Design and Evaluation of a Mobile Health Application for Adult Patients with Type 1 Diabetes Mellitus

by

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A thesis submitted in conformity with the requirements for the degree of Master of Applied Science
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Abstract

In this study, a user-centred design approach was used to develop a mobile health application designed to support adult T1DM patients with their self-management routine. In the requirements gathering phase, an observational study of a diabetes clinic and patient interviews were conducted. An analysis of the data collected from this phase helped identify the functional design requirements used to guide the design. Using a rapid prototyping approach, data visualizations, game-based elements, carb-counting and social networking features were explored. The final prototype developed in this research was evaluated for its ease of use and perceived usefulness. The design was found to be generally easy to use. With respect to data visualizations, participants preferred the scatter plot view of their blood glucose readings to a bar chart. In addition, it was found that all participants wanted a way to track their HbA1c on a regular basis.
Acknowledgement

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Big thanks to my lab mates. I am lucky to have worked alongside your brilliant minds. Thank you for sharing your experiences, giving great advice, and for providing the type of support only lab mates can provide.

To my family, thank you for always encouraging me to do what I believe in. I would be lost without you. And last but certainly not least, thank you Raphael for your advice, patience, and for always believing in me.
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1.0 Introduction

There were approximately 3 million Americans living with Type 1 Diabetes Mellitus (T1DM) in 2011 of which an estimated 85% were adults (JDRF, 2011). The cause of the disease is unknown as of this writing and a cure has yet to be discovered. However, with the discovery of insulin (extraction and purification) in 1920 by Dr. Frederick Banting and Charles Best, T1DM has become a manageable chronic disease. Patients worked with their diabetes care team to develop a self-management plan that works best for their individual needs. A plan typically involved performing regular blood glucose (BG) measurements and taking the appropriate amount of insulin either via multiple daily injections or a pump. As a result, paper logbooks used to track BG, insulin, and carbohydrate intake became a standard tool for T1DM patients to use on a daily basis.

With the increasing popularity of mobile devices, it was a natural transition to develop mobile electronic versions of these logbooks. Unfortunately, the majority of these applications did not offer anything more than simple logging features and did not utilize the powerful computing power and unique interface that mobile devices provide. To address this issue, the Centre for Global eHealth Innovation developed a mobile application named bant, targeted to T1DM adolescents that leveraged game-based designs, unique visualizations, and rewards (Cafazzo et al, 2012). The success of this application lead to further research in the mobile design space for various diabetes demographics, which resulted in the name bant becoming an umbrella brand for all research related to diabetes self-management mobile application development. The brand includes: Type 1 adolescents, Type 1 adults, Type 2, and patients with an artificial pancreas.

This research was conducted in collaboration with the Centre for Global eHealth Innovation. Therefore, the purpose of this research is to design and develop a mobile application (bant for adults) that can help adult T1DM patients better manage their disease. A user-centred design process was followed, with an emphasis on features
involving data visualization, social communities, and game-based design (gamification). The following questions motivated the research:

1. What is an effective and meaningful way to represent diabetes related information using a mobile interface?
2. What aspects of an online community are useful/helpful in supporting patients with their self-management?
3. What motivates users to remain engaged with mobile apps? And what motivates patients to maintain good health?

In summary, this design-oriented thesis used a user-centred design approach to design an application that would help people living with T1DM self-manage their disease.
2.0 Literature Review

The purpose of this literature review was to investigate existing diabetes self-management applications and explore research performed on various mobile platform design elements such as food photography, gamification (ie. Game based designs), and data visualizations. The majority of the studies focused on designing and developing apps for adolescents because T1DM is predominantly diagnosed at a young age. The overarching goal across studies was to design an application that T1DM patients would find useful in their day-to-day management.

Food photography was investigated for two reasons. Firstly, diet has always played an important role in the self-management of T1DM. Several studies have demonstrated that diabetes patients who adhere to dietary requirements are also likely to have better glycemic control (Patton et al, 2007) (Delhantry, 1993). However, it has also been shown that adolescents with T1DM lack accuracy when estimating carbohydrate counts of commonly consumed food (Bishop et al, 2009). This occurs despite being trained by a diabetes care team (ie. nutritionist, diabetes educator, nurse, etc.) on nutrition and carbohydrate counting, which demonstrates a need for an improved method for diet tracking and/or education amongst the T1DM population. Secondly, cameras have become a standard feature on present day mobile devices, making food photography an accessible tool to use when keeping a photo journal. Section 2.1 below reviews the research literature on the use of food photography in diabetes self-management.

Several mobile tools have been developed to aid in the self-management of diabetes, including applications that incorporate some aspect of carbohydrate counting (Rossi et al, 2009) (Charpentier et al, 2011). However, one of the challenges with these tools is that it is difficult to keep patients engaged in continual use. A potential solution to this problem is to introduce game-like aspects (ie. gamification) into the mobile application, which has been an increasing trend over the last several years in ehealth (Howell, 2005). Therefore, another subgoal of this literature review was to examine how gamification can be used in the design of a mobile diabetes self-management tool to engage patients in regular use.
Finally, T1DM patients using electronic tools to record large amounts of data related to their self-management such as blood glucose, insulin, activity, and carbohydrate intake, need a way to review this data in a meaningful way. In this review, various data visualization methods and their impact on health indicators such as blood glucose were explored.

2.1 Food Photography and Diabetes Logs

Many adults prefer to communicate and think visually (Ouellette, 2000), meaning food photography may be a useful tool for T1DM patients to contemplate their food intake; an element of their care they are required to constantly consider. In an exploratory study, a sample of T1DM adolescents was provided with cameras in order to capture photos of what healthy means to them (Hanna et al, 1995). By examining the collection of photos, four themes were discovered: nutritious food, exercise, studying and sleeping. There are two important findings from this study that are relevant to this review. The first; photography appears to be an effective means for T1DM patients to communicate, and second; they see nutritious foods as a benefit to their health. In addition to this, a study that examined the role of pictures in improving health communication found that photos could help the user with comprehension (Houts et al, 2006). In particular, when a picture demonstrates a relationship among facts a patient already knows, it can facilitate a deeper understanding of the idea being represented. These studies motivate the use of food photography to improve the self-management of diabetes.

