Abstract—Diabetes is a prevalent, deadly disease that is primarily managed through lifestyle choices. It is for this reason that doctors recommend patients record important factors that affects diabetes. This is however rarely done. Creating a system that will allow users to quickly and easily record this data on a mobile phone remains challenging and primarily a Human- Computer Interaction (HCI) problem. Our E-health application allows diabetes patients to record information about their disease. It also links with a social support system and a website. These systems together could help users better manage their disease. This paper presents the creation of a diabetes diary mobile application, usability evaluation and some insight into the utility the system offers. The results show that the system could be useful to diabetes patients.

Index Terms—Diabetes Management, Biological Sensor, Electronic Health-care, Human Computer Interaction, Usability and Utility testing.

I. INTRODUCTION

Diabetes mellitus, or just diabetes as it is now commonly known, is a chronic condition characterised by the body’s inability to control glucose levels in the blood [1, 2]. This occurs when either the pancreas does not produce enough insulin, the hormone regulating the amount of glucose in the blood, or when the body has problems using the insulin that the pancreas produces [2]. There are quite a large amount of different types of diabetes, Type 1 and Type 2 being most prevalent. Type 1 diabetes occurs when the pancreas produces too little insulin and usually requires the daily administration of insulin whereas Type 2 diabetes occurs when the body can’t effectively make use of the insulin produced. Approximately 90 percent of diabetes sufferers have Type 2 diabetes [2]. Type 2 diabetes is generally caused by lifestyle factors. Changes in diet and lack of physical activity in modern culture have been blamed for the rise in cases of diabetes [3]. Rural populations retaining traditional lifestyles show the lowest rate of diabetes and as such this further suggests that changes in lifestyles are the cause for the rise of diabetes. Diabetes is categorised by hypoglycaemic and hyperglycaemic events. These mean either too low or too high blood glucose levels respectively. Both hypoglycaemia and hyperglycaemia can lead to death. This means that patients must be able to monitor their insulin levels in order to correctly medicate themselves [1, 4].

In 2000 it was estimated that there were 171 million cases of diabetes worldwide and that this number would rise to 366 million by 2030 [5], diabetes is thus considered to be one of the most important global health issues [6]. Due to the pandemic nature of Diabetes, it can end up being a major economic burden to a country [7]. Hospital admission rates has also been found to be much higher for people living with diabetes, any programme that can thus lower these admission rates has the potential of considerable cost savings in any healthcare system [7, 8]. Diabetes management programmes has been proven to lower these admission rates and possibly result in an improvement in self management and glycaemic control [7, 9]. Self management of Type 1 diabetes has been shown to prevent long term complications [10] and poor glycaemic control can result in various other health complications [11].

This paper presents the development and evaluation of a mobile phone based diabetes diary that can potentially help diabetics better manage their disease. This diary forms part of a larger system known as the E-Health Diabetes Management Project [19]. Our approach is to involve diabetics/users in every step of the development process, which includes collecting system requirements, designing interfaces and user evaluation/testing. In Section II we present related work and Section III covers our system design and implementation. In Section IV we summarise user testing results. Section V presents our discussion and future research. Finally, we conclude the paper in Section VI.

II. BACKGROUND

In this section we first present factors that affect diabetes and then we review existing diabetes diary systems.

A. Factors that affect Diabetes

Blood glucose levels are affected by many different everyday events, the most commonly discussed of these are diet and exercise [3, 5, 12]. Other factors have also been identified, specifically mental factors [12].

Diet is probably the single most important factor in dealing with diabetes, it is however very complex and there has been a great deal of research done into what a diabetic should eat [3]. Physical activity is also known to help regulate blood glucose levels [3, 12, 13]. Experts recommend that patients suffering from diabetes get 30 minutes of moderately-intense exercise 5 times a week [13]. Exercise can however lower blood glucose levels too much and cause patients to become hypoglycaemic if they are not careful. It is therefore recommended that patients check their blood glucose level before exercise and have a small healthy snack if it is low [13].
Some factors are less understood as to how they affect diabetes and blood glucose levels. One of these is the affect alcohol has as it seems to promote a resistance to getting Type 2 diabetes in moderate drinkers [3, 14]. Alcohol consumption has also been seen to increase blood glucose levels and so it would appear to increase the risk of Type 2 diabetes [14, 15]. There is little understanding of why moderate alcohol use tends to decrease the risk of Type 2 diabetes when it appears to have a negative effect on controlling blood glucose levels. More research into its effects on blood glucose levels could therefore help our understanding of the issue [3].

