Mobile Diabetes Management System

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<td>Requirement Analysis and Design</td>
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<td>Experiment Design and Execution</td>
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<td>20</td>
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<tr>
<td>System Development and Implementation</td>
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<td>15</td>
<td>15</td>
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<tr>
<td>Results, Findings and Conclusion</td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Aim Formulation and Background Work</td>
<td>10</td>
<td>15</td>
<td>15</td>
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<tr>
<td>Quality of Report Writing and Presentation</td>
<td></td>
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<td>Adherence to Project Proposal and Quality of Deliverables</td>
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Abstract
Diabetes is a chronic disease that affects people worldwide. In 2006, there were approximately 6.5 million diabetics in South Africa [Health 24 2006] out of an estimated population of 47 million South Africans at that time period [Statistics South Africa 2006]. These statistics show that a system that aids in diabetes self-management is required. During the literature synthesis, it was discovered that there weren’t any publicly systems that could assist in the self-management of diabetes in South Africa. Initially, this project investigated what type of system that diabetic patients really need. This was achieved through the use of questionnaires and interviews. The results of the research were used to develop a system by means of an iterative design process whilst also using principles of user centred design. This project ensured that users were involved to a great extent in the research and the testing process of the diabetes management software. The final system was piloted to see if it is usable on a daily basis. Based on the evaluation of the final system, the system was successful in record and data keeping, and also helped the users in managing diabetes.

Author Keywords
Diabetes, User-Centred design, Mobile phone
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Table of Contents

Abstract.............................................................................................................................................. i
Author Keywords ................................................................................................................................... i
Acknowledgements ............................................................................................................................. ii
List of Tables and Figures ..................................................................................................................... v
1. Introduction ........................................................................................................................................ 1
   1.1 Problem Outline ............................................................................................................................ 1
   1.2 Proposed Solution .......................................................................................................................... 1
   1.3 Division of Work ............................................................................................................................ 2
   1.4 Report Outline .............................................................................................................................. 2
2. Background and Motivation ............................................................................................................... 3
   2.1 Introduction ..................................................................................................................................... 3
   2.2 Diabetes ......................................................................................................................................... 3
   2.3 Types of Diabetes ........................................................................................................................... 3
   2.4 Treatment of Diabetes .................................................................................................................. 3
   2.5 Current electronic systems that aid in treatment ......................................................................... 3
   2.6 Related Work ............................................................................................................................... 5
      2.6.1 Feasibility of Mobile Phone-Based Management of Chronic Illness ................................. 5
      2.6.2 Using a Cell Phone-Based Glucose Monitoring System for Adolescent Diabetes Management ................................................................................................................................. 6
      2.6.3 Effect of mobile phone intervention for diabetes on glycaemic control: a meta-analysis .............................................................................................................................................................................. 6
   2.7 Conclusion ..................................................................................................................................... 6
3. Requirement Analysis and Design process ...................................................................................... 7
   3.1 Introduction ..................................................................................................................................... 7
   3.2 Understanding key questions and considerations ....................................................................... 7
   3.3 Understanding the Users ............................................................................................................. 7
      3.3.1 Research Questionnaires ........................................................................................................ 7
      3.3.2 Questionnaire distribution ..................................................................................................... 8
      3.3.3 Evaluation of Questionnaire .................................................................................................... 8
      3.3.5 Interview with a support group leader .................................................................................... 14
      3.3.6 Interview with an Endocrinologist ....................................................................................... 14
      3.3.7 Interview with a Dietician ....................................................................................................... 15
   3.4 Conclusion ..................................................................................................................................... 17
4. Low Fidelity Design Iterations ........................................................................................................ 19
   4.1 Introduction ..................................................................................................................................... 19
List of Tables and Figures

Table 1: Diseases and associated health features [Smith et al. 2010] ............................................. 5
Table 2: Names of dairy food items and sample portion sizes .............................................................. 17

Figure 1: Overview of the proposed system ......................................................................................... 2
Figure 2: A patient uses a lancing device (1.) to draw blood from a fingertip and then uses the Blood-Glucose meter (2.) to read the glucose level in the blood [NDIC 2008] ......................... 4
Figure 3: Diabetes Pilot Software installed on a desktop computer (left) and on an Apple mobile phone (right) [Digital Altitudes 2010] .......................................................................................... 4
Figure 4: Graphs showing the age range of the diabetics ................................................................. 8
Figure 5: Pie charts on the survey on diabetes type ............................................................................. 9
Figure 6: Graphs showing the frequency that diabetics measure blood glucose levels ................. 9
Figure 7: Graphs showing the frequency that diabetics monitor their diet ..................................... 10
Figure 8: Graphs showing the frequency that diabetics monitor their insulin ............................... 10
Figure 9: Graphs showing the frequency that diabetics monitor their physical exercise .......... 11
Figure 10: Graphs showing the frequency that diabetics monitor medication ............................. 11
Figure 11: Graphs showing the frequency that diabetics monitor their weight ............................ 11
Figure 12: Graphs showing where diabetics have access to the internet ........................................ 12
Figure 13: Graphs showing how diabetics would like to view online information .................... 12
Figure 14: Pie charts showing whether the diabetics had a mobile phone for personal use .... 13
Figure 15: Graphs showing the type of phone that the diabetics used ........................................... 13
Figure 16: Spreadsheet that the dietician used to calculate an individual’s energy requirements ................................................................................................................................. 16
Figure 17: Spreadsheet that the dietician used to calculate an individual’s nutritional requirements ................................................................................................................................. 16
Figure 18: Diagrams showing examples of how to obtain user details (left) and how a user could enter blood glucose levels into the system (right) ................................................................. 20
Figure 19: Diagrams showing how a user could view their calorie information (left) and how they could add consumed meals to the system (right) ................................................................. 20
Figure 20: Diagrams showing how a user could add burnt calories to the system (left) and how a user could view past calorie levels (right) .................................................................................... 21
Figure 21: Screen representations of (1) Calories status, (2) Adding meal calories to the system and (3) Adding a new meal to the system ......................................................................................... 22
Figure 22: Screen representations of (4) how to select a dairy meal item, (5) how to select a cereal/porridge meal item, and (6) how to select a sugar food item ..................................................... 22
Figure 23: Screen representations of (7) viewing graph of calories history, (8) form to enter user details into the system, and (9) form to view and enter blood glucose levels into the system ................................................................................................................................. 23
Figure 24: Screen representations of (10) adding burnt calories to the system and (11) a representation of the options menu when it is selected ................................................................................. 23
Figure 25: Paper version of a Nokia phone with a hollow screen (left) and with one of the paper images (right)

Figure 26: Screen images of the insulin form that allows the user to enter insulin data and view insulin history

Figure 27: Screen images of the home page form

Figure 28: Overview of the layout of the mobile diabetes management system

Figure 30: Screen images showing (1) the first screen that takes a user to the registration form, (2) the home page form and (3) the login form

Figure 29: A screen image showing the 3 applications that can be run on the phone

Figure 31: Screen images of the blood glucose form where (1) the user can enter blood glucose levels into the phone's database, (2) viewing recent blood glucose levels and (3) the message alert when a user enters a blood glucose event into the phone's database

Figure 32: Screen images of the insulin form where (1) the user can enter insulin levels into the phone's database, (2) viewing recent insulin levels and (3) the message alert when a user enters an insulin event into the phone's database

Figure 33: Screen images of the calories status form where the user can (1) view needed daily calories, (2) view calories consumed on that day, and (3) view the calories still required for that day

Figure 34: Screen images of adding consumed meal calories with (1) the options, (2) the SUBMIT button and 'Add new meal or snack' button, and (3) the message alert when meal calories have been entered into the phone's database

Figure 35: Screen images of the form where (1 and 2) a user can add the meal item details into the phone’s database and (3) the message alert when a user enters a meal item into the phone's database

Figure 36: Screen images for the form that allows a user to add burnt calories. (1) the user can enter a value from a pedometer, (2 and 3) the user can select an exercise and enter the minutes exercised, and (4) the message alert when an exercise event is entered

Figure 37: Screen image of ‘Graphs’ form page where the blood glucose history graph is visible

Figure 38: Screen images of the reminders application where a user can enter reminders into the MYSQL database

Figure 39: Database model diagram of the e-health MYSQL database

Figure 40: Graph showing the frequency of meal item entries into the database

Figure 41: Graph showing the frequency of exercise event entries into the database

Figure 42: Graph showing the frequency of blood glucose entries into the database

Figure 43: Graph showing the frequency of insulin entries into the database

Figure 44: Diagram showing the layout of the proposed system for the support group members and the patients of the diabetes clinic
1. Introduction

1.1 Problem Outline

In 2004, about 3.4 million people worldwide died from elevated blood glucose levels [WHO 2011]. In 2006, there were approximately 6.5 million diabetics in South Africa [Health 24 2006] out of an estimated population of 47 million South Africans at that time period [Statistics South Africa 2006]. Furthermore, out of the 6.5 million diabetics in South Africa, only 8000 were registered with the Diabetes South Africa network [Health 24 2006]. These statistics show that a system that aids in the self-management of diabetes is required. Furthermore, a system that aids in the social support of the diabetes patients is required to allow patients to communicate with relevant users as well as to share experiences and knowledge about the illness.

During the literature synthesis, it was discovered that there weren’t any publicly available E-health applications or systems that could assist in the self-management of diabetes in South Africa. However, there were a variety of commercially available products, like the Diabetes Pilot software, which have to be purchased and are not affordable by an average person [Digital Altitudes 2010].

1.2 Proposed Solution

Initially, this project investigated what type of system that diabetic patients really need. This was achieved through the use of questionnaires and interviews. The results of the research were used to develop a system by means of an iterative design process whilst also using principles of User-Centred Design. This project ensured that users were involved to a great extent in the research and the testing process of the diabetes management software. The final system was piloted to see if it is usable on a daily basis.