Taking pictures has been shown to have a positive effect on diabetes self-management. For example, there are two key studies that have investigated the impact digital photography has on self-management behaviours when used in conjunction with a conventional diabetes log. In one study, a photographic food diary was compared to a traditional written log through a pilot study that ran for three months with T2DM adult patients (Yusuf, 2007). The results were positive; HbA1c dropped in both groups. However it’s important to note that the group assigned to complete the photographic log
had a larger decrease in HbA1c and also experienced weight loss (the group was overweight). In a qualitative study by Smith et al (2006), a visualization system that linked digital photographs with blood glucose readings was developed and tested with six T1DM undergraduate students. In interviews with the users, diet/nutrition was found to be the most common theme when reviewing and discussing the photographs. Also, from a design perspective, the usability issues that were identified mostly related to the lack of an integrated device; participants had to carry both a glucometer and digital camera. Related to this was the issue of synchronizing the data on the devices. These problems can be addressed by implementing a solution that utilizes a mobile phone that has the capability to take photos and record other relevant data. In the following section, the state of mobile diabetes self-management applications in the diabetes research community is assessed.

2.2 Diabetes Self-Management Applications

With the emergence of various mobile technology platforms and the need to make diabetes logs more accessible, several forms of diabetes self-management applications have been developed. These range from a straight translation of conventional paper logs into an electronic form, to unique designs that strive to achieve positive health behaviour changes in patients (Cafazzo et al, 2012). In fact, in a review of various T1DM and T2DM telemedicine solutions, three main types were identified: phone consultations (ie. SMS support), medical data transfer/sharing systems, and general mobile assistants (Franc et al, 2011). The review concluded that successful T1DM systems incorporate an easy to use system that facilitates easy interaction with the care team, and also provides timely feedback of BG readings and questions.

In one study, a mobile food record for assessing dietary intake was evaluated with adults and adolescents (Daugherty et al, 2012). The goal was to gage user capabilities and perceptions towards the food record. Not surprisingly, adolescents were more eager than adults to use the mobile phone to take pictures, and both groups noted that the software was easy to use. However, adolescents were less likely than adults to agree that taking
pictures before and after meals would be easy. This may have been due to a requirement of the study for a fiducial marker to be included in each picture, which meant that each user had to carry an item in addition to the mobile phone. The usability concern of carrying multiple devices is a common theme among diabetes patients because they already need to carry several items on a daily basis (ie. glucometer, BG test strips, medication, log book etc) (Smith et al, 2006). Therefore, it is important, if a photography log feature is included in the application, that it be well integrated into the design and does not require the support of any external devices.

In a study by Rollo et al (2011) of Nutricam, a mobile phone method for recording dietary intake, another usability concern was brought forward. This was the inability to go back in time to capture a photo of what was consumed earlier in the day. As a result, users underreported their dietary intake using Nutricam versus the paper log (users were asked to use both over a 3 day period). This highlights a design need to ensure that users have the flexibility, with the photography feature, to go back and add in notes about what was consumed earlier in the day. The details of this and others relevant studies have been summarized in Table 1 below. All involve some form of mobile self-management technology; the first two listed focus on carb/insulin ratios, the following five focus on food photography, and the last study investigates the impact that gamification and food photography have on health behaviours.
<table>
<thead>
<tr>
<th>Researchers</th>
<th>Intervention</th>
<th>Description</th>
<th>Key Findings</th>
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| Rossi (2009) | Diabetes Interactive Diary (DID) | • Several features included with the ability to count carbs, calculate insulin dose and also guide diet through a food exchange  
• 2 pilot studies were conducted; one to investigate feasibility & acceptability, the second to investigate effectiveness on metabolic control  
• 50 diabetes patients for pilot 1 and 41 for pilot 2 | • When features were ranked by usefulness, carb counting, insulin bolus calc, and food diary were the top 3 in order  
• 63% of patient stated that using the DID changed their eating habits due to greater knowledge of food, BG, and insulin |
| Charpentier (2011) | Diabeo | • smartphone software with bolus calculator taking into count carb intake  
• 6 month parallel-group study with 180 adult T1DM patients  
• 3 groups: quarterly visits, Diabeo + quarterly visits, Diabeo + 2 week teleconsultation | • Showed a significant improvement in HbA1c with Diabeo use  
• Main advantage of systems was the correct interpretation of data and accurate insulin dose recommendation |
| Arsand (2008) | The Food Photo Moblog | • Smartphone & PC interfaces  
• Used by patients in collaboration with care team  
• Photos blogging of meals which can be annotated with carb estimate  
• Feedback on ‘moblog’ can be provided by anyone granted access permissions  
• Type 1 & 2 diabetes participants, 18-65 years old | • Participants stated that the act of taking photos of their food intake was inherently motivating  
• The mobile capture approach was noted as not being suitable for routine use but rather for occasional recording of unfamiliar meals  
• Concluded that further development of mobile dietary and nutritional support for diabetes patients is justified |
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<th>Researchers</th>
<th>Intervention</th>
<th>Description</th>
<th>Key Findings</th>
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<tr>
<td>Daugherty (2012)</td>
<td>Mobile Telephone Food Record</td>
<td>• Images of food are captured before and after eating</td>
<td>• Adolescents were quicker to learn how to capture appropriate pictures but were less likely to agree that capturing pictures before and after eating were easy</td>
</tr>
<tr>
<td>Rollo (2011)</td>
<td>Nutricam</td>
<td>• Captures a food photograph prior to consumption</td>
<td>• Intake was significantly underreported using nutricam over the written log book</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Stores a voice recoding describing the contents</td>
<td>• The software was well received with users favouring the Nutricam method over pen and paper</td>
</tr>
<tr>
<td>Fonda (2010)</td>
<td>Personal Health Application (PHA)</td>
<td>• Photography of food is one of many features provided</td>
<td>• Feedback so far indicate that users can be overwhelmed by too much choice in the PHA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Photos are not analyzed for nutrition</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• User can capture food data from an external source</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Not tested but going through an iterative design process</td>
<td></td>
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<tr>
<td>Froisland (2012)</td>
<td>Diamob</td>
<td>• Target communication between patient and care team</td>
<td>• Appreciated the picture based tool over a paper and SMS based solutions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Photographic documentation of foods consumed</td>
<td>• Reported that reviewing pictures of their own food gave a visual understanding of their own unhealthy diet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Physical activity recorded by selecting the most relevant pictogram</td>
<td>• Connecting to the mobile browser was cumbersome</td>
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<tr>
<td></td>
<td></td>
<td>• Integrated onto a mobile phone that also communicated via Bluetooth with the glucometer</td>
<td>• Statistically no significant change in HbA1c</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Target user group was T1DM patients</td>
<td>• SUS score of 73</td>
</tr>
<tr>
<td>Researchers</td>
<td>Intervention</td>
<td>Description</td>
<td>Key Findings</td>
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| Pollak (2010) | Time to eat! | • Mobile phone based virtual-pet game designed for adolescents to improve eating behaviour  
• Incorporated food photography, gamification, and social community in the design  
• iPhones given to 53 grade 7 & 8 students for one month | • Kids who played ‘Time to eat!’ chose a healthier breakfast more often than those who didn’t play (52% vs 20%) |

