.5.3 Task 3:
The task is to find the help guidelines to upload the glucose values.
- The participants were able to distinguish the bulb icon from the rest of the interface. All the participants were successful in identifying the help guidelines for uploading the data. Participants felt that it was an attractive feature when a page dropped down when the bulb icon is touched.
- However, most of the participants have done this task by mistake when they were trying to figure out the second task.
5.5.4 Task 4:
The task is to share the scorecard through email.
- The author has observed that every participant is aware of the share icon. All were successful in sending the scorecard via email. However, 20 (9 students + 11 elderly people) out of 30 participants felt that the share icon’s color blends in with the background color. They felt that it would be better if there were a dark color for distinguishing the icon more clearly.

5.5.5 Task 5:
The task is to change the password for the mobile application.
- The author has observed that 16 (7 students and 9 elderly people) participants were not able to find the option for changing the password in the first go. Participants navigated to different tabs and finally they were able to find the person icon at the top right corner of the interface.
- Once participants were aware of the icon, they were able to change their password without any difficulty.
- All participants mentioned that they did not receive any pop up message informing that the password has been changed.

All participants were able to complete the tasks. Summary of time taken for completing the tasks are described in Table 3 and Table 4 below:

Table 3. Summary of task duration (Students)

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Total time (Minutes)</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Pre-test)</td>
<td>3:52</td>
<td>2:20</td>
<td>35s</td>
<td>5s</td>
<td>22s</td>
<td>30s</td>
</tr>
<tr>
<td>2(pre-test)</td>
<td>3:00</td>
<td>1:44</td>
<td>15s</td>
<td>4s</td>
<td>35s</td>
<td>22s</td>
</tr>
<tr>
<td>3</td>
<td>3.31</td>
<td>1:40</td>
<td>50s</td>
<td>5s</td>
<td>30s</td>
<td>26s</td>
</tr>
<tr>
<td>4</td>
<td>4:24</td>
<td>2:03</td>
<td>1:15</td>
<td>4s</td>
<td>32s</td>
<td>25s</td>
</tr>
<tr>
<td>5</td>
<td>3:29</td>
<td>1:46</td>
<td>42s</td>
<td>4s</td>
<td>35s</td>
<td>22s</td>
</tr>
<tr>
<td>6</td>
<td>2:59</td>
<td>1:44</td>
<td>18s</td>
<td>4s</td>
<td>31s</td>
<td>22s</td>
</tr>
<tr>
<td>7</td>
<td>4:00</td>
<td>1:59</td>
<td>1:01</td>
<td>5s</td>
<td>30s</td>
<td>25s</td>
</tr>
<tr>
<td>8</td>
<td>3:41</td>
<td>1:44</td>
<td>50s</td>
<td>4s</td>
<td>35s</td>
<td>28s</td>
</tr>
<tr>
<td>9</td>
<td>3:44</td>
<td>2:01</td>
<td>43s</td>
<td>4s</td>
<td>31s</td>
<td>25s</td>
</tr>
<tr>
<td>10</td>
<td>3:07</td>
<td>1:50</td>
<td>16s</td>
<td>4s</td>
<td>35s</td>
<td>22s</td>
</tr>
<tr>
<td>11</td>
<td>3:12</td>
<td>1:46</td>
<td>22s</td>
<td>4s</td>
<td>35s</td>
<td>25s</td>
</tr>
<tr>
<td>12</td>
<td>3:26</td>
<td>1:49</td>
<td>35s</td>
<td>4s</td>
<td>36s</td>
<td>22s</td>
</tr>
<tr>
<td>13</td>
<td>3:14</td>
<td>1:52</td>
<td>18s</td>
<td>4s</td>
<td>34s</td>
<td>26s</td>
</tr>
<tr>
<td>14</td>
<td>3:12</td>
<td>1:44</td>
<td>23s</td>
<td>5s</td>
<td>35s</td>
<td>25s</td>
</tr>
<tr>
<td>15</td>
<td>3:46</td>
<td>2:10</td>
<td>32s</td>
<td>4s</td>
<td>34s</td>
<td>26s</td>
</tr>
<tr>
<td>Subjects</td>
<td>Total time (Minutes)</td>
<td>Task 1</td>
<td>Task 2</td>