The core aspects of this project were diabetes self-management using mobile technology, diabetes self-management using an online social network, and a diabetes self-management website and server that also integrates the data from the mobile devices, online social network and website. The system aimed to assist in the method of record and data keeping, which is an essential part of a patient’s daily life. The proposed system had to be easily accessible and available at a low cost. In addition, it also had to provide social support for diabetic patients in areas where there is scarcity of support groups through the use of social networking [Smith and Christakis 2008]. A diagram outlining the proposed system is shown below.
1.3 Division of Work

The project was divided into 3 different sections. Each team member was allocated to a specific area of research and the implementation of this particular section of the system. This included an initial investigation, as well as developing and evaluating prototypes. The allocation of the different sections is outlined below.

**Dalton Jacobs:** Diabetes self-management website  
**Brian Sebastian:** Diabetes self-management using mobile technology  
**Nidheesh Sharma:** Diabetes self-management using an online social network

1.4 Report Outline

The Background and Motivation chapter outlines a brief introduction to diabetes and current existing methods of managing this disease. An analysis of previous research that is related to this project is then summarized, and a conclusion that includes a motivation for this project is presented. The Requirements Analysis and Design process chapter starts by providing an analysis of the results of the questionnaire survey in order to understand the users of the final system and their requirements.

The Low fidelity Design iteration chapter outlines the low fidelity prototype that is produced based on the questionnaires and interviews from the research. A summary of the results of the user evaluations is then presented. The High fidelity Design iteration chapter outlines the high fidelity prototype that is produced based on the evaluations from the Low fidelity Design iteration chapter. The prototype is evaluated and the results are also summarized. The Final Experiment chapter presents the final system and the results of the evaluation that is undertaken after pilot testing. The Conclusion chapter outlines the overall success of the project and also presents possible ideas that may be undertaken for future research.
2. Background and Motivation

2.1 Introduction

There has been substantial research into diabetes including the use of technology to assist diabetics in managing diabetes. This chapter outlines a brief introduction to diabetes and current existing methods of managing this disease. An analysis of previous research that is related to this project is then summarized, and a conclusion that includes a motivation for this project is presented.

2.2 Diabetes

Diabetes is a medical disorder that is characterized by raised glucose levels due to insufficient insulin secretion or reduced insulin action, or both. It is diagnosed by measuring the glucose level in the blood [Butler 2009]. Diabetes can cause long-term damage, dysfunction and failure of various organs [WHO 1999]. There are 2 main types of diabetes that are outlined in the sub-section below.

2.3 Types of Diabetes

‘Type 1’ diabetes is primarily caused by the destruction of pancreatic islet beta-cells of which no specific causes can be assigned, and also includes the cases that are caused by an autoimmune process. The end result is usually a total insulin deficiency which leads to insulin being required for survival [WHO 1999]. ‘Type 2’ diabetes is the most common form of diabetes which results due to low insulin secretion [2]. Type 2 diabetes accounts for 85 to 90% of all diabetes cases [Butler 2009]. A major cause of the deficiency is increased resistance to insulin that is attained [WHO 1999].

2.4 Treatment of Diabetes

Successful management of diabetes requires close teamwork between the patients and their health care providers. The Health care providers need to prescribe optimal medications and counsel patients on treatment plans, and the patients need to sustain this often-complicated treatment plan consisting of medication, diet and exercise plan [Heisler et al. 2003]. Diabetic patients have to maintain their blood glucose levels by keeping up a healthy lifestyle that includes eating a healthy diet and exercising. It is usually necessary to record the details of the blood glucose levels regularly in order to determine whether the blood glucose levels are staying at an optimal level or if adjustments need to be made to their diet, exercise and insulin intake. The art of maintaining this treatment plan is called Self-Management [Heisler et al. 2003]. The American Diabetes Association propose that patients should perform self-monitoring of blood glucose (SMBG) at least 3 times a day for type 1 patients and as clinically necessary as possible for type 2 [Thomas et al. 2008].

2.5 Current electronic systems that aid in treatment

There are a variety of electronic systems that are available that aid in the treatment of diabetes. Some of these electronic systems are targeted at the patients. They range from
devices that actually monitor or read values from the patient to systems that aid in structuring the day to day plan for the patient.

Blood glucose meters are used by diabetics to perform SMBG by reading the level of glucose in the blood. The process of reading the level of glucose in the blood is outlined in figure 2 below. There are a variety of commercially available blood glucose meters. According to a comparison performed by Thomas et al, the devices tested all produced clinically acceptable accuracy when producing readings of glucose levels [Thomas et al. 2008].

![Figure 2: A patient uses a lancing device (1.) to draw blood from a fingertip and then uses the Blood-Glucose meter (2.) to read the glucose level in the blood [NDIC 2008]](image2)

The Diabetes Pilot is an example of commercial software that is available for diabetic patients that makes it easier to record and maintain glucose measurements, and assist in maintaining a healthy diet. This software has different versions that can be installed on a variety of desktop computers and mobile devices including mobile phones [Digital Altitudes 2010]. However, this software is costly and not affordable by an average user thus limiting the product’s recognition in a society.

![Figure 3: Diabetes Pilot Software installed on a desktop computer (left) and on an Apple mobile phone (right) [Digital Altitudes 2010]](image3)
2.6 Related Work

2.6.1 Feasibility of Mobile Phone-Based Management of Chronic Illness

Smith et al. explored the feasibility of using current mobile phone technology to improve the management of chronic illnesses. They included a table that presented the different diseases and the associated health features that could assist in managing the different diseases. The table outlining the diseases and associated health features is shown below.

<table>
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<tr>
<th>Disease Areas</th>
<th>Associated Health Features</th>
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<tr>
<td>Arthritis, Osteoporosis, and Chronic Pain</td>
<td>Access to care, Diet, Education, Medication, Physical Activity, Weight</td>
</tr>
<tr>
<td>Cancer</td>
<td>Access to care, Diet, Education, Medication, Physical Activity, Substance Abuse</td>
</tr>
<tr>
<td>Cardiovascular Diseases</td>
<td>Access to care, Diet, Education, Heart rate, Medication, Physical Activity, Respiration, Stress, Substance Abuse, Weight</td>
</tr>
<tr>
<td>Chronic Kidney Diseases</td>
<td>Access to care, Blood Pressure, Diet, Education, Medication, Substance Abuse, Weight</td>
</tr>
<tr>
<td>Diabetes</td>
<td>Access to care, Blood Pressure, Blood glucose, Diet, Education, Medication, Physical Activity, Substance Abuse, Weight</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Blood pressure, Diet, Education, Medication, Weight</td>
</tr>
<tr>
<td>Mental Health &amp; Disorders</td>
<td>Access to care, Depression, Education, Medication, Stress, Substance Abuse</td>
</tr>
<tr>
<td>Overweight</td>
<td>Blood Pressure, Education, Diet, Physical Activity, Weight</td>
</tr>
<tr>
<td>Respiratory Diseases</td>
<td>Access to care, Air quality, Education, Heart rate, Respiration, Substance Abuse</td>
</tr>
<tr>
<td>STDs/HIV/AIDS</td>
<td>Access to care, Education, Medication</td>
</tr>
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Table 1: Diseases and associated health features [Smith et al. 2010]

They investigated these health features that needed to be managed using a mobile phone, and discovered that each one of the health features has been successfully managed using a mobile phone. They discovered that even the most basic phones could successfully assist in managing their health, even though in some cases the lack of features reduced the quality of assistance. They stated that current health phones focus mostly on specific markets like fitness with much less focus on the medical market. They mention that for future work, usability and user interface design for more complex management of chronic illnesses is of prime importance. They conclude by stating that they believe that the mobile phone will lead to improved care and disease management for patients suffering from chronic illness.
2.6.2 Using a Cell Phone-Based Glucose Monitoring System for Adolescent Diabetes Management

Carroll et al. investigated the feasibility and acceptability of a cell-phone glucose monitoring system called Glucophone for adolescents with Type 1 diabetes. Each participant used the system for 6 months whilst they filled out surveys every 3 months in order to measure the usability and satisfaction that they had with the cell phone glucose monitoring system.

The results showed that the adolescents reported that they had positive feelings about the technology and the service although a concerning number of them had considerable technical issues that affected the continued use of the device. However, the use of the Glucophone did not significantly change the quality of life of the participants with regard to the self-management of diabetes or their average glycaemic control. This was due to the short timeframe of the study. Carroll et al. concluded that the feasibility study was successful in demonstrating that cell phone glucose monitoring technology can be used in an adolescent population to track and assist in self-monitoring behaviour.

2.6.3 Effect of mobile phone intervention for diabetes on glycaemic control: a meta-analysis

Liang et al. conducted a survey on previous clinical studies that were performed in order to verify if mobile phone intervention had an effect on glycaemic control for Diabetic patients. A total of 22 trials were selected for the analysis, which represented a total of 1657 participants. They discovered that on average, there was strong evidence that mobile phone intervention led to a statistically noteworthy improvement in glycaemic control and self-management in diabetes care. They further noted that the change was more significant for Type 2 diabetics than for Type 1 diabetics.

2.7 Conclusion

This chapter has outlined an introduction to diabetes and the current existing methods of managing the disease. An analysis of related research that has been undertaken to view if mobile phones can be used to assist in the management of diabetes has also been presented. The first chapter of this report shows that there is a need for methods to assist in the management of diabetes and the Related work section of this chapter shows that a system that assists in the management of diabetes by using a mobile device such as a mobile phone can be well received by potential users and can also achieve positive results in terms of improving the management of diabetes. The next chapter outlines the research undertaken to establish the potential users of the final system and to determine the necessary functions that users and experts in diabetes felt that the final system should contain.
3. Requirement Analysis and Design process

3.1 Introduction

An iterative design process was used in this project whilst also using principles of user centred design. User centred design has been a useful design methodology for creating interactive systems because it puts users first all the time [Maunder et al. 2007]. The idea behind using the principles of user centred design was in order to produce a system whereby it was intuitive to use by users and therefore did not need any manuals or instructions. The steps involved in the iterative process are outlined below.