Table 1: Summary of key findings of research conducted on mobile phone dietary and food photography applications

Overall, mobile self-management applications that incorporated a photography feature were well received by users. Adolescents preferred a picture diary over paper based systems, which highlighted the importance of dietary intake in their self-management routine (Frøisland et al, 2012). This supports the need for further research to develop a well designed and well integrated food photography feature. However, adults were less likely to take photos of their food than adolescents. In the following section, the implementation of gamification in design and how this may encourage patients to regularly use a mobile app to support their self-management is examined.

2.3 Gamification

Gamification is an informal term used to describe how game-design features are applied in non-gaming contexts (Deterding, 2011). In the context of T1DM self-management in adolescents, gamified design has been used to encourage patients to adhere to their care regime. For example, Cafazzo et al. (2012) awarded users points for loading blood glucose (BG) values from a Bluetooth connected glucometer. Once a sufficient number of points were accumulated, the user was able to redeem the points for an iTunes reward. The results were positive, in that the number of BG readings significantly increased in comparison to the period prior to the pilot; however, HbA1c values did not improve.
Thus there is a need to engage patients in positive health behaviours, in addition to frequent BG monitoring.

In a usability study on food registration design concepts outlined in Section 2.2 (Arsand et al, 2008) it was found that the act of recording eating habits was inherently rewarding, but the authors noted that in order to sustain this action, external forms of rewards at the point of data entry may be required. This again presents an opportunity to combine gamified design with features that promote healthy behaviours, in order to improve self-management adherence and potentially healthy outcomes as well.

With the exception of ‘Time to eat!’ (Pollak et al, 2010), a virtual pet game designed to encourage healthy eating behaviours in adolescents, there have not been many mobile apps that have integrated the use of game-like design with food photography. However, there has been one study of an integrated gaming paradigm for sustainable diabetes management that focused on exercise and self reported food intake (Kahol, 2011). In this design, patients used an iPhone and wore sensors that collected movement data, which then allowed them to progress through different stages of a virtual game. This is a relatively new form of game design in a mobile self-management application and it has yet to be validated for usability, compliance and effectiveness.

What guidelines currently exist for gamification in health design, and how have fields other than healthcare implemented gamified design? In a paper that discussed games for health, a couple of T1DM related educational video games were analyzed to identify concepts that health games should aim to achieve (Howell, 2005). These have been listed below:

- Enhance the players’ self-awareness through the use of avatars
- Improve self efficacy
- Increase knowledge
- Include communication and social support
Although these are not explicit design guidelines, they do outline key factors to consider when designing gamified applications. In this case, game-based design features were used in the hope of increasing knowledge and improving learning.

The prevalence of E-Learning has been increasing with the rise of distance and online courses being offered. Though there has been a lack of empirical evidence to support whether the application of gamification in learning has been successful (Freitas, 2011), there have been several researchers who have delved into what makes games appealing and how gamification can be applied to learning. In particular, aspects of game-design elements and how they can be used to further engage students have been evaluated. There has been a book chapter (Freitas, 2011) and a paper (Muntean, 2011) that have attempted to do this, and several common themes have emerged. For example, both papers predict the adoption of avatar-driven approaches for distributed learning. Muntean emphasizes a need for rewards, leaderboards, and a clear means to portray progression. This, in essence, is a means to improve self-efficacy through rewards, and communication through sharing leaderboards for competition and/or social support. However, what is lacking in the literature is a clear mapping between appropriate game-design features and corresponding design goals. Thus in designing mobile health applications, research is needed to determine what kinds of motivational tools (e.g., badges, levels, points, rewards, etc) should be used to achieve the desired behaviors in various contexts.