Although this is an extensively researched field, there are many factors to consider regarding the food we eat and the complex human metabolic system. The result has been that we are far from understanding everything there is to know about the different factors involved when managing diabetes.

B. Diabetes Diary Systems

Diabetes, especially Type 2 diabetes, is a disease primarily treated through self-care practices. It has been said that 99% of the treatment regimen consists of self-care behaviours [16]. Considerable research has thus been done into the benefits of keeping what is called a diabetes diary. In this diary diabetics record information about factors that could affect the state of their diabetes. These include exercise, diet, blood glucose readings and medical treatments among others. These diaries are kept so that trends can be established between lifestyle factors and blood glucose levels. The analyses of these trends will hopefully help patients to better self-manage their diabetes. Recently there have been many attempts to create digital versions of these diaries. These digital systems benefit from being able to offer users feedback and share this information with medical practitioners [1, 17, 18]. Many different methods have been used to try and get the most effective system for managing this information.

In 2004 there was an attempt to use SMS (Short Messaging Service) to record patient information and then display this information to doctors through a web interface [18]. This system had some positive responses and seemed to improve patients’ ability to manage their disease as well as doctors ability to monitor patients. The system also highlighted some issues with using a mobile phone and SMS, for example, it was found to be hard to use by older participants and expensive by the younger participants. There was also a very small amount of data gathered by this system (only an average of 33 SMS’s per month from 23 patients). Although this system did not work too well it did show that it was a promising field and that with the potential of wireless blood glucose sensors not requiring manual input of readings a lot more could be done [18].

In 2007 another more modern approach was tried [1]. This system used mobile phones to collect information wirelessly from blood glucose measuring devices. This information was then sent to doctors over eHit’s Health Gateway using cellular networks (such as GSM, GPRS, and 3G). Health Gateway is a secure tool for transferring data to health care providers. This system allows health practitioners to receive real-time information from their patients. Patients were also able to receive a clear graphical follow-up on their mobile devices. This gave the patient real time feedback on his/her blood glucose behaviour. Other sensors could also be connected through the Health Gateway such as blood pressure monitors in order to give more detailed data to the health care personnel. Health care personnel also had the ability to provide feedback directly to patients through their mobile devices. There was a positive response from patients using the system as the feedback provided more motivation to manage their diabetes [1].

Diabetes is a growing epidemic worldwide. Fortunately the most common variety, Type 2, can be managed primarily through self-care practices. It will however require patients to be aware of the many factors influencing their disease and what impacts they have on them specifically. Mobile phones have been shown to have promise in providing patients with this information. There are however several issues with using them, specifically the difficulty in providing inputs (primarily the dietary inputs) and the issues with displaying a large amount of information.

If the mobile phone interface for a diabetes diary is improved so that it is not a burden on users to enter data and clear feedback is given a wealth of new information can be provided to medical practitioners and patients alike. Overall there appears to be considerable room for commercial applications and research in the field of mobile platforms for managing diabetes.

III. DESIGN AND IMPLEMENTATION

The E-Health Diabetes Management Project deals with creating a mobile system that could potentially allow patients to better manage their diabetes. This project builds on the fact that diabetes is a disease affecting a large group in the population and that it’s primarily managed with lifestyle choices. The system will therefore help users better understand and manage their own disease. The use of mobile phone technology should allow the system to be used by a large proportion of diabetes sufferers.

A. System Overview

Our system is divided into three distinct parts as illustrated in Figure 1. The first (on the left hand side) is a mobile phone application for recording data regarding a user’s diabetes including a Bluetooth link to a blood glucose meter. The second part is a mobile phone application displaying data recorded in the first system. The third is a social network implementation for viewing other user’s data that they choose to share and for communication between users. All communication between the different parts of the system occurs through a web server which stores and retrieves information in a central database. Users also have the option of using a web site interface for data entry and social networking functionality. The system also allows for integration with existing social networks and databases.

This paper presents and discusses the first part of the system, the mobile phone application for recording data regarding a user’s diabetes, known as the Mobile Diary Application. This part of the system is vital to the functioning of the complete system as it provides an
interface for the user to enter inputs which will be used by the rest of the system.

B. Design Principles

We used the principles of “User-centric” and “Iterative” design. This increases user satisfaction by allowing users to give input throughout the design and development process, not just evaluation of the final product.