1. Perform Requirements Analysis
2. Produce prototype/system
3. Test prototype/system with users
4. Obtain feedback from users
5. Refine the prototype/system based on the feedback from users
6. Repeat steps 2 to 5 until the final system has reached an acceptable standard

The rest of this chapter outlines the first step above i.e. the analysis that was carried out in order to discover the requirements of the final system. Step 2 to step 5 are repeated by producing different types of prototypes each time. The prototypes are evaluated by users and refined based on the feedback given by the users. Chapter 4 outlines the low fidelity prototype that is created and evaluated and chapter 5 outlines the high fidelity prototype that is created and evaluated. Chapter 6 outlines the final system that is created and evaluated.

3.2 Understanding key questions and considerations

In order to fulfil a satisfactory analysis of the requirements of the final system, it was necessary to interact with diabetics and experts in the field of diabetes. 2 comprehensive questionnaires were created. One questionnaire was designed to obtain important information from diabetics and to also assist us in deciding the potential users of the final system. This questionnaire and the results obtained are discussed in the next section.

The second questionnaire was designed to obtain information from doctors that specialized in diabetes. This questionnaire was designed in order to obtain useful information regarding the expectations of doctors with regard to their patients’ self-management of diabetes, and ideas that could assist us in designing a system that could assist in improving the outcomes of the doctors’ expectations. However, we could only get one interview with a doctor specializing in diabetes, and the responses to the questions are outlined in section 3.4.

3.3 Understanding the Users

3.3.1 Research Questionnaires

In order to determine the potential users of the final system, a questionnaire was designed and evaluated. Two types of the questionnaire were created in order to maximize on the number of people that could gain access to this survey. One was a paper-based
questionnaire and the other was an online version of the same questionnaire. The questionnaire gave insight to the following points below:

- What diabetics go through on a regular basis
- What kind of features they would like to interact with on the proposed system
- If they have access to a personal computer, a mobile phone and the internet
- Which locations that they frequent on a regular basis in order to investigate the feasibility of implementing a possible location-based service
- Which social networks they are members of
- Their habits when interacting with social networks
- If they would like to use their social network to assist them in managing their illness
- If they would like to participate further in our project

A copy of the questionnaire can be found in Appendix A.

3.3.2 Questionnaire distribution

The questionnaire was distributed by meeting with users in person, and by placing a link to the online version of the questionnaire on different Facebook and Twitter groups that focused on diabetics as well as putting up posters with the link to the online questionnaire. We approached South Africa’s largest network of diabetics called Diabetes South Africa and they gave us contacts to some of Western Cape’s largest support groups. We then proceeded to approach the support groups in order to distribute the questionnaires. Through these different distribution methods, we interacted with a diverse age group of users in order to obtain contribution from both Type 1 and Type 2 diabetic patients. A total of 56 paper based questionnaires were filled out at the support groups, and 44 people filled out the online questionnaire. The evaluation of the results is outlined in the following section.

3.3.3 Evaluation of Questionnaire

After obtaining the results of the survey, it was necessary to evaluate the results in order to assist us in making decisions on the design of the final system.

The Age range of the diabetics

The graph for the support groups survey (top) shows that the diabetics were all at least middle-aged, whereas the graph for the online respondents (bottom) shows a more even distribution between the age groups with the majority being in the 21-30 year
old age group.

The survey on diabetes type

The pie chart for the support group survey (top) shows that the diabetics were mostly Type 2, whereas the pie chart for the online respondents (bottom) shows a more even distribution between Type 1 and Type 2 diabetics.

Doctor/ Clinic visits – The majority of the diabetics in both the online respondents and the support groups visited the doctor less than once a month. 63% of the support group members and 73% of the online respondents visited the doctor less than once a month.

How often diabetics measure Blood Glucose levels

The graph for the support groups survey (top) shows that just over a quarter of the members check their blood glucose levels daily, whereas the graph for the online respondents (bottom) shows that just over half of the respondents check their blood glucose levels daily.

How often diabetics measure Blood Pressure – The results from both the online respondents and the support group survey show that most of the respondents do not check their blood pressure on a regular basis. 23% of the online respondents and 16% of the support group members check their blood pressure at least once a week.

How often diabetics measure Cholesterol - The results from both the online respondents and the support group survey show that most of the respondents do not check their cholesterol on a regular basis. 2% of the online respondents and 16% of the support group members check their cholesterol at least once a week.
How often diabetics monitor Diet

The graph for the support groups survey (top) shows that just 41% of the members monitor their diet at least once a week, whereas the graph for the online respondents (bottom) shows that over half of the respondents monitor their diet at least once a week with 39% of them monitoring their diet daily.

How often diabetics monitor Insulin

The graph for the support group survey (top) shows that 18% of the members monitor their insulin intake at least once a week, whereas the graph for the online respondents (bottom) shows that 41% of the respondents monitor their insulin intake at least once a week. However, 45% of the online respondents and 41% of the support group members did not monitor their insulin intake.

How often diabetics monitor Physical Exercise

The graph for the support group survey (top) shows that 41% of the members monitor their physical exercise at least once a week, and the graph for the online respondents (bottom) shows that 59% of the respondents monitor their physical exercise at least once a week.
How often diabetics monitor Medication

The graph for the support group survey (top) shows that 43% of the members monitor their medication daily, and the graph for the online respondents (bottom) shows that 45% of the respondents monitor their medication daily.

How often diabetics monitor Weight

The graph for the support group survey (top) shows that 23% of the members monitor their weight at least once a week, whereas the graph for the online respondents (bottom) shows that 45% of the respondents monitor their weight at least once a week.

How often diabetics monitor their sleep patterns – 32% of the support group members monitored their sleep patterns at least once a week, whereas none of the online respondents monitored their sleep patterns at least once a week.

Tasks that diabetics find important in managing diabetes – The tasks that the support groups find important in order to manage diabetes are:

- Viewing blood pressure history (49% check at least once a month)
- Viewing trends in glucose levels (47% check at least once a month)
- Viewing medication intake history (44% check at least once a month)
- Viewing weight history (33% check at least once a month)
The tasks that the online respondents find important in order to manage diabetes are:

- Viewing trends in glucose levels (81% check at least once a month)
- Viewing diet plan history (82% check at least once a month)
- Viewing exercise plan history (78% check at least once a month)
- Viewing medication intake history (68% check at least once a month)
- Viewing weight history (59% check at least once a month)

**Where the diabetics have access to the internet**

The graph for the support group survey (top) shows that 77% of the members do not have internet access whilst 15% of the members access the internet by using their mobile phones. The graph for the online respondents (bottom) shows that 48% of the respondents access the internet by using their mobile phones.

**The platform that diabetics would like to use to view online information**

The graph for the support group survey (top) shows that 19% of the members prefer to view online information by using a mobile phone whilst 77% of the members do not prefer to view online information at all. The graph for the online respondents (bottom) shows that 39% of the respondents prefer to use a mobile phone to view online information.
If the diabetics had a mobile phone for personal use

The pie chart for the support group survey (left) shows that 41% of the members do not have access to a mobile phone, whereas the pie chart for the online respondents (right) shows that only 14% of the respondents do not have a mobile phone for personal use.

![Pie charts showing whether the diabetics had a mobile phone for personal use](image)

The type of phone that they use

![Graphs showing the type of phone that the diabetics used](image)

The graph for the support group survey (left) and the graph of the online survey (right) show that the most popular mobile phone brand the respondents use is Nokia. However, on asking to see the actual models of the phones that the support groups members have, it was discovered that they mostly have the most basic models with very limited features.

What tasks that the diabetics performed with their phones – The tasks that the support group members with mobile phones perform occasionally with their mobile phones are:

- Sending SMS (57% of the members)
- Taking pictures (45% of the members)

The tasks that the online respondents perform regularly or once in a while with their mobile phones are:

- Sending SMS (75% of the respondents)
- Surfing the Internet (65% of the respondents)
- Listening to Music (38% of the respondents)
- Taking pictures (50% of the respondents)
- Sending Email (50% of the respondents)
Using social networking applications (54% of the respondents)

**The amount of money spent on mobile phone expenses each month** – None of the support group members that answered this question spend more than R400 on mobile phone expenses each month with a majority of the members with mobile phones spending less than R100. Conversely, the majority of online respondents spend more than R100 each month.

**The amount of money diabetics were willing to spend on mobile phone expenses each month** – 52% of the support group members and 56% of the online respondents that answered this question stated that they were willing to spend less than R50 extra.

**How the diabetics regarded their internet connectivity on their phone** – 20% of the support group members that answered this question found the internet connectivity on their phone as slow and difficult to connect whereas none of the online respondents found the internet connectivity on their phone as slow and difficult to connect.

### 3.3.5 Interview with a support group leader

When meeting with the support groups, we also interviewed 2 support group leaders. We wanted to gain more knowledge on diabetes and if they had any advice that could assist us in the project. A list of the points that came out of the interview is outlined below.