2.4 Data Visualization

Since T1DM is a life long disease, data collected for an individual patient can be massive and difficult to interpret (Bellazzi, 2009). However, it is important for patients and their health care providers to regularly survey this data to maintain a good understanding of how the disease is being managed. The paper logbook, although helpful with tracking data, does not provide the patient with useful information at a glance when filled out. Electronic tools can provide a means for turning this data into rich visualizations. For example, insulin pumps collect data over extended periods of time on behalf of a patient.
When uploaded into a computer, a series of reports are displayed to the patient; these reports tend to be complex and difficult to understand. Kerr (2010) argues that regardless of whether a patient uses a pump or multiple daily injections (MDI), patients need to be adept at handling numbers in order for them to be able to properly understand the nuances of glucose monitoring.

Several researchers have attempted to address this issue. Frost and Smith (2003) conducted a preliminary study looking at how associating photographs to visualizations of blood glucose over time would impact patients and their understanding. The blood glucose visualization was essentially a chart with each column representing a day and each row representing an hour; coloured boxes were used to indicate whether a reading was low, high, or acceptable. Upon review with diabetics and medical professionals, it was confirmed that the visualization allowed them to easily inspect blood sugar trends. However, this type of visualization may be too detailed to view easily on a mobile device.

Harris et al (2010) extended a web-based system to a mobile platform and tested tabular and graphical feedback of blood glucose meter uploads for desirability. Patients found value in the feedback and preferred the graphs to tables; however one participant felt the graphs were too small to read on the phone. Skrøvseth et al (2012) conducted a study with 30 participants by providing mobile phones with the Few Touch Application loaded. Participants were encouraged to record BG, insulin, dietary info, activity, and T1DM symptoms. It was found that patients required training to understand the visual feedback. It was recommended that, when trends would be presented to the user, they should only be shown in real time with properties that are currently relevant. Overall, these studies have found that providing visualizations of collected data to patients is valuable. However, an appropriate means to do this on a mobile device that is easy to understand has not yet been developed.
2.5 Summary

T1DM patients are encouraged to collect a significant amount of data from the day they are diagnosed. This information has typically been recorded in a paper logbook or kept stored in a glucose meter only to be reviewed when prompted either by a loved one or a member of their care team. With the increasing popularity of mobile devices, it seemed the next logical step would be to develop mobile applications that can help support patients in their data collecting endeavours and also utilize computing technology to provide useful feedback.

In this chapter, several mobile applications were reviewed with a focus on exploring specific design features. There has been some benefit demonstrated in studies that have attempted to include a form of photographic log in mobile self-management tools. However, an adult user may need more encouragement to take photos. Gamification may be the solution to continued user engagement but there have been few, if any, empirical studies on what game designs work best to meet certain design goals. Finally, visualizing the collected data was found to be useful, but there is a need to create designs that are easy to understand and are appropriate for a mobile interface.
3.0 Requirements Gathering and Analysis

Qualitative research was carried out in order to develop a deeper understanding of adult T1DM patients. The main goal was to understand their culture and to generate a theory about what their needs would be for a mobile self-management support application. Since the focus of this stage was to understand the T1DM population, an ethnographic research approach was taken for the requirements analysis. Jackson (2003) summarized the ethnographic research activities into three phases: pre-field, fieldwork, and post-field. In this thesis, ethnographic methods complemented UCD with respect to understanding the user, their tasks, and their environment. Figure 1 below depicts the relationship between ethnography and UCD.

![Figure 1: Ethnography and User Centered Design](image)

The two main components of fieldwork utilized in this research were: observation and semi-structured interviews. Brainstorming was also included in this phase as the results from this activity contributed to defining themes and design ideas used to guide the development of questions for the semi-structured interviews. Figure 2 below depicts the overall approach taken to solve the design problem.
The following sections describe the methodology and subsequent analysis in detail.

### 3.1 Observation

#### 3.1.1 Clinic Shadowing

Due to the work being conducted in parallel on an adolescent version of a mobile self-management application (bant for adolescents), the opportunity to shadow at the Diabetes Clinic in the Hospital for Sick Children (REB 1000017742) was presented. Although the patient age range (infant to 18) at this clinic does not match that of the target population for this research, observing the interaction between patient and physician at a routine visit still proved to be valuable in understanding the disease and the impact it has on an individual.

A total of 5 patient visits were observed. Prior to observing any appointments, patients and their parents/guardian were first asked for permission by their healthcare provider. Although a visit to the clinic may take approximately 2-3 hours total for the patient, direct interaction with the clinician lasts approximately 10-30 minutes depending on the case. Visits often take longer than anticipated due to scheduling of blood work, physicals, and other clinic related activities such as pump information sessions etc. These visits are routinely scheduled every three months.
Patients were asked to provide their blood glucose (BG) monitor or pump, from which all of their readings taken over the last 30 days were imported into the clinic computer and printed out for review. The only data a typical BG monitor provides is the BG measurement, date, and time of day the reading was taken. Pumps will also include insulin bolus/basal rates. For additional information, the clinician would often request to review a handwritten logbook. These logs would typically include additional information such as carbohydrate counts, level of activity, and the amount of insulin taken. This data was then used to cross reference readings in order to better understand out of range BG measurements and identify the root cause of trends. The physician would then work with the patient to recommend appropriate changes to help regulate BG levels. Changes would either be made to insulin basal or bolus dosage, diet, and activity levels. For raw notes collected from the observations, please refer to Appendix A.