<td>Task 3</td>
<td>Task 4</td>
<td>Task 5</td>
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<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>1 (Pre-test)</td>
<td>6:58</td>
<td>3:31</td>
<td>1:37</td>
<td>15</td>
<td>1:00</td>
<td>35</td>
</tr>
<tr>
<td>2(pre-test)</td>
<td>5:32</td>
<td>2:19</td>
<td>1:15</td>
<td>19</td>
<td>57</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>7:48</td>
<td>3:29</td>
<td>2:26</td>
<td>15</td>
<td>1:00</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>8:40</td>
<td>3:46</td>
<td>1:58</td>
<td>20</td>
<td>1:46</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>7:31</td>
<td>3:36</td>
<td>2:11</td>
<td>12</td>
<td>58</td>
<td>34</td>
</tr>
<tr>
<td>6</td>
<td>7:53</td>
<td>2:56</td>
<td>2:23</td>
<td>15</td>
<td>1:21</td>
<td>58</td>
</tr>
<tr>
<td>7</td>
<td>7:14</td>
<td>3:02</td>
<td>2:09</td>
<td>9</td>
<td>1:03</td>
<td>51</td>
</tr>
<tr>
<td>8</td>
<td>6:18</td>
<td>2:20</td>
<td>1:48</td>
<td>13</td>
<td>1:15</td>
<td>42</td>
</tr>
<tr>
<td>9</td>
<td>5:34</td>
<td>2:11</td>
<td>1:22</td>
<td>20</td>
<td>1:02</td>
<td>39</td>
</tr>
<tr>
<td>10</td>
<td>7:51</td>
<td>3:31</td>
<td>2:15</td>
<td>10</td>
<td>1:12</td>
<td>43</td>
</tr>
<tr>
<td>11</td>
<td>7:19</td>
<td>3:39</td>
<td>1:43</td>
<td>15</td>
<td>1:08</td>
<td>34</td>
</tr>
<tr>
<td>12</td>
<td>6:16</td>
<td>3:15</td>
<td>1:20</td>
<td>12</td>
<td>52</td>
<td>37</td>
</tr>
<tr>
<td>13</td>
<td>5:43</td>
<td>2:43</td>
<td>1:25</td>
<td>11</td>
<td>49</td>
<td>35</td>
</tr>
<tr>
<td>14</td>
<td>6:20</td>
<td>2:51</td>
<td>1:46</td>
<td>12</td>
<td>51</td>
<td>40</td>
</tr>
<tr>
<td>15</td>
<td>5:46</td>
<td>2:47</td>
<td>1:22</td>
<td>9</td>
<td>59</td>
<td>39</td>
</tr>
</tbody>
</table>

In addition to the above tasks, the author conducted an interview with each participant after the usability test to discuss about the application. Since the application functionality of uploading the glucose values with NFC enabled device needs a blood sample which involves ethical issues, images were taken from the company participating in the Health in Hand project. Images include the reports that depict the usage of the functionality. They were given to the participants in order to get their view on the reports.
Table 5. Summary of observations

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 1</strong></td>
<td>Creating an account is easily understandable. All the text fields are well organized. Option for adjusting the font size is needed. Scrolling option for two text fields in the second page is attractive.</td>
</tr>
<tr>
<td><strong>Task 2</strong></td>
<td>Unable to find the tabs at the bottom of the interface application. The icon for help guidelines was not visible. Change of icons color to a darker color is suggested. Contents of the help guidelines are not readable.</td>
</tr>
<tr>
<td><strong>Task 3</strong></td>
<td>The icon is easy to distinguish. The icon’s background color i.e. blue also made the help guideline able to be distinguished from the rest of the contents on the page.</td>
</tr>
<tr>
<td><strong>Task 4</strong></td>
<td>The share icon is easily identifiable but it blends with the other content of the application as they are both light in color.</td>
</tr>
<tr>
<td><strong>Task 5</strong></td>
<td>Difficulty in identifying the option for changing the password. Acknowledgement for changing the password is not shown.</td>
</tr>
</tbody>
</table>