- Diabetes is a chronic disease that a majority of people seem not to know about based on the talks and seminars that they attend
- Support groups assist diabetics in gaining knowledge and advice on how to maintain a healthy lifestyle
- Type 2 diabetes is becoming more prevalent in South Africa mainly due to lack of knowledge of the causes of this diabetes type. The main causes are a poor diet and exercise regimen
- Children as young as 9 years old are now being diagnosed with Type 2 diabetes in South Africa due to having a poor diet and exercise regimen
- Young diabetics do not want to participate in Diabetes support groups because they feel that there is a stigma attached to being a diabetic
- A majority of the support group members are women.
- The women are more open to discussing the state of their health and gaining advice than the men

### 3.3.6 Interview with an Endocrinologist

We had a meeting with the endocrinologist in charge of the Groote Schuur Hospital Diabetes Clinic. We asked some questions that could assist us further in our initial survey by using the questionnaire that was designed to obtain information from doctors that specialized in diabetes. A list of the responses is outlined below:

- The age range of patients that visit the clinic is between 22-80yrs old with a median age of 45yrs old
- The patients are a combination of Type 1 and Type 2 diabetic patients
- An average of 300 patients visit clinic every month
- A patient visits the clinic on average once every 3 months
• The usual communication channels are visitations and telephone
• The doctor asks the patient to maintain a diary or record of completed tasks
• Tasks the doctor expects patients to perform for self-management are:
  o Blood Glucose levels
  o Maintaining a healthy diet
  o Insulin intake
  o Physical exercise
  o Checking feet to ensure they are dry
• The information that the doctor is interested in viewing when patients visit is:
  o History of past Blood Glucose levels
  o Diet history
  o Insulin intake history
  o Physical exercise history
• The doctor would be interested in receiving alerts or notifications of patient records if the feedback is outside of the normal threshold
• The doctor would be willing to give advice online if patients requested assistance
• The challenges that the doctor currently faces when it comes to analyzing or discussing a patient’s progress are:
  o A majority of the patients perform inadequate monitoring of glucose control and diet
  o Difficulty in monitoring if patients comply with medication, insulin intake, exercise and dietary requirements.
  o Difficulty in ensuring that patients are making adequate adjustments to their self-management
  o Failure of patients to act on their glucose measurements if they are above or below normal threshold values

The doctor also made some constructive comments that were intended to assist us in our project. The comments are listed below:
• Diabetes self-management is complicated as a whole. It is far easier to understand what a doctor has thought about as a possible solution and implement that idea.
• Being a diabetic is inflexible. For example, for the purposes of this project, it may be necessary for participants to check their blood glucose levels at the same time.
• A majority of the patients that visit the clinic are poor, and the poor community should not have to spend money from a research point of view.
• A possible solution should include general reminders e.g. inspecting feet, not using hot water bottles, when to take insulin etc.
• It may be necessary to work with a dietician to get advice on how to maintain the daily calorie intake of a participant, or to use a chart to estimate calories consumed.
• Patients currently don’t have an active measure of how they are progressing.

3.3.7 Interview with a Dietician

After the interview with the doctor, we decided that the next was to set up an interview with a dietician in order to gain knowledge on how dieticians expected diabetics to maintain
their daily caloric intake. We met with a registered professional dietician and the information that we gathered is outlined below:

3.3.7.1 Calculating Energy Requirements of Individuals
The dietician gave us a spreadsheet showing an example of how we could calculate energy requirements of individuals. The energy requirements are then used to estimate the amount of specific nutrients that an individual is supposed to eat each day. An image of the spreadsheet with a pre-calculated example of the energy requirements of a female weighing 65kg and with a height of 1.7 metres is shown below.

![Figure 16: Spreadsheet that the dietician used to calculate an individual’s energy requirements](image)

3.3.7.2 Calculating nutritional exchanges required
Once the energy requirements are calculated, the dietician then calculates the specific quantities of nutrients that the individual needs to consume on each day. An image of the spreadsheet used with a pre-calculated example of the nutritional exchanges required for an individual requiring 1300 Calories per day is shown below:

![Figure 17: Spreadsheet that the dietician used to calculate an individual’s nutritional requirements](image)

a) The dietician first calculates the specific amounts of carbohydrate, protein and fat required for the individual.

b) The dietician calculates the amount of portions of specific food products that the individual should eat in a given day.
Once the dietician has decided on the specific portions of food items that an individual should eat, she compiles an eating plan for the individual that includes tables of the different types of recommended food items and sizes of portions. An example of one of the tables with portion sizes is shown below.

**DAIRY PORTIONS: (Choose 2 per day)**

<table>
<thead>
<tr>
<th>FOOD ITEM</th>
<th>PORTION SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk (fat-free)</td>
<td>1 cup</td>
</tr>
<tr>
<td>Milk (low-fat)</td>
<td>½ cup</td>
</tr>
<tr>
<td>Plain yogurt (low-fat or fat free)</td>
<td>1 cup</td>
</tr>
<tr>
<td>Fruit yogurt (sweetened)</td>
<td>175ml</td>
</tr>
<tr>
<td>Fat free cottage cheese</td>
<td>1/3 cup</td>
</tr>
<tr>
<td>Low fat cottage cheese</td>
<td>¼ cup</td>
</tr>
<tr>
<td>Ricotta cheese</td>
<td>2T</td>
</tr>
<tr>
<td>Reduced-fat hard cheese</td>
<td>3 slices/ 1/3 cup of grated cheese (30g = a matchbox size)</td>
</tr>
<tr>
<td>Feta</td>
<td>30g (a matchbox size)</td>
</tr>
</tbody>
</table>

Table 2: Names of dairy food items and sample portion sizes

This comprehensive eating plan is then given to the individual so that he or she can maintain a healthy eating lifestyle.

### 3.4 Conclusion

After evaluating all the information that is outlined in this chapter, it was necessary to decide on the potential user that the system was going to be developed for. The online respondents were chosen as the potential users of the final system for the reasons outlined below:

- **Technology constraints of the users** – The online respondents used more features on their phone that the support group members, who only used their phones mainly for making phone calls and sending SMS. Therefore the online users are more prone to use a mobile diabetes management system and give an evaluation within the timeframe of an honours project.

- **Time constraints** - The support group members mostly had the most basic mobile phones and user-testing a prototype would possibly require training the users. However due to the Honours project time limitation this seemed an infeasible feat especially since this would have meant travelling to Mitchells Plain on a regular basis where a majority of the support group members live. The online respondents were more flexible to work with because they could meet us on the university campus at a mutually beneficial time.

- **Health sciences ethical clearance issues** – In order to develop a system that is aimed at the patients of the diabetes clinic, it was necessary to initially obtain ethical clearance from the Health Science faculty. However health sciences ethical clearance application is time consuming and the actual waiting time for the approval
takes a few weeks. It therefore made more sense to focus on the diabetics that had answered the questionnaire instead.

- **Honours project requirements** – It was necessary to satisfy some of the minimum requirements of an honours project. One of the requirements is that the E-Health project had to share a common boundary between the three sections of the project. If the potential users selected for the mobile diabetes management system had been different to the users selected for the other sections of the project, it might have ended up causing conflicts and difficulty in merging the different sections together.

However, despite the decision of not selecting the support group members and the patients of the diabetes clinic as the potential users, an idea for a project that may possibly benefit these 2 groups is outlined in the ‘Future Work’ section in the final chapter.

The evaluation of all the information that is outlined in this chapter also gave some ideas as to how the mobile diabetes management system should be designed.

- **Connect to the internet only when necessary** – The results of the survey have shown that a majority of the people wanted to spend as little money as possible when using a mobile diabetes management system. Therefore it is necessary to develop a mobile diabetes management system that stores information in the phone’s memory and uses the phone’s internet connection only when necessary.

- **The mobile phone brand to initially develop for** – The results of the survey have shown that Nokia is the most popular brand in use by the people surveyed. As a result, it is necessary to initially develop a mobile diabetes management system that works on Nokia handsets.

In addition, the evaluation of all the information that is outlined in this chapter also gave some ideas on what features to add to the mobile diabetes management system. According to the doctor’s recommendation, it is better to have as few functions as possible, but also to have the necessary functions that help to manage diabetes. Using this advice, the functions that were selected for the mobile diabetes management system are listed below.

- Blood glucose management
- Management of diet
- Management of exercise

These functions were used to create the low fidelity paper prototype that is outlined in the next chapter.
4. Low Fidelity Design Iteration

4.1 Introduction

The design and development stage involved creating a low fidelity paper prototype and performing qualitative assessments. A qualitative assessment generates a description which is generally in non-numeric terms [Marsden and Jones 2006]. An initial low fidelity design was created by using a white board, and is outlined in the next section. The evaluation of this design led to a low fidelity paper prototype. This prototype was used to perform tests with potential users found in the analysis stage. A paper-based prototype is easy to implement and modify. It also gives the users the opportunity to have immense contributions to the system thus focusing greatly on user centred design. The users were asked to interact with the prototype and give feedback on the system’s functionality. The process is explained in section 4.3.2.

4.2 Design on Whiteboard

The white board was used to formulate the initial low fidelity designs that were going to be used for the initial evaluation purposes. The white board was used because it was large enough for the three researchers that were involved to add and quickly edit any ideas that each researcher had. This design gave us an idea of the functionality that was going to be included into the 3 systems that were going to be implemented. The following sections outline the reasons behind the design.

4.2.1 Design

The first chapter outlines a need for a system that aids diabetics in the management of diabetes, and part of the research from the questionnaire gave us an idea of the following 2 points below:

- What diabetics go through on a regular basis
- What kind of features they would like to interact with on the proposed system

The research outlined the need to include the following functionality:

- Blood glucose management
- Management of diet
- Management of exercise

The following sets of diagrams outline the initial design based on the functionality stated above.

The diagram below on the left shows how a potential user can enter the details required to calculate the daily calories required. The diagram on the right shows how potential users are able to view their recent blood glucose readings and also add a reading at the same time.
Figure 18: Diagrams showing examples of how to obtain user details (left) and how a user could enter blood glucose levels into the system (right)

The diagram below on the left shows a screen representation of how a potential user can view the amount of daily calories required, as well as the amount of calories consumed and the amount of calories burnt. The user can also view the amount of calories still required for that particular day. The diagram below on the right shows a screen representation of how a user can add the amount of calories that the user has consumed by either directly adding a specific number of calories or by selecting a meal from the drop-down boxes. The user also has an option to add new meals to the database by clicking on the ‘NEW...’ buttons.

Figure 19: Diagrams showing how a user could view their calorie information (left) and how they could add consumed meals to the system (right)
The diagram below on the left shows how a potential user can add the amount of calories that the user has burnt by either adding a specific number of calories or by inserting a pedometer reading of the number of steps taken by the user. The number of steps taken would then be used to calculate the amount of calories burnt by that particular user by using the user’s height and weight. The diagram below on the right shows how a user can view a graphical representation of the amount of calories consumed in recent days.