To elaborate further on logbooks, the majority of glucometer or pump providers have created their own versions. Although the size and format of these logbooks vary slightly from one to the next, the layout of data is fairly consistent. It was important to take note of this, as the majority of T1DM patients either use a paper log on a regular basis or have been encouraged to use a log book at some point from someone within their circle of care. Figure 3 below depicts what the standard logbook layout looks like. Columns are organized by context (blue box); users are encouraged to log their blood glucose according to the context of each reading. These are typically defined as meals: breakfast, snack, lunch, and dinner. Each row (pink box) represents a day of the week. The format for recording data (green box) varies but users are encouraged to record their blood glucose before and after a meal, as well as track the number of carbs consumed and units of insulin taken.
Overall, the main point of discussion for all appointments was blood glucose and how best to regulate and keep it within target range. In addition, a lot of emphasis was placed on the HbA1C measurement, a measure of average plasma blood glucose over extended periods of time. Figure 4 below summarizes the common factors discussed that contribute to fluctuations in blood glucose.
3.1.2 Carbohydrate Counting Class

In order to develop a deeper understanding of what self-management involves for adult T1DM patients, I attended a carbohydrate counting seminar offered by the Toronto General Hospital Diabetes Clinic. The seminar is offered to anyone interested and is recommended to newly diagnosed patients and/or patients considering switching from multiple daily injections (MDI) to an insulin pump. The session is mandatory for pump users because pumps require a precise carbohydrate count in order to calculate the correct bolus. A qualified diabetes dietician facilitates the interactive one-hour session with the use of slides and various measurement tools.

The seminar began with a round of introductions, followed by a reflection activity that involved listing everything that was consumed the day before. This was an effective method to raise immediate awareness around diet and food consumption. This activity was followed by a series of slides outlining the importance of carbohydrate counting and what it involves. More specifically, there were discussions around how to read labels properly, what a portion size looks like, and a review on how to calculate the insulin to carb ratio. There were two additional activities built into the session:

1. Self-Assessment: A quiz that tests how knowledgeable the patient is on carb counting tools, sources of carbohydrates, and glycemic index.
2. Bolus Insulin Worksheet: This form consists of three scenarios where the patient was asked to determine how much insulin to take based on the information provided.

To conclude the seminar, a sample meal was provided on a tray and participants were encouraged to work together to estimate the total carbohydrate count using the scales and various tools (ie. books and calculators) provided. Each food item was provided on a ‘Carb Counting Worksheet’ and the goal was to determine the portion size and grams of carbs for each portion.
Observing this session confirmed many of the findings from shadowing at the HSC diabetes clinic and highlighted some of the challenges that patients face when estimating their carbohydrate intake. Dining out and trying unfamiliar foods were identified as the most difficult situations for everyone who participated in the session. Also, two additional factors that impact blood glucose in adults were highlighted: alcohol consumption and pregnancy. Although alcohol consumption can technically be categorized into diet, it is identified as a unique factor due to the special impact it has on glucose absorption. It is important to note that although attending this session was helpful in deepening my understanding of adult T1DM, the information collected was focused primarily on techniques used for carb counting (as expected). As the design of the mobile application will be focused on how to effectively present data to users, this session highlights the need to allow users to record their carb counts in relation to their blood glucose measurements.

3.2 Pilot Data Review & Brainstorming

As noted previously, this research was conducted in parallel with the re-design of the adolescent version of a mobile self-management app: bant. This version was developed with a user centred design method and had undergone a mini-pilot study in 2010. There were several key findings from the results of that study, the most impressive being a significant increase in the number of BG measurements taken daily (Cafazzo, 2012). Unfortunately, exit interviews with the pilot users were not conducted. As a result, the Centre for Global eHealth Innovation hosted a brainstorming session to review the data collected and determine what design changes need to be made in order to address the issues with the application uncovered from the pilot. The group included engineers (Masters & PhD’s), human factors experts, software engineers, and a person with Type 1 diabetes.

Although brainstorming is not typically considered a means for collecting and defining user requirements, it is an effective tool to develop and collect many design ideas in a group setting (Osborn, 1953). The session was approximately an hour in duration and
topics ranging from software design to hardware elements were discussed. Following a brief review of the findings from the pilot, any and all ideas were welcomed. As a result of the session, the following four design features were listed as ‘most wanted’:

1. Leaderboard: This feature would display a list of ‘leaders’ in the community who have accumulated the highest number of points. The purpose of the leaderboard would be to introduce a competitive element to the mobile app with the goal of motivating users to become a leader on the board.

2. Community Statistic: A community statistic would display how the community is performing as a whole with respect to blood glucose readings. In other words, this feature would display the average community blood glucose whenever a user is uploading their reading(s).

3. Progress/Status Bar: The purpose of this feature would be to display information regarding a user’s overall ‘status’ for the day. Also, since the application leverages points to encourage certain behaviours, letting the user know how far they are from achieving their next reward is important.

4. Updated Points Algorithm: The version of the app used for the pilot rewards a user for uploading a reading. The purpose of this feature would be to reward other positive behaviours such as loading a reading within range or resolving a negative trend (defined as 3 consecutive readings out-of-range)

Although this feature discussion was specific to the adolescent version of the app, it provided a good starting point for beginning to map out and visualize the adult version. This also helped guide the questions for the semi-structured interviews regarding whether specific design features would be appropriate for a more mature user.
3.3 Semi-Structured Interviews

The next stage of requirements gathering involved conducting interviews with adult T1DM patients (REB 12-5578, U of T 28496). The recruitment inclusion criteria were: any English-speaking adult (19 and older) who had been diagnosed with T1DM for a minimum of a year, and who was willing to provide consent to participate in the study. A total of 8 participants were recruited from the Toronto General Hospital Diabetes clinic; half were pump users and half used multiple daily injections (MDI) of insulin.