In the usability test with the participants, the author was able to discover different problems that were faced by the participants. They were asked to play with the app and they were also presented with a paper prototype where the results of using the application i.e. glucose level chart, average glucose level, variation from the previous day, timeline for a particular day of updating of the glucose levels and a standard day report where all glucose levels of all the days are layered one above the other.

When the author presented images of the report, some participants experienced difficulty in understanding the reports. For the timeline block in the reports, participants were not able to determine why there are different colors. Although it means something, the participants were unable to determine which color represents what and when they went through the help guidelines, they did not find any help concerning the meaning of the different colors. 14 (6 students and 8 elders) out of 30 participants were able to distinguish the colors as red means high, green means the glucose level is within the OK range and blue means normal. But they also mentioned that it would have been better if the color representation was mentioned in the help guidelines. Another 4 participants felt that when the timeline is touched, the results should be shown in landscape mode. Later the 4 participants realized that when the phone is oriented in landscape mode they were satisfied with what they want to have. The author has observed that they were not able to find this feature in the first go.

Regarding the standard day block and three pie charts block at the bottom of the results page, the author has observed similar problems as stated above.
The above graph (Figure 3) shows the time taken by elderly people and the students. It can be observed that elderly people have taken more time than the students have for completing the test. This may be due to a combination of the degradation of cognitive, physical and sensory abilities as people grow older and the fact that most older people today have lived most of their lives in the pre-mobile-phone-age and thus do not use mobile phones and mobile applications as much and as proficiently as young people, such as the students who were tested, do today. During the usability test, the author has also observed that the importance of the problems which occurred while using the application was not perceived in the same way by elderly and students. For example, elderly people stressed the importance of increasing the font size, but the students gave a suggestion to increase the size of the font if the application is for elderly people, although most of them were comfortable with the present size of the font size. This shows that there is a difference in perception of the usability issues encountered in mHealth applications between different age groups, when people who differ in age use it.

5.6 Findings from usability test

In this section, the author will discuss about compiled observations from all the participants. From the observations of the usability test, the author has observed where the end users (elderly people) may find difficulty when using the application. Observations showed that participants were not able to follow the navigation structure of the application. When the participants were asked to perform the second task, they performed the third task instead of the second task. This shows that participants were not able to grasp the navigation structure with ease. As some of the participants are elderly people, they often complained about font size. Although some participants were satisfied with the font size, other participants felt that the font size was not readable. The next issue was the icons. Participants did not perceive icons as actionable buttons in the second and fourth tasks. In the reports tab of the application, participants were not able to perceive all the details about the health graphs. They felt that they should have additional information on how to read their health graphs. The health graphs are depicted using different colors which made some of the participants wonder what these different colors represent. All the participants were comfortable with spacing and wordings of the text fields. Participants were not comfortable with the background color of the application as
they seem to blend in with the interactive icons on the screen. Participants were not able to distinguish between the layout and the icons.

5.7 Questionnaire

Questionnaires serve the purpose, in this case, of collecting quantitative data. The data obtained from the questionnaires provides an overall overview of strengths and weakness of the mHealth application [34]. The data collected through the questionnaire was analyzed through statistical analysis. The observed results were categorized into the five quality components proposed by Nielsen. To evaluate the application, the questionnaire was prepared in such a way that it was answered according to the five quality components. This questionnaire can be answered by the people who have used the application. So it was answered by the participants who have participated in the usability test. The questionnaire was prepared using google forms. Likert scale was adjusted such that each question was answered along a scale from strongly disagree to strongly agree.