C. Mobile Diary Application Specification Collection

Our first step was to perform a literature survey. Information obtained from the survey has been summarised in Section II. The literature survey provided details on what factors are important regarding diabetes management as well as what systems already exist. This information was then used to create a questionnaire in order to investigate several areas involved in designing the system:

- information on the feedback diabetics currently receive regarding their diabetes
- how useful they find this information
- what information users currently record about their disease
- what doctors recommend they record
- mobile phone access and usage
- internet access and usage

The questionnaire underwent several revisions and once done it was then distributed to people deemed to be the potential users of the system, diabetes patients. There were 60 questionnaires filled out by potential users and subsequently analysed. The analysis was done using SPSS, a statistical analysis program. The following is a few results observed from the questionnaire relevant to the Mobile Diary Application:

- A total of 43% of respondents own a mobile phone compared to 23% who have access to the internet. We thus have some justification for developing the application for the mobile phone. Notice that the number of mobile phone users is significantly lower than is said to be the average in South Africa. This could be due to the fact that the participants in the survey were generally older (54% being 51 or older). The participants younger than 51 had a mobile phone usage of 85%.
- 38% of mobile phone users had a Nokia device. Samsung was the second most used brand at 23%. This means that Nokia’s Symbian platform would be a good starting place to develop on.
- 82% do not record anything about their disease, even though 75% are instructed to record at least one type of event. Figure 2 highlights the events/factors that should be recorded due to the high amount of doctor instructions to do so. The figure also pinpoints the significant difference between what was instructed to be recorded and what respondents actually record. Respondents seemed to record little about a factor even when they themselves find it useful, as is the case with medication and sugar levels. The biggest reason given for this discrepancy was noted to be too much time taken to record and diminished motivation over time, especially for hand written notes. The Diabetes Diary System would therefore be useful if it made it possible to record these things in a quick painless manner.
- Although there was no explicit question on the questionnaire asking whether doctors required patients to record their weight, input from the questionnaire and further analysis of the literature surrounding what affects blood glucose levels showed that this should be included.
- Reviews of other systems pointed out that a feature to record a miscellaneous event/factor was used in most existing systems to incorporate factors other than the ones presented. It was therefore decided to include a feature to allow an “other” factor to be recorded.
D. System Implementation

The system was developed for Nokia’s Symbian using J2ME. The following is a list of the key features that the diabetes diary application implemented:

- A secure login function that will allow entry of information only with the correct username and password.
- The ability to enter information about any factor or event that affects the user’s health and diabetes. The system refers these factors as events, e.g. diet event.
- The ability to retrieve readings from a Bluetooth enabled blood glucose meter.
- Conversion of this information to XML and transmitting this to the web server using the user’s login details.

These features are intended to provide a user with a complete diabetes diary application which will eventually replace their manually written out diary. Figure 3 shows the first iteration of the diary. Users would have to press the “options” key and would then be presented with a list of events. After user testing this was changed as user feedback indicated that this method is too text heavy and has too much menu scrolling. Figure 4 shows the revised menu. “Enter new event” was given as an option and users were then taken to a screen where they would select their event. This new list with pictures helped maintain consistency with the rest of the system (website and social support application) by using the same images.

IV. System Evaluation

There are two important areas that must be evaluated in order to declare that the system has been successful. The first is that the system is usable; the second is that the system provides utility.

A. System Usability Testing

For a system to be usable it should allow users to be able to achieve their desired outcome from all of the systems features. This means that they should be able to use each feature without producing any errors. Where errors mean not only explicit errors produced by the system but also results that differ from what the user intended but might not have noticed. This is important for a diabetes diary application because if a user cannot use a feature, they will not be able to record accurate information.

The first few iterations of the system were tested as follows. Users were explained the purpose of the system and then asked to complete a series of tasks, such as log in, record event, etc. While the users completed the tasks their actions were closely observed. This was done as a passive observer, meaning that no hints or advice were provided to them. There were however situations during the test where help was required. These were when a user was stuck and
was starting to get frustrated with themselves and the system. In these cases if a user had struggled for too long they were helped or told to move on to the next task.

There were a number of mistakes made during the tests such as time format and features that the users did not like; menu’s that were too text heavy for example. Other lessons learned from testing were that the testing environment played an important role as it could put the users under stress to perform well. Psychological issues also occurred sometimes as users felt like they were the ones being tested and not the system. Therefore testing time and environment are both critical. After several system revisions, we were satisfied with user testing feedback and were ready to move on to our next step, extended user testing.