Interviews were conducted at the Centre for Global eHealth Innovation and were approximately one-hour each in duration. Data collected through the literature review, observational research, and brainstorming session helped guide the development of the semi-structured interview questions. Particular areas of interest include effective data tracking and visualization, social community interaction, and motivational design techniques (ie. reward mechanisms). The list of questions used to guide the interviews are outlined in Table 3 below.

| Social Community | • Who do you typically share your blood glucose information with? When? How frequently?  
|                  | • What type of information do you typically share? With whom? What motivates you to share that information with others?  
|                  | • How often do you communicate about your diabetes with others?  
|                  | • How does sharing information help you?  
|                  | • Overall, what do you like most about your current information sharing practices? What would you like to improve or change? |
| Data Visualization | • How do you currently track and record information related to your diabetes management? What information do you record and why? How often?  
|                   | • How and when do you review and interpret your blood glucose results? What tools do you employ?  
|                   | • Do you ever look back through your logs? If so, how far back do you go and why?  
|                   | • When you do make changes to your routine, what do you base your decisions on and why? |
| Rewards & Motivation | • Overall, what works well in your current information capture and review practices? What would you like to change?  
• What keeps you motivated to stay on track with your self-management practices?  
• Do you ever set goals relating to your self-management practices or overall health? If so, how do you set out to achieve them?  
• Do you currently play any mobile games? If so, what keeps you interested in the app? |

*Table 2: Semi-structured interview questions*

In addition to being asked questions, participants were shown and encouraged to provide feedback on rough paper sketches and high fidelity screenshots of preliminary design ideas. To review these screenshots, please refer to Appendix B. Before concluding each session, participants were asked to interact with the existing adolescent bant application. The purpose of this activity was to collect preliminary design feedback and to determine which design features, if any, would be appropriate for adult use as well. The following section outlines the analysis performed on the data collected from these patient interviews.

### 3.4 Qualitative Data Analysis

An affinity diagram was used to analyze the data collected from the interviews. This method was created as a means to sort many ideas into useful groups or themes. It involves four steps: label making, grouping, charting, and written or verbal explanation (Scupin, 1997). In this case, the goal was to take the identified groupings and translate them into user requirements.

Each of the eight participant interviews was transcribed. Maintaining anonymity, participant statements were printed and mounted onto cards (label making) for easy grouping. The next step involved organizing the statements into groups. In order to avoid bias, it is best that this step be carried out with a group of people rather than an
individual. It is for this reason that members of the Interactive Media Lab (Figure 5 below) were recruited to group related statement cards together.

Figure 5 – Affinity diagraming with members of the Interactive Media Lab

Due to the large number of statements, the cards were classified by interview category: information sharing, data visualization, design elements (comments on preliminary sketches), and rewards/motivation. The statements could have been categorized one level further into answers for each question; however in order to allow for original ideas to diverge, the cards remained in the larger groups of categories.

The lab members worked together to sort cards, and once agreed upon, the sub-groups were finalized. Appropriate titles were determined and statement cards were charted accordingly. The following section outlines the resulting affinity diagrams for each category. The final step of the method written explanation, is outlined in section 3.5 User Requirements.

3.4.1 Affinity Diagrams

The resulting affinity diagrams from the grouping activity are outlined below. Figure 6 depicts the chart of statements for the information sharing category.
There were a total of seven sub categories identified:

- Motivation: The motivation behind sharing diabetes related information with others.
- Online: Opinions and behaviours towards online information sharing practices.
- Recipient (who): The individuals who are likely to be the recipient of the information shared.
- Content: A cross-section of the type of information that patients choose to share.
- Frequency: The frequency of which information is shared with others.
- Community: Participation in diabetes communities either online or in person.
- Questions: How to handle diabetes related questions between clinic visits.

The affinity diagram for data visualization was rich in data (Figure 7 below). This was expected due to the number of questions asked under this category. Also, collecting data is a task that is required for the majority of persons with diabetes and as a result, people had lots of opinions on how to present and visualize that information.
There were a total of 6 sub-categories identified:

- Reflection Period: How far back patients look through data collected.
- Data Loads (Frequency): The frequency with which BG readings and other information are recorded or loaded.
- Data Tracked: The information that is actually tracked.
- Tools Used: A summary of the various tools used to assist with data tracking.
- Making Decisions: Insights into how decisions related to diabetes self-management are made.
- Making Changes (Frequency): How often changes are made to self-management routines.

When participants were shown the sketches and preliminary screen shots, the interviews shifted from a question/answer format to an open discussion around thoughts and opinions on the drawings. The resulting affinity diagram (Figure 8 below) may help indicate what areas of the design participants found most interesting and helpful.
Five sub-categories were identified and are described briefly below:

- **Historical Data**: How far back participants looked through data.
- **Important Statistics**: The numbers and figures that participants found most interesting and helpful.
- **Desired Features**: Features that participants look for in a mobile application.
- **Data Organization**: The preferred way to view data.
- **Colour Meaning**: Colours associated with high and low BG readings.

The final affinity diagram (Figure 9) summarizes the data collected on what keeps patients motivated to stay healthy and the types of rewards adults find appropriate. As a result, two of the three sub-categories were motivation and rewards. The third, goals, provides an understanding of what type of data participants use to set goals.
Each step in the process of creating these affinity diagrams was an opportunity to become more familiar with the data collected from the interviews. This exercise was useful in identifying sub-categories of ideas that would not have otherwise been extracted from looking strictly at the data as simply answers to questions. Also, the involvement of individuals external to the process provided a means to approach the data with a different perspective.

3.5 User Requirements

With the data from the interviews organized into category and sub-category, the next stage of the process was to translate the groupings into user requirements. Table 4 below summarizes the findings identified from the affinity diagrams and relates them to design principles that were used to guide prototype development.

Design principles were classified into *firm* and *flexible* user requirements. Firm requirements were identified as design principles that must be included in the app. These have been shaded blue in Table 4. These requirements form the basis of the application, which means without them, the app will not be able to function. This includes input related requirements such as recording information, as well as basic output requirements.
such as displaying collected data intelligently to the user. Flexible requirements were
design principles identified as important elements to help guide the design but are not
mandatory to include. In other words, these features are ‘nice to have’ but are not crucial
to developing a functional application. These have been shaded orange in Table 4 above.