![Calorie Calculator](image1.png) ![Calorie History](image2.png)

*Figure 20: Diagrams showing how a user could add burnt calories to the system (left) and how a user could view past calorie levels (right)*

### 4.2.2 Evaluation

The white board designs were presented to the project supervisors at the Initial Feasibility demonstration in order to ensure that it satisfied the requirements of an honours project. After the demonstration, low fidelity paper prototypes of each section of the diabetes management system were produced in order to obtain evaluations and findings from potential users of the final system.

### 4.3 Paper Prototype

A low fidelity paper prototype of the mobile diabetes management system was created by making basic screen designs in Microsoft Word and then printing them out on paper. The idea behind creating screen designs was so that users get a feel of how the final system would look. At this stage, paper prototypes were used because they are easy to create and edit. The following section outlines the design of the paper prototype and is subsequently followed by the evaluation and findings made after testing the paper prototype with potential users.
4.3.1 Design

The paper prototype provided additional screen representations to the low fidelity designs that were created by using the whiteboard. There were a few modifications to some of the interfaces for the following reasons below:

- The pedometers that were purchased for the project could calculate the calories burnt whilst walking. This meant that the adding of steps walked was no longer necessary for the purposes of this project.
- The interview with the dietician occurred after the design on the whiteboard, and the information obtained was taken into account for the paper prototype.

The screens that were used are shown below.

![Calorie Manager](image1)

**Figure 21**: Screen representations of (1) Calories status, (2) Adding meal calories to the system and (3) Adding a new meal to the system

![Calorie Manager](image2)

**Figure 22**: Screen representations of (4) how to select a dairy meal item, (5) how to select a cereal/porridge meal item, and (6) how to select a sugar food item
Figure 23: Screen representations of (7) viewing graph of calories history, (8) form to enter user details into the system, and (9) form to view and enter blood glucose levels into the system.

Figure 24: Screen representations of (10) adding burnt calories to the system and (11) a representation of the options menu when it is selected.

In addition to the screens above, a large paper version of a mobile phone was also used to increase the realism of the prototype. An example of the way in which the participants viewed the prototype is shown below.

Figure 25: Paper version of a Nokia phone with a hollow screen (left) and with one of the paper images (right).
4.3.2 Evaluation and Findings

6 potential users of the final system volunteered to participate in the evaluation of the low fidelity prototype. Each participant was interviewed separately so that there was no influenced decision and moreover every user was unable to gain experience by watching the others test the prototype. Once the user was seated at a table, the paper-based prototype was presented. A sheet of paper with the interface of the application drawn on it was placed in front of the user and the user was given a series of tasks to perform. As an option was chosen on the interface by the user, a new paper was placed on the table showing the next set of options.

During the test, the interviewer recorded notes on paper. The interviewer did not intervene and give any suggestions in implementing the various tasks. If the users were confused, they were instructed to go with their instincts and do guess work if necessary. The reason behind this was so that the choices made by the user were not manipulated and also to help us understand how easy or difficult the prototype and the tasks are. The tasks were executed in the order of difficulty, starting with the simplest tasks so that the user could get the feel of the prototype. Once all the tasks were completed and the notes were written on paper, a short interview was conducted where the user was asked questions to assist in improving the investigation.

The participants were also encouraged to criticize the prototype, in order to get a great number of constructive criticisms that will be used to prepare the high fidelity prototype.

**Evaluation of tasks**

In general, the participants took longer to answer the first few questions, but their speed improved as they progressed through the tasks. The questions that the participants were asked to perform are listed below along with the results of the task performed:

1. **You have just had breakfast consisting of the following:**
   a. 1.5 cup bran flakes
   b. 2 teaspoons brown sugar
   c. 1 cup low fat milk

   Please enter this meal into the system.

   **Evaluation of task:** All 6 participants successfully performed this task with ease.

2. **You have just taken your blood glucose measurement and it is 7.5mmol/L. Please enter the value into the system.**

   **Evaluation of task:** 2 participants were initially confused as to how to navigate to the Blood glucose screen, but they eventually remembered to use the Menu button on the phone in order to view the menu that had the option to navigate to the Blood glucose screen.

3. **You have just taken a walk using a pedometer. The reading is 200 calories. Please enter this into the system**

   **Evaluation of task:** All 6 participants successfully performed this task with ease.
4. You would like to view your past calorie levels. Please navigate to the Calories History screen
   Evaluation of task: All 6 participants successfully performed this task with ease.

5. You have lost weight. Please adjust your weight settings.
   Evaluation of task: All 6 participants successfully performed this task with ease.

6. You would like to add a food item to the database. 100 g spaghetti
   a. 12.3g protein
   b. 74.3g carbohydrates
   c. 1.8g fat
   Please enter this into the database
   Evaluation of task: All 6 participants successfully performed this task with ease.

Feedback from tasks and interview sessions

- 5 participants also used insulin as part of their diabetes self-management and stated that it would be a worthwhile addition to the system.
- 2 participants also wanted a reminder system that they could use to remind them on when to take insulin. The other 4 participants said that they did not need reminders to take insulin, but they said that they would use the reminder system to schedule other tasks like doctor appointments.
- 3 participants preferred that pre-defined exercises were added to the system instead of using pedometers. In this way, the users could select an exercise and enter the amount of time that it took to complete the exercise.
- 5 participants also wanted to view graphs for blood glucose history, and for insulin history. 4 participants wanted to view a history of up to 2 weeks whilst 1 participant wanted to view a history of up to a month on the graph.
- 5 participants preferred to enter the date and time of blood glucose readings manually, and 1 participant preferring the system to automatically enter the date and time.
- 2 participants preferred that a home page that had all the possible tasks that the system could perform be implemented rather than having the Calories Status screen as the home page. 1 participant preferred that the home page should be the Blood glucose screen because that was the function that she was going to use more often. 1 participant wanted a home page that also showed glucose levels of the past 2 days.
- 4 participants responded that they would like to receive notifications from the system about new products or other related news. 2 participants said that they would rather want the option of manually downloading the notifications rather than automatically receiving notifications.
- All 6 participants stated that they would use the mobile diabetes management system on a regular basis if it were implemented.
4.4 Conclusion

The initial designs on the white board allowed for the design of a paper prototype that was not confusing or too difficult to use by the participants. This was noted by the fact that all participants were able to complete all the tasks, even though some of the users struggled in the beginning of the prototype evaluation.

After evaluating the low fidelity paper prototype, it was clear that there were some additions and alterations that had to be considered when creating the high fidelity prototype. The additions and alterations are stated below.

- Adding insulin management to the system
- Adding a reminders function to the system
- Adding notifications section to the system
- Adding pre-defined exercises to the system
- Adding graphs for blood glucose history and insulin history
- Adding a Home page to the system that offered a menu of the different functions of the system

The above-mentioned changes were taken into account for the high fidelity prototype that is detailed in the next chapter.
5. High Fidelity Design Iteration

5.1 Introduction

The design and development stage focused on the implementation and qualitative assessment of a high fidelity prototype. The prototype provided the interface functionality of the final system and was used to perform further user tests. The users were asked to interact with the prototype and give feedback on the system’s functionality. The process is explained in section 5.2.2.

5.2 J2ME High fidelity Prototype

The high fidelity prototype was created using the Java Platform Micro Edition Software Development kit. The reason behind using this kit was because it was also going to be used to create the final system. This would allow for a seamless transition from evaluating the high fidelity prototype and making necessary modifications to the interface whilst adding the back-end of the system. The next section outlines the design of the prototype with a main focus on the modifications that were added to the project.

5.2.1 Design

The prototype was designed and installed on a Nokia N96. The prototype was a horizontal prototype meaning that it showed all the interface functions of the system with only a few of the functions unimplemented. All the menus were interactive but the system did not store any values or make any calculations since the prototype only had code that controlled the interface.

The modifications that were included into the high fidelity prototype are listed below.

- Adding insulin management to the system (diagram 1 below)
- Adding graphs for blood glucose history and insulin history. A generic graph was used to represent the position where the graph was going to be located, and questions were asked during the evaluation as to whether the location was good or bad. An example of the location of the insulin history graph can be seen in diagram 1 below.
- Adding a Home page to the system that offered a menu of the different functions of the system (diagram 2 below)
- The home page showed if there were notifications that were unread, and had a link for the user to download more notifications. These were just static and the intention was for the user to see if this interface made sense.
5.2.2 Evaluation and Findings

5 potential users of the final system volunteered to participate in the evaluation of the high fidelity prototype. As in the low fidelity prototype evaluation, each participant was interviewed separately so that there was no influenced decision and moreover every user was unable to gain experience by watching the others test the prototype. Once the user was seated at a table, a Nokia N96 with the installed prototype was presented. The user was then instructed to perform a series of tasks on the phone.

During the test, the interviewer recorded notes on paper. The interviewer did not intervene and give any suggestions in implementing the various tasks. The reason behind this was so that the choices made by the user were not manipulated and also to help us understand how easy or difficult the prototype and the tasks are. The tasks were again executed in the order of difficulty, starting with the simplest tasks so that the user could get the feel of the prototype. Once all the tasks were completed and the notes were written on paper, a short interview was conducted where the user was asked questions to assist in improving the investigation.

The participants were also encouraged to criticize the prototype, in order to get a great number of constructive criticisms that will be used to prepare the final system.
Evaluation of tasks

In general, the participants took longer to answer the first few questions, but their speed improved as they progressed through the tasks. 3 of the participants owned Nokia phones and were familiar with the Nokia interface. These 3 participants performed tasks quicker than the other 2 participants who had to get acquainted with the interface. The questions that the participants were asked to perform are listed below along with the results of the task performed:

1. Please register your details into the system.
   Evaluation of task: All 5 participants successfully performed this task with ease.

2. You have just had breakfast consisting of the following:
   a. 1.5 cup bran flakes
   b. 2 tablespoons brown sugar
   c. 1 cup low fat milk

   Please enter this meal into the system.
   Evaluation of task: 4 participants successfully performed this task with ease. 1 participant forgot to enter the number of portions of the meal items into the system.