B. Extended User Testing

After initial user testing was completed, five users were given the system to use in their daily routine for a period of five days. User ages ranged between 21 and 50. Users were given Nokia mobile phones preloaded with the Mobile Diary Application. Events entered during this period were stored in the database. At the end of five day testing period, semi-structured interviews were also conducted with the users to gain insight into their experience with the system. Table 1 shows a summary of the data collected over the five days.

Table 1. Extended User Testing Data

<table>
<thead>
<tr>
<th>Event type</th>
<th>Average time to complete (in seconds)</th>
<th>Average amount of entries per user</th>
<th>Average amount of entries per day per user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal</td>
<td>73.2</td>
<td>11</td>
<td>2.2</td>
</tr>
<tr>
<td>Exercise</td>
<td>35.2</td>
<td>4.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Medication</td>
<td>55.8</td>
<td>8.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Mood</td>
<td>40.5</td>
<td>6</td>
<td>1.2</td>
</tr>
<tr>
<td>Blood glucose</td>
<td>*</td>
<td>12</td>
<td>2.4</td>
</tr>
<tr>
<td>Weight</td>
<td>38.5</td>
<td>2.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Other</td>
<td>81</td>
<td>0.7</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The first column of Table 1 shows the event type, followed by the average time it takes a user to complete entering one event of that particular event, the average amount of entries per user for the five day period, and lastly, the average amount of entries per user per day. The '*' for blood glucose indicates that users were using Bluetooth to get readings from their meter and as such there was no time associated with inserting the event.

An observation that was made is that the amount of text entered for an event is directly proportional to the amount of time it takes to create that event. This means that the choice of using preselected lists for almost any kind of selection vastly decreased the time taken to enter events. Blood glucose, meal and medication events are the most often created. This is a great result because the questionnaire indicated that these events were requested the most to be recorded by doctors. They were requested 75%, 59% and 59% respectively. The most frequently used events could possibly be moved further up the list in further iterations of the system. The weight event could potentially be dropped and form part of the “other” event since it is entered so little. This could be due to the limited testing time of the system. One of the users explained during the semi-structured interviews that the mere fact of recording certain factors, exercise and blood glucose levels for example, impacted their behaviour and helped them have a “healthier” week. This shows that the system could potentially be of quite significant value to users.

It took users an average of 363.6 seconds per day (6:03) to record all of their events. This is not a very long time, especially considering it is to manage a potentially fatal disease. The system is therefore a viable option to record diabetes information. It can also be speculated that as users grow more accustomed to the application and mobile phone, their average time will possibly decrease. Further testing could be conducted to substantiate this.

V. DISCUSSION AND FUTURE RESEARCH

The system had improved upon usability between iterations, it had however not reached the pinnacle of usability. A good place to start with future research could therefore be in creating an even more usable system.

The utility, benefit to the user, of the system could not be tested directly. The reason for this was the time constraints that applied during this project. Simply allowing users to use the system for longer periods would provide more compelling results. It would also be beneficial to track users actual health benefits from using a system similar to this by involving the user’s doctors. This would be a more intrusive experiment and would require user’s consent but could yield some interesting results for not only computer scientists but also medical sciences.

The system or a similar one could also be used for medical research. Vast amounts of data can be gathered to help medical professionals better understand the workings of diabetes and the factors that affect it. Future continuous glucose monitors or even those available currently could potentially make this information even more meaningful.

VI. CONCLUSION

This paper presented the development of a user-centred Mobile Diary Application for diabetes management. The research produced interesting results. The first result that was obtained is that it’s possible to design and implement a mobile application to be used as a diabetes diary. This was shown through the usability testing that was done. This testing showed that although the system could still be
improved upon, it did allow users to record all the information needed to better manage their diabetes.

The second and arguably more interesting result is that a mobile diabetes diary system can potentially provide utility to its users. This was shown in the testing and semi structured interviews; the most notable example of this being the users stating that simply using the system to record information had helped them have a healthier week.

The system as a whole generally received positive feedback from diabetes patients. Though there are a lot of room for further research and improvements as indicated in Section V. We plan to fine-tune the system and deploy it on a larger scale such as in a Diabetics Support Group.

REFERENCES