5.7.1 Questionnaire results

The author has prepared the questionnaire for the participants in the usability test. The author has used this questionnaire for evaluating the mobile application in addition to the usability test and it also served the purpose of validation. Table 5 below shows the results obtained from both students and elderly people. For the explicit questions in the questionnaire, see appendix A.

<table>
<thead>
<tr>
<th>Usability Attributes</th>
<th>Students</th>
<th>Elderly</th>
<th>Students</th>
<th>Elderly</th>
<th>Students</th>
<th>Elderly</th>
<th>Students</th>
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<tr>
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<td>0%</td>
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<td>26.7%</td>
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<td>66.7%</td>
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</tr>
<tr>
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<td>40%</td>
<td>13.3%</td>
<td>6.7%</td>
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<tr>
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<td>0%</td>
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<td>26.7%</td>
<td>0%</td>
<td>40%</td>
<td>73.3%</td>
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<tr>
<td>6</td>
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<td>26.7%</td>
<td>53.3%</td>
<td>26.7%</td>
<td>13.3%</td>
<td>0%</td>
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</table>
In addition to the above 15 questions, there are two closed questions included in the questionnaire. The questions were “Are you able to perform all the tasks in first attempt?” and “Do you feel there is a need for assistance while preforming the task?” and these questions can only be answered with yes or no. For the first question, 66.7% (10 out of 15) of the students has answered yes but in the case of elderly people only 33.3% (5 out of 15) has answered yes. For the second question, 86.7% (13 out of 15) of the students have answered yes and in the case of elderly people 93.3% (14 out of 15) have answered yes.

5.7.2 Analysis of the questionnaire

The author has generated tables and graphs from the obtained results to show statistical data obtained from questionnaires. Below graphs (Figures 4 and 5) show the overall responses on the questionnaire from both students and elderly people. When each quality component was observed in both graphs, it can be observed that there were some differences between them. In this section, the author discussed these differences by considering each quality component.

From both graphs, it can be observed that there is a difference in the level of agreement on the questionnaire. This was interpreted as being mainly due to the age and lack of knowledge on how to use the technological artifact. When learnability is considered, it was observed that some of the elderly people have difficulty in understanding the application and they felt that it was not easy to learn. This difference is made visible in the fact that elderly people tended to agree but not strongly agree.

When efficiency was considered, it can be observed that elderly people have more often opted for disagree when compared to students. This appears to be mainly due to the navigational structure. Elderly people had problem in understanding the
navigational structure. They were often confused when performing the tasks. Another problem that led to the selection of disagree or neutral here was that they were not able to interpret the data in the reports.

When memorability was considered, elderly people have selected agree but students have selected strongly agree. The author has interpreted this as being mainly due to deterioration of cognitive, physical and sensory abilities with age, although amount of acquired experience, skill and proficiency with using mobile applications, which is more common among young people today, probably also plays a part here. Since there was no help or walkthrough of the application provided, it was difficult for elderly people to memorize the application. However, there were guidelines for reading the report, if users wanted to review them again.

When error rate was considered, students have played with the application more when compared to the elderly people. Elderly people mainly concentrated on the tasks but not on the errors, whereas students have observed the errors (like notification of what the error is) when performing the tasks and this has led to a difference in the level of agreement between elderly people and students.

When satisfaction was considered, the students seem to have much more experience in using mobile applications than the elderly people who participated in the test. This is probably the reason why most of the students were satisfied with the application. During the usability test, the elderly participants have mentioned that the diabetic application was useful. However, if there were some more functionalities (this does not mean complex functionalities) they would be completely satisfied. Both students and elderly people agreed that these types of applications have the potential to improve the quality of life. Further they provided some recommendations for improvements which would result in that they would be satisfied with the application.

Figures 4 and 5 below show the overall responses from the questionnaire.