3. You have just taken your blood glucose measurement and it is 7.5mmol/L. Please enter the value into the system.
   Evaluation of task: All 5 participants successfully performed this task with ease.

4. You have just taken a walk using a pedometer. The reading is 200 calories. Please enter this into the system.
   Evaluation of task: All 5 participants successfully performed this task with ease.

5. You would like to view your past calorie levels. Please navigate to the graph with the calories history
   Evaluation of task: 3 participants successfully performed this task with ease. 2 participants had trouble finding the graph with the calories history. 1 participant stated that the graph should be placed separately from the Calories status page.

6. You have lost weight. Please adjust your weight settings.
   Evaluation of task: All 5 participants successfully performed this task with ease.

7. You would like to add a food item to the database. 100 g spaghetti
   a. 12.3g protein
   b. 74.3g carbohydrates
   c. 1.8g fat

   Please enter this into the database
   Evaluation of task: All 5 participants successfully performed this task with ease.
Feedback from tasks and interview sessions

- All 5 participants stated that the system was easy to use
- 1 participant noticed that the food database did not have sweetener since she used sweetener instead of sugar
- 2 participants stated that they preferred to have pre-defined exercises in the system rather than using a pedometer

After evaluating the results of the prototype testing, it was necessary to research on the addition of predefined exercises to the system. It was necessary to meet with an expert in the field of sport science in order to gain an understanding and possible advice on the feasibility of adding predefined exercises to the system.

5.3 Interview with a Sports Science expert

The team met with a sports science expert at the Sport Science Institute in order to gain more knowledge into how we could add predefined exercises to the system. The expert informed us that calculating calories burnt using predefined values called metabolic equivalent values (MET) shows an approximation of possible calories burnt. We were given a link to a website [Ainsworth et al. 2011] that had a comprehensive list of exercises and their MET values. MET values are used to calculate the energy cost of physical activities. The calories burnt could be calculated by using the equation below:

Calories burnt = minutes exercised \( \times \) ((MET value \( \times \) 3.5 \( \times \) weight) / 200)

5.3 Conclusion

The evaluation of the high fidelity prototype confirmed that the prototype was not confusing or too difficult to use by the participants. This was noted by the fact that all participants were able to complete all the tasks and stated that the prototype was easy to use.

After evaluating the high fidelity prototype, it was clear that there was an addition that had to be considered when creating the final system, which was adding pre-defined exercises to the system.

The above-mentioned addition was taken into account for the final system that is detailed in the next chapter.
6. Final system and evaluation

6.1 Introduction

This chapter will detail the features of the final system as well as the experiment that was carried out in order to assess the success of the final system.

6.2 Features of the final system

The final system comprised of a package consisting of 3 applications that were compiled into a single jar file which could be downloaded and installed on a Nokia phone.

The applications could access the same data stored on the phone. The J2ME Record Management System provides a mechanism that allows java applications to persistently store data across multiple invocations [Ghosh 2002]. The Record Stores are created in non-volatile device memory.
The Record stores that were created and used by the system are listed below.

- User record store
- Blood Glucose record store
- Insulin record store
- Calories consumed record store
- Calories burnt record store
- Record store for storing exercises and their MET values
- Record stores for storing the different meals in different food type stores

6.2.1 FitnessApp application

This application contained the features that involved entering data into the system, storing the data on the phone, and viewing the data on the phone. The features that were incorporated in the application are listed below:

- Viewing and adding Blood glucose levels
- Viewing and adding Insulin taken
- Viewing Calories overview
- Adding consumed meals to the phone’s database
- Adding burnt calories to the phone’s database
- Viewing graphs of blood glucose, insulin and Calories history
- Updating user settings

a. Home page and Options menu

A user first has to register the necessary details into the system before viewing the Home page. When a user logs into the system, a ‘Home page’ is presented that outlines the different options that a user can perform using the FitnessApp application. When the user exits and restarts the application, a login screen is shown for the user to enter the necessary details. This allows the data to only be accessible to authorised users on the phone.

Figure 29: A screen image showing the 3 applications that can be run on the phone

Figure 30: Screen images showing (1) the first screen that takes a user to the registration form, (2) the home page form and (3) the login form
b. Viewing and adding Blood glucose levels
When a user selects to view or add glucose levels, (1) is presented, and the user can scroll down to view the recent glucose levels as shown in (2). When a user enters a blood glucose level into the system, (3) is presented for 2 seconds showing the user that the blood glucose level has been entered into the system. The only change from the high fidelity prototype was that the graph was removed from this section and placed in a separate section for viewing all the graphs.

Figure 31: Screen images of the blood glucose form where (1) the user can enter blood glucose levels into the phone’s database, (2) viewing recent blood glucose levels and (3) the message alert when a user enters a blood glucose event into the phone’s database.

c. Viewing and adding insulin taken
When a user selects to view or add insulin taken, (1) is presented, and the user can scroll down to view the recent values of insulin taken as shown in (2). When a user enters a value for Insulin into the system, (3) is presented for 2 seconds showing the user that the insulin value has been entered into the system.

Figure 32: Screen images of the insulin form where (1) the user can enter insulin levels into the phone’s database, (2) viewing recent insulin levels and (3) the message alert when a user enters an insulin event into the phone’s database.

d. Viewing Calories overview
When a user selects to view calories overview, screen (1) below is presented. The user can click on the ‘Settings...’ button in order to update the user settings used to calculate the values on the screen as outlined in section i below. The user can scroll down to see how many calories have been consumed on that particular day as shown in (2) below. The user
can click on the ‘Add’ button in order to add a meal that was consumed. This is outlined in section e. On scrolling down further, the user can see how many calories have been burnt on that particular day (3). The user can also see the amount of calories that the user still needs to consume on that particular day. The user can click on the ‘Add’ button in order to add an exercise or calories burnt. This is outlined in section g.

![Figure 33: Screen images of the calories status form where the user can (1) view needed daily calories, (2) view calories consumed on that day, and (3) view the calories still required for that day]

e. Adding consumed meals to the phone’s database
When a user selects to add consumed meals to the phone’s database, a set of 9 dropdown boxes is presented as in (1) below. Each dropdown box represents a specific meal type. Each dropdown box is also accompanied by a textbox where the user can enter the amount of portions consumed for that specific meal item. The user can then scroll down to the ‘SUBMIT MEAL(S)’ button in order to submit the meals that the user may have eaten as in (2) below. The user can also enter a meal that was not on any of the lists by clicking on the ‘Add new meal or snack...’ button. If the user enters a meal into the database, (3) is presented for 2 seconds, and the Calories Status screen is shown with updated values.

![Figure 34: Screen images of adding consumed meal calories with (1) the options, (2) the SUBMIT button and ‘Add new meal or snack’ button, and (3) the message alert when meal calories have been entered into the phone’s database]

f. Adding a new meal or snack to the phone’s database
In this section, the user can add a new meal by filling out the details of the specific meal including the Nutritional information (1 and 2). Clicking on the ‘SUBMIT’ button enters the
new meal into the phone’s database. The screen (3) is shown when the data is successfully entered into the database.

![Figure 35: Screen images of the form where (1 and 2) a user can add the meal item details into the phone's database and (3) the message alert when a user enters a meal item into the phone's database](image)

**g. Adding burnt calories to the phone’s database**

When a user selects to add calories burnt to the phone’s database, the screen (1) below is presented. The first option allows a user to enter the calories burnt whilst using a pedometer or other device that can calculate calories burnt. The user can either enter a value or scroll down to option b as shown in screen (2).

In the second option, a set of dropdown boxes is presented. Each dropdown box has a list of exercises that can be chosen. The list of exercises is broken down into different alphabetic sections in order to be able to easily navigate through the whole list of exercises. Each dropdown box is also accompanied by a textbox where the user can enter the time that it took to complete that specific exercise. The screen (4) is shown when the data is successfully entered into the database.

![Figure 36: Screen images for the form that allows a user to add burnt calories. (1) the user can enter a value from a pedometer, (2 and 3) the user can select an exercise and enter the minutes exercised, and (4) the message alert when an exercise event is entered](image)
h. Viewing graphs of blood glucose, insulin and Calories history

When a user selects to view graphs, the form with the graphs is loaded and the user can navigate through the 3 different types of graphs. An example of one of the graphs can be seen on the left. J2ME doesn’t have an existing graph API so one had to be found to draw the graphs. A proprietary library was found that was imported to the project. This library allowed for non-commercial use.

![Figure 37: Screen image of ‘Graphs’ form page where the blood glucose history graph is visible](image)

i. Updating user settings

When a user selects to update user settings, the form with the settings that affect calculation of calories is presented. The user can update the height, weight and Weight objective (maintaining weight, losing weight or gaining weight).

6.2.2 SMSReminders application

This application contained the features that involved setting a reminder and placing that reminder into the database on the server. Once the user filled out the details of the reminder as shown in (1) and (2) below, the ‘Connect’ option in the menu allowed the user to place the reminder into the database on the server. This Application used the internet connection on the phone to place the reminder into the database. The server would return a message showing whether the reminder was successfully placed into the database or not. This message is displayed on the screen until the user clicks on ‘Done’ to clear the message.

![Figure 38: Screen images of the reminders application where a user can enter reminders into the MYSQL database](image)

6.2.3 SyncData application

This application contains the features that involved synchronizing the user’s details from the phone into the database on the server. The ‘Connect’ option in the menu allows the user to synchronize the details into the database on the server. This application uses the internet connection on the phone to place the data into the database. The server returns a message
showing whether the data was successfully placed into the database or not. If the data was successfully synchronized, it is then deleted from the phone in order for new data to be placed in the phone’s database.

6.3 The E-Health MYSQL Database

The image below shows the structure of the database that was created for this project. The tables with a red border were used by the mobile diabetes management system only, and the tables with a green border were used by all of the diabetes management systems.

Key:  * = Primary key  
** = Foreign key

The reasons why the mobile diabetes management system had different tables for Calories consumed and calories burnt are listed below.