<table>
<thead>
<tr>
<th>Category</th>
<th>Finding</th>
<th>Design Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Sharing Practices</td>
<td>Patients share diabetes related information with close family members and significant others on a monthly basis and are not interested in sharing with an online community.</td>
<td>The app should provide users with a means to occasionally (1/month) share information related to their diabetes with close family and friends.</td>
</tr>
<tr>
<td></td>
<td>Sharing information helps patients to better understand T1DM and their bodies.</td>
<td>The app should not link into a pre-existing online social community.</td>
</tr>
<tr>
<td></td>
<td>The majority of patients have an online presence (ie. Twitter, Facebook, etc.), but do not use them as a means to discuss diabetes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patients would be interested in seeing and contributing to a published community blood glucose and believe it would be a motivating factor in maintaining a healthy BG.</td>
<td>The app should clearly display the community BG on a screen that is frequently accessed by the user.</td>
</tr>
<tr>
<td>Data Visualization</td>
<td>Patients most frequently track and record the following information: carbohydrates, blood glucose, insulin, and activities.</td>
<td>The app should allow users to record and track their blood glucose, carbohydrate intake, insulin, and activities.</td>
</tr>
<tr>
<td></td>
<td>Patients make adjustments to their self-management routine based on how they are feeling (physically/emotionally), BG lows and highs, as well as on insulin and carbohydrate intake.</td>
<td>The app should allow users to keep track of and review their physical and emotional well being; this data should be displayed with other recorded data.</td>
</tr>
<tr>
<td></td>
<td>Logs are typically reviewed a week to one month back.</td>
<td>The app should present data in one-week increments as far back as one month.</td>
</tr>
<tr>
<td></td>
<td>Recording information is time consuming. Patients reported recording regularly only in anticipation of a clinic visit.</td>
<td>The act of recording data into the app should be fast, easy, and straightforward.</td>
</tr>
<tr>
<td>Design Elements</td>
<td>Being aware of average blood glucose and the percent of readings in and out of range is helpful to know.</td>
<td>The app should clearly display the users average BG and the percent of readings that are in and out of range.</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Reviewing a summary of data by day (time on the x-axis) is more clear and valuable than seeing data summarized by context.</td>
<td>The app should provide a summary of collected data by day.</td>
</tr>
<tr>
<td></td>
<td>Patients associate the colour green with being in range. However, there is no consensus on a colour code for low and high readings (blue vs red).</td>
<td>The colour green should be used to indicate in range readings and red to indicate out of range readings regardless of whether the values are high or low (as red is commonly known to represent ‘danger’).</td>
</tr>
<tr>
<td>Rewards/Motivation</td>
<td>Fear of future T1DM related complications motivate patients to stay on track.</td>
<td>The app should highlight or emphasize the use of good health and feeling well to motivate the user to stay on track.</td>
</tr>
<tr>
<td></td>
<td>General good health and feeling well motivates patients to stay on track with self-management practices.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patients set a goal to achieve or maintain an in-range A1C and also set goals related to general health.</td>
<td>The app should have a place where users can track and review their A1C for goal setting purposes.</td>
</tr>
</tbody>
</table>

Table 3: Summary of Findings and Design Principles

For a detailed breakdown of patient statements by category, please refer to Appendix C. The following section describes the prototyping process and outlines how these design principles were met.
4.0 Prototype Development

Designing from data requires taking a creative leap. There are no set rules that outline how to translate user requirements into specific design features. However, there are tools that can be used to help guide the process. In this section, the steps used to develop the prototype and the final design prepared for usability testing are described in detail.

4.1 Storyboards

*Storyboarding* is a technique that was derived from the film industry and has now been commonly applied to developing system designs. Bayer and Holtzblatt (1998) describe storyboards as a means to demonstrate how specific tasks will be accomplished in the new world. In this case, storyboarding was used to identify what tasks an adult T1DM will attempt to complete using the mobile application and what the expected system response would be to accommodate the action. Therefore, when the design principles were reviewed and organized by similarity: the following five user tasks were identified:

<table>
<thead>
<tr>
<th>Design Principle</th>
<th>User Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>The app should allow users to record and track their blood glucose, carbohydrate intake, insulin, and activities.</td>
<td></td>
</tr>
<tr>
<td>The app should allow users to keep track of and review their physical and emotional well-being and should be displayed with other recorded data.</td>
<td>Record Data</td>
</tr>
<tr>
<td>The act of recording data into the app should be fast, easy, and straightforward.</td>
<td></td>
</tr>
<tr>
<td>The app should provide a summary of collected data by day.</td>
<td>Review Recent Data</td>
</tr>
<tr>
<td>The app should clearly display the community BG on a screen that is frequently accessed by the user.</td>
<td></td>
</tr>
</tbody>
</table>
The app should present data in one-week increments as far back as one month.
The app should clearly display the users average BG and the percent of readings that are in and out of range.
The app should provide users with a means to occasionally (1/month) share information related to their diabetes with close family and friends.
The app will not link into a pre-existing online social community.
The app should highlight or emphasize the use of good health and feeling well to motivate the user to stay on track.
The app should have a place where users can track and review their A1C for goal setting purposes.
The colour green should be used to indicate in range readings and red to indicate out of range readings regardless of whether the values are high or low.

| The app should present data in one-week increments as far back as one month. | Review Historical Data |
| The app should clearly display the users average BG and the percent of readings that are in and out of range. |  |
| The app should provide users with a means to occasionally (1/month) share information related to their diabetes with close family and friends. | Share Data |
| The app will not link into a pre-existing online social community. |  |
| The app should highlight or emphasize the use of good health and feeling well to motivate the user to stay on track. | Look for Motivation |
| The app should have a place where users can track and review their A1C for goal setting purposes. |  |
| The colour green should be used to indicate in range readings and red to indicate out of range readings regardless of whether the values are high or low. | Miscellaneous Design Guideline (Not a user task) |

*Table 4: Design Principles ➔ User Tasks*

Upon review of these user tasks, it is evident that the main purpose of the application is to record information. Without collecting day-to-day data, the app will not be able to provide the user with a representation of recent or historical data, or the ability to share this information with others. If we consider the findings from observing T1DM patients, there are several factors that typically need to be tracked. This helped drive the storyboarding process and resulted in Figure 10 below.
This storyboard does not address all of the identified design principles, however the thinking process behind creating the above figure was useful in determining an initial user workflow. In other words, the act of thinking through how a user may approach the mobile application was helpful in determining what the user might expect to see and be able to do. The following section outlines the iterative approach taken to develop the prototype.