![Overall user responses on questionnaire (Students)](image-url)

**Figure 4. Overall user responses on questionnaire (Students)**
5.8 Interview Results

This section presents the results and analysis of the interviews conducted with UX designers about how usability issues are considered in the design and development process. Five interviews were conducted with five different participants where 2 belong to the same organization and the other 3 belong to other, different organizations. All these participants have experience in UX design and have established themselves as UX designers in their respective organizations. All the interviews were conducted by telephone and anonymity of the respondents was promised. All the information collected through the telephonic interviews has been noted down in transcripts. Due to reluctance of the respondents, audio recording was not used during the conversations. The RQ3, that is, “What could be the strategies for improving the usability of a mHealth application?” was the main question that was asked in the interviews, and a few spontaneous follow-up questions were asked in the middle of the conversation during the interviews.

5.8.1 Overview of the interviews conducted

To gather information regarding the strategies applied in practice for improving the usability of mHealth application, the following interviews were conducted:

<table>
<thead>
<tr>
<th>ID</th>
<th>Interviews conducted date</th>
<th>Experience (in years)</th>
<th>Time spent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17th December, 2015</td>
<td>6</td>
<td>18 min</td>
</tr>
<tr>
<td>2</td>
<td>20th December, 2015</td>
<td>4</td>
<td>23 min</td>
</tr>
<tr>
<td>3</td>
<td>27th December, 2015</td>
<td>10</td>
<td>25 min</td>
</tr>
<tr>
<td>4</td>
<td>8th January, 2016</td>
<td>5</td>
<td>18 min</td>
</tr>
<tr>
<td>5</td>
<td>10th January, 2016</td>
<td>7</td>
<td>20 min</td>
</tr>
</tbody>
</table>

Figure 5. Overall user responses on questionnaire (Elderly people)
5.8.2 Analysis of the interviews

Data obtained from the interviews were analyzed using thematic analysis. Through thematic analysis, collected data can be used to generate codes for categorizing the data, and thereafter sorted and organized, which is useful for analyzing, identifying and reporting themes from the collected data. The author focused on the main theme i.e. strategy to mitigate usability issues in mobile health applications. So the author has generated codes under this theme. The following phases are carried out in thematic analysis [60]:

- Familiarizing with data
- Generating codes
- Search for themes
- Reviewing the themes
- Defining and naming themes
- Producing the report

As a first step, the author has organized the collected information from the interviews and analyzed it. Based on this analysis, the author has generated codes from the collected information in such a way that the codes fall under the theme strategy. Using the codes, the author has thereafter analyzed this information. The codes generated in the interview under the theme strategy were:

- User centered design
- Activity centered design
- Context of use
- Consistency
- Error handling
- Navigation structure

5.8.3 Analysis of responses given to question about usability strategies

When the author asked the question, among the 5 respondents, 2 of them have said that the first thing that came to mind were two approaches:

- User centered design (Design process where users are involved throughout the design and development)
- Activity Centered design (Design process which focuses on the task of the user when they were given a piece of technology)

Based on the application domain, context of use, intended user groups and ease of use of mobile application, one approach was chosen among these three. When the author mentioned that the focus of the study was about mHealth applications, User centered design was stated as being preferred by all the interviewees. The reason given for this preference was that in mHealth end users play an important role. One explanation along this line, offered by an interviewee, is “With user centered design, end users will be able to engage in the design process. By bringing them into the design process, assumptions made by the designers can be omitted and the real need of the users can be identified”.

In addition, they mentioned at least 3 of the following six different methods that are used in UCD such as Focus groups, Usability testing, Card sorting, participatory design, Questionnaires, Interviews. They both mentioned that focus groups and usability testing were the most common methods. Further, they also mentioned that participatory design is also the best approach but they said that they did not follow it in their respective companies. In participatory design, all the stakeholders are involved in the design process which makes the resulting application more usable. Here both respondents have mentioned that they should consider the end user i.e. elder people in this case as one of
the stakeholders. The respondents felt that participatory design can give efficient results regarding the mobile application for health.