- The mobile diabetes management system allowed users to enter new meals into the phone’s database and these meals were not accounted for in the Consumed table.
• The mobile diabetes management system allowed the user to enter the calories burnt by using a pedometer, and this value was stored in the phone’s database with the name of the exercise as ‘Pedometer’ and this was not accounted for in the Daily_Exercise table.
• The volunteers that participated in the prototype evaluations stated that they would like to store their insulin data on the mobile phone, but they did not share the same sentiment for the other E-health diabetes management systems.

6.4 The Server-side Application

The server-side application consisted of 2 java servlets that communicated with the mobile diabetes management system.

a. Setting reminders
The java servlet getConnection obtained user and reminder details from the SMSReminders application and stored the details into the database on the server. The servlet went through the process outlined below.

• Obtain all the necessary data from the phone and store it in memory
• Enter the user’s personal details into the server’s database if they do not already exist
• Enter the reminder into the database

The servlet sent a response to the SMSReminders application based on the success of inserting the data into the database

b. Synchronizing the user’s data into the server database
The java servlet getConnection2 obtained the user’s data from the SyncData midlet and stored the details into the database on the server. The servlet went through the process outlined below.

• Obtain all the necessary data from the phone and store it in memory
• Enter the user’s personal details into the server’s database if they do not already exist
• Enter all the user’s blood glucose values into the server database
• Enter all the user’s insulin values into the server database
• Enter all the user’s values for calories consumed into the server database
• Enter all the user’s values for calories burnt into the server database

The servlet sent a response to the SyncData application based on the success of inserting the data into the database

6.5 Final experiment

6.5.1 Introduction
The implementation stage focused on the implementation and assessment of the final prototype. This stage focused on continuous evaluation where the participants were given a 5 day period to utilize the system and include it in their daily life. 3 participants
volunteered to participate in the 5 day study. They were each provided with a Nokia N96 phone with the mobile diabetes management system installed. They were informed to integrate the system into their daily lives during these 5 days. They were also informed to continue with their usual daily methods of managing diabetes as well. After the 5 day period, an evaluation was performed using a questionnaire followed by a short interview.

6.5.2 Review of tasks performed by users

The different tasks that were performed by the users and their frequency are detailed below.

**Adding Calories Consumed**

User 1 made 7 meal item entries over a 2 day period. User 2 made 51 meal item entries over a 5 day period. User 3 made 35 meal item entries over a 6 day period.

**Adding a new meal item to the database** – User 3 entered 7 new meal items to the database. User 1 and User 2 did not enter any new meals.

**Adding calories burnt**

User 2 entered 5 exercise entries over a 6 day period. User 3 entered 7 exercise entries over a 6 day period. User 1 did not make any exercise entries. None of the users used the pedometers to calculate calories burnt.

**Adding Blood glucose readings**

User 1 entered 8 blood glucose readings over a 5 day period. User 2 entered 12 blood glucose readings over a 5 day period. User 3 did not enter any glucose readings because the user did not perform daily glucose readings.

**Adding Insulin readings**

User 1 entered 11 insulin readings over a 5 day period. User 2 entered 18 insulin readings over a 5 day period.
User 3 did not enter any insulin because the user did not use insulin.

**Setting reminders** – User 3 used the reminders feature twice. The other 2 users did not use the reminders feature.

### 6.5.3 User evaluation and findings

Below is a summary of the results of the questionnaire and the findings from the short interview sessions.

**Results from Questionnaire**

- All the users felt that the details stored on the system were not too personal.
- User 1 and User 2 both felt that recording their blood glucose readings was quick and efficient. This was not applicable to User 3.
- User 1 and User 2 both felt that recording their insulin intake was quick and efficient. This was not applicable to User 3.
- User 1 and User 2 both felt that the display of their blood glucose history was helpful. This was not applicable to User 3.
- User 1 and User 2 both felt that the display of their insulin history was helpful. This was not applicable to User 3.
- User 2 felt that the graph of their blood glucose history was helpful. User 1 did not find the graph helpful. This was not applicable to User 3.
- User 3 found the reminders feature easy to use.
- User 3 agreed that the reminders feature sent all reminders to the user at the correct time.
- All users found the Calorie Calculator easy to use.
- User 2 and User 3 agreed that entering food consumptions allowed them to monitor their diet. User 1 disagreed.
- User 2 and User 3 found that entering daily exercise activities encouraged them to be more active.
- All users found the results of the calorie calculator to be helpful.
- All users felt that the system was quick and it did not take a lot of their time.
- User 2 and User 3 agreed that they did not have to think of what to do when using the system. User 1 neither agreed nor disagreed.
- User 2 and User 3 agreed that they were not confused when using the system. User 1 neither agreed nor disagreed.
- User 1 and User 2 felt that the system gave accurate results. User 3 neither agreed nor disagreed.
- All users felt that the extra cost incurred in using the system was insignificant.
- User 2 and User 3 agreed that they would want to continue to use the system. User 1 neither agreed nor disagreed.

**Results from Interview sessions**

- User 1 found the viewing of the blood glucose history as the best feature of the system. The user felt that viewing a history that spans the last 2 days instead of the last 5 readings would be more beneficial. The user felt that the graph for viewing blood glucose history could be improved by adding multiple lines that compare
multiple days on the same graph. The user had a program installed on a computer that performed graph comparisons and stated that if the graph feature was updated, then she would definitely continue to use the system. The user also wanted a feature on adding meals whereby one can add 2 types of the same food item at the same time.

- User 2 found the graphs to be the best feature because they gave a simpler interface than the user’s blood glucose meter for viewing history. The user also found that the feedback from the calorie calculator gave a good idea of how many calories that the user had left for the day. The user found 2 drawbacks which were
  - The user couldn’t rectify mistakes once something had been added into the system
  - Some of the names of the food options were too long and could not be viewed properly on the phone

- User 3 found that the calorie calculator, graphs and reminders function were good features. However, the user also found a few drawbacks which were
  - The user couldn’t rectify mistakes once something had been added into the system
  - Some of the names of the food options were too long and could not be viewed properly on the phone
  - The user could not find nutritional information for some of the food that the user consumed
7. Conclusion and Future work

7.1 Conclusion

The first 2 chapters of this report show that there is a need for methods to assist in the management of diabetes and that a system that assists in the management of diabetes by using a mobile device such as a mobile phone can be well received by potential users and can also achieve positive results in terms of improving the management of diabetes. It was therefore necessary to produce a system aimed to assist in the method of record and data keeping, which is an essential part of a patient’s daily life. The proposed system had to be easily accessible and available at a low cost.

Based on the evaluation of the final system in the previous chapter, the system was successful in record and data keeping, and also helped the users in managing diabetes. The mobile diabetes system was available and easily accessible for diabetics with Nokia phones. However, the mobile diabetes management system needs further iterations in order to develop a perfect final system that can be released to the public. The work that needs to be performed is outlined in the next section.

7.2 Future work

7.2.1 Future work for this project

Due to time limitations, it was infeasible to make changes to the system and perform a second iteration. However, the results of the first iteration showed that with time permitting, a perfect system would have been well received by diabetics. A list of the changes and updates that would ensure the widespread success of this project if this system were updated and released to the public is outlined below.

- The drawbacks of the final prototype that were outlined by the users in the 5 day evaluation need to be addressed. A list of these drawbacks is outlined below.
  - The system needs a function that deletes the last record entered into the system in case the user makes a mistake whilst entering data
  - The names of some of the food options need to be shortened in order to be fully legible on the phones
  - A more comprehensive survey on the foods that people consume needs to be completed in order to have a wider variety of foods in the phone’s database. A survey would be better than just importing a large existing database because it would be easier and quicker to navigate to the required meal item on the phone.
  - The graphs need to be updated such that separate lines representing separate days appear on the same graph in order for users to be able to perform comparisons of different days. This may involve searching for a better graph API or creating one that can perform this action on the J2ME platform.
- The system needs to be adapted such that it can work on multiple phone models. Although the phone model that had the largest percentage of users from the initial
questionnaires was Nokia (section 3.3.3), the other phone models also had a very significant percentage of users.

- The users of the system should be able to export all their data that is synchronized to the E-Health server. A possible solution would be having a function on the Facebook application and the website that exports the data to a document that the user can print.
- Due to time limitations, it was difficult to find more diabetics to perform the 5 day iteration. However, the 3 users were able to successfully perform an evaluation that would lead to eliminating the current drawbacks and performing a second iteration with more users.

7.2.2 Future work for the support groups and patients of the diabetes clinic

Despite developing the mobile diabetes management system for the users that filled out the online version of the research questionnaire, it is also necessary to focus on the diabetics that were not selected as potential users in this project. In section 3.4, the reasons behind not selecting the support group members and the patients of the diabetes clinic are presented. These reasons along with potential solutions are outlined below.

1. Technology constraints of the users

As outlined in section 3.3.3, the support group members used their phones mainly for making phone calls, sending SMS and taking pictures. This needs to be taken into account when designing a system for these potential users. Some examples of potential ways for users to interact with an e-health system are listed below.

- Sending data using USSD connection
- Sending data using SMS and MMS
- Using an Interactive Voice Menu system

One of the issues discovered from the research outlined in section 3.3.3 was that the support group members wanted to spend as little money as possible when using a mobile diabetes management system. Another issue was that 77% of the support group members did not want to view online information. This means that the system does not have to have a main focus on allowing the diabetics to view their information online.

The first 2 options outlined above involve spending money in order to make a connection to the server. The third option can be implemented by using a Toll free number, but interacting with an interactive voice menu system takes considerably longer than sending data using a USSD connection or sending data using SMS or MMS. However, its advantage over the first 2 options is that it can be accessed by using any ordinary landline phone. A possible research area would be to see which one of these options would be the best option to use if all 3 options cannot be implemented at the same time.

2. Time constraints

As outlined in section 3.3, the support group members mostly had the most basic mobile phones and user-testing a prototype would possibly require training the users. However due to the Honours project time limitation this seemed an infeasible feat especially since this would have meant travelling to Mitchells Plain on a regular basis where a majority of
the support group members live or to wait for the support group meetings which take place once every 2 weeks. Due to this case, a possible solution would be to perform this research as a Masters project whereby the 3 possible technology solutions are developed and tested in order to see which one is best suited for the support group members and the patients of the diabetes clinic.

3. Health sciences ethical clearance issues

As outlined in section 3.4, it was necessary to initially obtain ethical clearance from the Health Science faculty in order to develop a system that is aimed at the patients of the diabetes clinic. If this project were to be continued, more time would have to be devoted to applying for the Health Sciences ethical clearance. The doctor that was interviewed was very happy to supervise a project that assisted diabetics in the management of diabetes. Moreover, he was willing to assist in the application process for ethical clearance since he knew exactly what the process entailed. The next step for developing a diabetes management system that focuses on the patients of the diabetes clinic would therefore be to meet with the doctor and discuss the objectives and anticipated outcome of the project.

4. Honours project requirements

It was necessary to satisfy some of the minimum requirements of an honours project. One of the requirements is that the E-Health project had to share a common boundary between the three sections of the project. Due to this fact, it would be better if the project that focused on the support group members and patients of the diabetes clinic was performed as a single person project or a 2 person project in order to allow for fewer requirements that affect its successful completion.

The 4 points above detail the 4 considerations that need to be taken into account when developing a system for the support group members and the patients of the diabetes clinic. Using the research that was completed and evaluated in section 3.3.3 and the research form the interview with the doctor, the features that can be implemented for these diabetics are

- Recording Blood Glucose levels
- Monitoring diet
- Monitoring Insulin intake
- Monitoring Physical exercise
- Reminders for diabetics to perform important tasks
  - E.g. Checking feet to ensure they are dry

A diagram outlining the proposed system is shown below.
The e-health server would allow physicians and authorised experts to continuously monitor the data from the diabetics and thereby allowing diabetics to get real-time feedback on their progress rather than waiting for 2 weeks (support group member meetings) or 3 months (diabetes clinic visitations).
References


Appendix A: Results from initial questionnaire for diabetics used in Analysis stage

Note: 1. The Graph/Pie chart of the online survey is followed by the Graph/Pie chart of the Support group survey in each question

2. The results exclude the responses to questions on social networking

2. What type of Diabetes do you have?
3. How often do you consult the doctor?

4.b. How often do you perform the following tasks? - Measure Blood Glucose Levels

4.b. How often do you perform the following tasks? - Measure Blood Pressure
4.b. How often do you perform the following tasks? - Measure Cholesterol

4.b. How often do you perform the following tasks? - Monitor Diet
4.b. How often do you perform the following tasks? - Monitor Insulin

4.b. How often do you perform the following tasks? - Monitor Physical Exercise

4.b. How often do you perform the following tasks? - Monitor Medication
4.b. How often do you perform the following tasks? - Monitor Weight

4.b. How often do you perform the following tasks? - Monitor Sleep
5. With whom do you discuss the state of your diabetes for the following tasks?

5.1 Blood Glucose levels

5.2 Blood Pressure
5.3 Cholesterol
5.6 Physical Exercise
### 5.7 Medication

<table>
<thead>
<tr>
<th>Source</th>
<th>Count</th>
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<td>Doctor</td>
<td>35</td>
</tr>
<tr>
<td>Family</td>
<td>28</td>
</tr>
<tr>
<td>Friends</td>
<td>21</td>
</tr>
<tr>
<td>Other Diabetics</td>
<td>14</td>
</tr>
<tr>
<td>Acquaintances</td>
<td>12</td>
</tr>
<tr>
<td>Strangers</td>
<td>7</td>
</tr>
<tr>
<td>No one</td>
<td>0</td>
</tr>
</tbody>
</table>

### 5.8 Weight

<table>
<thead>
<tr>
<th>Source</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor</td>
<td>15</td>
</tr>
<tr>
<td>Family</td>
<td>12</td>
</tr>
<tr>
<td>Friends</td>
<td>10</td>
</tr>
<tr>
<td>Other Diabetics</td>
<td>9</td>
</tr>
<tr>
<td>Acquaintances</td>
<td>6</td>
</tr>
<tr>
<td>Strangers</td>
<td>5</td>
</tr>
<tr>
<td>No one</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Do you belong to a Diabetes support group?
7.a If you had the opportunity, what information would you like to view about other diabetics? - Sugar Levels (viewing glucose levels)

7.a If you had the opportunity, what information would you like to view about other diabetics? - Physical Exercise (viewing exercise plan)

7.a If you had the opportunity, what information would you like to view about other diabetics? - Mood (viewing mood changes)
7.a If you had the opportunity, what information would you like to view about other diabetics? - Medication (viewing medication taken)

7.a If you had the opportunity, what information would you like to view about other diabetics? - Other Remedies

7.a If you had the opportunity, what information would you like to view about other diabetics? - Blood Pressure (viewing blood pressure measurements)

7.a If you had the opportunity, what information would you like to view about other diabetics? – Diet
7.b If you had the opportunity, what information would you want to share with other diabetics on your diabetes condition? - Sugar Levels (viewing glucose levels)

7.b If you had the opportunity, what information would you want to share with other diabetics on your diabetes condition? - Physical Exercise (viewing exercise plan)

7.b If you had the opportunity, what information would you want to share with other diabetics on your diabetes condition? - Mood (viewing mood changes)
7.b If you had the opportunity, what information would you want to share with other diabetics on your diabetes condition?

- Medication (viewing medication taken)

- Other Remedies

- Blood Pressure (viewing blood pressure measurements)

- Diet
8. Which of the following tasks are important for you in managing your diabetes? - Viewing Blood pressure history

8. Which of the following tasks are important for you in managing your diabetes? - Viewing past cholesterol levels
8. Which of the following tasks are important for you in managing your diabetes?
- Viewing trends in glucose levels

8. Which of the following tasks are important for you in managing your diabetes?
- Viewing diet plan history

8. Which of the following tasks are important for you in managing your diabetes?
- Viewing exercise plan history
8. Which of the following tasks are important for you in managing your diabetes? - Viewing medication intake history

8. Which of the following tasks are important for you in managing your diabetes? - Viewing weight history
8. Which of the following tasks are important for you in managing your diabetes?

- Viewing past sleep patterns

- Seeking advice online

- Notification service on when to take insulin, tablets etc.
8. Which of the following tasks are important for you in managing your diabetes? - Viewing past insulin intake

9. From where do you have access to the Internet?
10. If you had a website that you could access in order to assist in managing your diabetes, how would you want to view the online information?

11. Do you have a cellphone for personal use?
12. What type of phone do you use?

- Apple
- Blackberry
- HTC
- LG
- Motorola
- Nokia
- Samsung
- Sony Ericsson
- Other

13. How often do you use your cellphone for performing the following tasks? - Sending SMS

- Often
- Less Often
- Rarely
- Never
13. How often do you use your cellphone for performing the following tasks? - Surfing the Internet

13. How often do you use your cellphone for performing the following tasks? - Playing games

13. How often do you use your cellphone for performing the following tasks? - Listening to Music
13. How often do you use your cellphone for performing the following tasks? - Taking Pictures

13. How often do you use your cellphone for performing the following tasks? - Sending Emails

13. How often do you use your cellphone for performing the following tasks? - Using Social Networking Apps e.g. Facebook, Twitter, BBM chat etc.
13. How often do you use your cellphone for performing the following tasks? - Using GPS e.g. for Navigation

14. How much money do you spend on cellphone expenses each month?

15. How much extra would you be willing to spend on cellphone expenses each month to manage your diabetes?
16. How do you regard the internet connectivity on your cellphone?

17. Would you prefer to send and receive updates if you installed and used software on your cellphone by going to a specific location where you can connect to the database directly?

18. If you selected YES above, please select or state which locations that you would prefer to go to in order to send and receive updates? - Shopping Mall
18. If you selected YES above, please select or state which locations that you would prefer to go to in order to send and receive updates? – School

18. If you selected YES above, please select or state which locations that you would prefer to go to in order to send and receive updates? – Community Centre

19. Would you be interested in receiving locations of stores that have specials on necessities based on your cellphone GPS location in a shopping mall?
Appendix B: Questionnaire used in Evaluation of final experiment

**E-HEALTH**

**Evaluation of the final E-Health 5-day prototype pilot testing**

Please answer the following questions in relation to your experience in the event or activity you have just completed. These questions relate to the thoughts and feelings you may have experienced while taking part. There are no right or wrong answers. Think about how you felt during the event/activity, and then answer the questions using the rating scale below. For each question circle the number that best matches your experience.

<table>
<thead>
<tr>
<th>During the: ______________________ (website / cell / facebook E-Health)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 I felt my details stored on the system were not too personal</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>2 I felt that recording my glucose readings were quick and efficient</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>3 I felt that recording my insulin readings were quick and efficient</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>4 I felt that the display of my glucose history was very helpful</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>5 I felt that the graphs showing my past glucose levels were helpful</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6 I mostly used the SMS reminder feature</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7 I mostly used the Email reminder feature</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>8 I felt that the reminder feature was easy to use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>9 I felt that the reminder feature sent all reminders to me at the correct time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>10 I felt that the calorie calculator was easy to use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>11 Entering food consumptions allowed me to monitor my diet</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>12 Entering my daily exercises encouraged me to be more active</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>13 I found the results of the calorie calculator very helpful</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>14 I was able to easily contact the E-Health team for any queries or suggestions</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>15 I felt that the system assisted me with the management of diabetes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>16 I felt that using the system was quick and it did not take a lot of my time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neither Agree nor Disagree</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>----------</td>
<td>---------------------------</td>
<td>-------</td>
<td>----------------</td>
</tr>
<tr>
<td>17</td>
<td>I did not have to think of what to do when using the system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>I was not confused when using the system</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>I felt that the system gave accurate results</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>I felt that the extra cost incurred in using the system was insignificant</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21</td>
<td>I felt that I could easily access the system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>I would want to continue to use the system to manage diabetes and reason</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>