The other 3 respondents have mentioned that “a good strategy would be to engage end users in the design process”. In addition to the previous one, to improve the usability, they also mentioned some key points when the mHealth application is for elderly people. One of the explanations given was “most of the elderly people have problems with their eye sight. So, developers should design the interface in such a way that the contents of the application are readable. Navigation structure should be simple and the application should be easy to use.” One of the interviewees who works in the design phase of mHealth application development has suggested that “Most important information should be included and this should be presented to end users at the beginning of the application. Unnecessary information (text) or functionalities should be eliminated. Error handling should be efficient.” These statements together appear to concur with the explanation given by another interviewee that “Users should be able to find the necessary help whenever they need it. The application should be fully supportive of users to accomplish the tasks in an efficient way.”

5.9 Recommendations

With the suggestions obtained from participants and observations from the usability test, the author has recommended improvements for the mobile application. The overall performance of the application was good. But some changes were suggested to enhance the application for efficient use.

Customization option for font size and language is advisable. By including this option, users can choose appropriate size of the font. This improves the visibility of the contents of the application. Although English language is widely accepted, users may opt to use their regional language for ease of use. If there is a customization option for language settings then it would improve the readability and accessibility of the application.

Currently, the tested mobile application does not have a walkthrough or a video of how it works, the available functionalities and the terminology usage. This may cause frustration for users which prevent some users from using the application.

Observations shows that users are unable to distinguish the help icon from the background. Icons of darker color seem to attract the attention of the users better than colors which easily blend in with the background.

Observations also showed that participants were not able to understand the navigational structure. As suggested above, a walkthrough or video of how the application works can mitigate this problem.

The tested mobile application does not provide support for alerting the care takers of the patient. Patients (users) may forget to check the reports sometimes. Therefore the option of including mobile number of caretaker such that it automatically informs the status of the user is advisable.
6 DISCUSSION AND VALIDATION

This chapter contains discussion, an attempt at answering the research questions based on the results of the study, and validation assessment of the thesis.

6.1 Discussion

The purpose of this thesis was to explore the usability issues that occur in a mHealth application that targets T2D patients. For this purpose, a prototype from the Health in Hand project was selected for this case study. The author has used a systematic approach to evaluate the application and identify usability issues.

6.1.1 Usability quality components

In this thesis, the author has selected usability criteria from the literature study and has conducted usability tests and collected feedback based on the usability criteria selected.

6.1.1.1 Learnability and Memorability

While performing the tasks, the user should be able to learn the procedure to use the application with ease. The author has observed that there is a variance in the completion time of the participants. However, all participants were able to learn and memorize the application once used. 24 (9 students and 15 elder people) out of 30 participants have suggested an instruction or a walkthrough of the application to grasp the features of the application in their first use of the application.

6.1.1.2 Efficiency

Most of the participants were able to navigate and find the required options when performing the tasks. Although they have taken more steps to perform the task than the ideal steps, they might have been able to follow. With the increase in the steps to perform the task, time to achieve the task has also increased. The author observed that font also had an effect on the participants. Participants expressed difficulty when finding the guidelines for reading the report. They were not able to recognize the icon and all participants have suggested to make it bigger or change the icon or color. When they navigated to reports page, the participants were confused concerning which color represents what. Participants suggested explaining and visualizing which color denotes what in the guidelines. For the navigation to be much easier, participants have proposed to highlight the tab which denotes the present page.

6.1.1.3 Error rate

Most of the participants have reported that while doing the registration, partial filling of the text field shows a red background but it does not say which type of error has occurred. For example, for an input field for entering your email account if it partially completed and if the user presses next then it does not show what type of error it is but it highlights the text field with a red background color. However, if the input is not filled in at all, a message pops up at the bottom of the screen about the error.

6.1.1.4 Satisfaction

Participants showed overall satisfaction regarding the application. However, the color representation in the reports has confused some of the participants concerning what it represents. Excluding the color representation issue, the participants felt that the structure of the mobile application is simple and the terminology is consistent and it is easy to use.
6.2 Answers to the research questions:

**RQ1:** What role does usability evaluation play during mHealth application development?

Usability evaluation is an approach for collecting data on how well users understand and are able to use an application and how user groups use the product to perform a specific task under certain conditions. To answer this question, the author has conducted a literature review on how usability evaluation helps in application development. In mHealth application development, usability evaluation helps in understanding the users and their expectations concerning the mobile application. See also the theoretical work presented in sections 4.2 and 4.3.

**RQ2:** What are the usability issues involved when developing a mHealth solution for elderly T2D patients?

To explore and identify usability issues, the author has conducted a usability test. There was initially a serious limitation here, i.e. since the author was initially not able to get elderly people to perform the test, the author conducted a usability test with students. This has later been addressed through an additional usability test which was conducted with 15 elderly people. In both usability tests, the author analyzed the behavior of the participants through observation of the tasks they performed. The author also conducted an informal discussion for analyzing the views of the participants A questionnaire was also answered by participants which was prepared in such a way that it added to results of the usability evaluation in the context of Nielsen’s usability quality components. Details of the usability test and their results are discussed in sections 5 and 6.

**RQ3:** What could be the strategies for improving the usability of a mHealth application?

From the analysis of the interview results which are presented in section 5.8, strategies which are being applied in design and development practice to improve the usability of mHealth applications were investigated. Based on the respondent’s response, it was concluded that the use of participatory design methods within the framework of User Centered Design (UCD), building a consistent application with simple navigational structure and which handles the errors, are strategies which are considered to contribute to yielding efficient results regarding usability. This third research question would benefit from being addressed more extensively in future research, including for instance participatory observation of design practices and a more extensive survey among multiple providers of mHealth applications.

6.3 Validity discussion

The author has followed a mixed approach (qualitative and quantitative) in this thesis and the results are validated with guidelines given by Lincoln and Guba [61][62]. The criteria includes credibility, transferability, dependability and conformability. When using a mixed methodology approach, validation of the results are important. The main part of the research is done through a qualitative approach according to the theoretical work and usability test conducted on the students and the elderly people. For validation purpose, a quantitative approach was included that deals with a questionnaire that is intended to show the satisfaction of the participants with the presented results. The results from the questionnaire appear to verify the observations from the usability test.
6.3.1 Credibility
Credibility refers to the acceptance of the results from the viewpoint of the participants [62]. A systematic approach is used by the author to achieve credibility. The graphs in section 5.7 showed that all participants were satisfied with the application. Author has conducted a survey using questionnaire to check whether the results obtained from the usability test can be trusted. Further, results from the interviews, though limited in scope and number, can be trusted as they were conducted with experienced Ux designers who were guaranteed anonymity. Due to time limitations, the results from the interviews could not be presented to the respondents for further discussion and clarifications. This could however be a starting point for further research on what strategies are being applied in practice when it comes to addressing and mitigating usability issues in design and development of mHealth applications.

6.3.2 Dependability
Dependability refers to the findings from the study are consistent and could be repeated [61][62]. This thesis targets older adults but due to the initial unavailability of resources, the author conducted the initial usability test with students at BTH. Later, this problem was addressed by carrying out another usability test, this time with elderly participants. This provided the opportunity to compare results between the first group, with young participants, and the second group, with elderly users, which showed clear differences between the groups concerning what, and how, usability issues were perceived and how they affected error rate and the time it took to accomplish the required tasks in the usability test.

Based on the findings of the literature review and the usability tests, a questionnaire was designed. Since the questionnaire was posted 3 days after the usability test, the participants may have forgotten some features of the mHealth application, which is a threat. This threat was mitigated by giving the contact information of the author so that they could contact the author if they wanted to go through the application once again.

6.3.3 Transferability
Transferability refers to the extent to which the qualitative research results can be generalized or applied to other contexts [61][62]. In this thesis, the selected mobile application is similar to many other mobile applications that transfer data from mobile phones to a cloud server. As the results obtained from this research are interface based, they can be related to many other mobile applications. However, if functionalities are considered, the recommendations obtained from this research can only be applied to a similar context.

6.3.4 Confirmability
Confirmability refers to the extent to which other researchers can confirm the results [61][62]. The author has made use of usability criteria that were previously used in the literature to conduct the usability test. The usability test was carefully planned and systematically organized and the analysis is further discussed in the sixth chapter. The author has used think-aloud technique which has been widely used for evaluating usability [38]. The results are validated with the aid of a feedback questionnaire.
7 CONCLUSION AND FUTURE WORK

The major objective of this thesis is to identify and map usability problems that occur in the selected prototype. The author has conducted a literature review as a first step to gain knowledge about usability evaluation methods and to find related research work. In the next step, the author has selected 30 participants (15 students and 15 elderly people) from BTH, where 4 (2 students and 2 elderly people) of them were used for a pre-test. The author try to simulate a natural environment in a limited space i.e. BTH group rooms or home environment. A usability test was conducted with the participants individually. The findings from the usability test and literature review helped the author in designing the questionnaire. The questionnaire was distributed by creating a google forms for students and elderly people who have participated in the usability test and the author has validated the results with the help of the questionnaire. The questionnaire also helped the author to identify the level of participants’ subjective satisfaction. This study resulted in a mapping of the usability problems that surfaced when the participants interacted with the user interface of the mHealth application. The observed usability problems provide input for the Health in Hand project where they will be helpful for designing efficient mobile applications in the future. Efficient mobile applications should ideally support and enhance efficient communication between healthcare providers and patients and contribute to transforming health care delivery and disease prevention through innovative mHealth solutions.

Limitations:

- Since some ethical issues are involved when it comes to measuring glucose values through blood tests and glucose measuring of these tests in a glucometer, this functionality of the mobile application was not tested. Instead, the sample images from the company participating in the Health in Hand project were used as a paper mock-up for this part of the test and shown to the participants to identify the views of the participants about the application. The author has conducted an usability test with the participants to capture the views, perceptions and experiences of the individual participants.
- Not all participants were diabetic, so the author may have overlooked some of the usability problems that can occur when the application is tested with and by diabetes patients.

Future work:

The findings obtained from this thesis will be supportive for enhancing the mobile application being tested in the Health in Hand project. In this thesis, research was conducted from the perspective of patients. Future work should also focus on usability issues from the perspective of healthcare providers and from the perspective of efficiently supporting communication between patients and healthcare providers. Additionally, interviews were carried out with five experienced User Experience experts from four different IT companies, in order to explore what strategies are currently being applied in practice to mitigate usability problems in design and development of mHealth applications. This part of the study was limited in scope and content, but could serve as a starting point for future, more extensive research on how user centered design is being put into practice in the rapidly evolving area of mHealth.
REFERENCES


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<td></td>
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<td>Navigational structure is simple and related information is in place</td>
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<tr>
<td>8</td>
<td>I am able to deduce the information I need from the report</td>
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<tr>
<td>9</td>
<td>The application is easy to remember.</td>
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<td>10</td>
<td>No need for reviewing guidelines once used</td>
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<td><strong>Error rate</strong></td>
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<td>11</td>
<td>In case of error, the application has notified.</td>
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<td>12</td>
<td>I am able to determine the cause of error.</td>
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<td></td>
<td><strong>Satisfaction</strong></td>
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<tr>
<td>13</td>
<td>Satisfied with the application.</td>
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<td>14</td>
<td>The application helps in improving the quality of life.</td>
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<tr>
<td>15</td>
<td>I am satisfied with the present functionalities</td>
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