4.2 Prototype Evolution

With an understanding of how users are expected to interact with the mobile application, a formative usability approach was applied to design and develop the initial prototype for testing (see Section 5.0). Formative usability is defined as a method that is iterative in nature, which means that evaluation, problem diagnosis/identification, recommendations,
and changes to the design occur in a cyclical fashion (Tullis & Albert, 2008). With support from the Interactive Media Lab and the Centre for Global eHealth Innovation, several iterations of formative usability occurred prior to finalizing the prototype for usability testing with patients.

The initial version of the prototype was developed using the design guidelines identified from the results of the requirements gathering phase. The design was also partially influenced by the existing adolescent version of bant with respect to the number of tabs and the layout of the bottom navigation bar. The navigation bar was used as a starting point to guide the design with the expectation that it would iterate and change as the prototyping process moved forward.

In the first iteration of design, there were five tabs in the application: trends, bant book, readings (home), challenges, and a social network depicted from left to right in Figure 11 below.

![Figure 11: Bottom navigation bar – Iteration 1](image1)

Although sharing personal experiences in a community, whether in person or online, was noted to be healing and educational (according to the data collected from the patient interviews), the majority claimed they were not interested or willing to share diabetes information with an existing online community. As a result, the social network tab was later removed and was replaced with a food database as shown in the updated menu bar below.

![Figure 12: Bottom navigation bar – Iteration 2](image2)
As a result, in the screenshots that follow, depending on the iteration being discussed, the rightmost icon in the menu bar will shift from a social networking tab to a food database tab. However, since users typically share information with close family and friends, a ‘Share’ icon has been included on each screen. This will allow the user to send a pre-formatted email or SMS of the content on a specific screen of interest.

![Figure 13: Share icon](image)

The designs use colour coding to align readings by context. For example, all breakfast readings and data associated with them will be coded the colour blue. Therefore, the design assumes users have adequate color vision. The following five sub-sections describe in detail the designs for each tab and what changes were made with each iteration.

### 4.2.1. Home Screen

When the application is first launched, it opens to the home screen. This page acts as a dashboard that summarizes the data collected throughout the day and it is also the gateway for users to enter self-measured data. As the system will allow the user to record their blood glucose, carbohydrate intake, insulin dose, activity levels, and emotion, it is important to display this data in a meaningful way to the user. Figures 14a and 14b below depict the first iteration of the home page design.
The screen is divided into three sections. The top portion is a mini dashboard that displays in the top left corner the community blood glucose (the average blood glucose of all users of the app at the current time), and in the top right corner, the individual user blood glucose. Figure 14a depicts the screen before the user inputs their most recent BG measurement and other related information. The middle portion is a graph of the blood glucose measurements taken throughout the day with the time on the x-axis and mmol/l on the y-axis. The light green band through the middle indicates the target blood glucose range. This target range can be changed in the settings to accommodate individual needs. Note from figure a to b, the line extends by one reading. The bottom portion is a summary of all the other data collected organized by reading. The readings are colour coordinated by context, which can be set by the user.

In an early evaluation of this design, it became clear that the tabular representation of the data in the bottom portion of the screen would not quickly convey useful information to the user. It would take time to read through each line item, which is not ideal, particularly for mobile use. As a result, the bottom portion of the design changed in the second iteration to a more visual representation. A menu was introduced with the option for the user to toggle through their carbohydrate estimates, insulin boluses, level of activity, and how they were feeling throughout the day. This has been depicted from left
to right below in figures 15a to 15e. Each BG reading in the top graph aligns vertically and is colour coded to match the carb and insulin bar graphs below.

Upon review of the home screen and the user requirements, an additional field was added to the top portion of the home screen: the ability to log HbA1C. The decision to add this was driven by the fact that the majority of patients interviewed set goals around achieving an A1C within the target range. As a result, a third item was introduced on the left hand side of the top mini dashboard (Figure 16). Also, text to direct the user to ‘click through’ the menu was added to the bottom portion of the screen.
The act of logging a reading occurs within the home screen. When the user clicks on the circle below ‘Log my recent BG’ in the top right corner, they will be directed to a new screen (Figure 17a) that will allow them to log their BG and other related information. This screen will automatically default to the meal or other context that is most relevant to the time of day the application is being used. In other words, if it’s 7am, the large circle at the top centre of the screen would have defaulted to blue and the text left of the circle would indicate that it’s a breakfast reading. If the user would like to change the context of the reading, they can simply drag and drop the desired circle from the top menu bar onto the large circle below.

![Figure 17a](image1.png)  
![Figure 17b](image2.png)  
![Figure 17c](image3.png)

*Figure 17: Reading Details Screens*

Each of the grey circles represents a piece of data that can be collected by the app. These correspond with the requirements, allowing the user to record and track how many carbs they are consuming (carbs), how many units of insulin they are taking (bolus), the type of activity/exercise they have participated in (activity), how they are feeling (emotion), and their basal dose (basal). The decision to record emotions was based on the data collected through requirements gathering. In interviews, some patients stated that they relate their BG readings to how they were feeling emotionally. For example, a bad emotional day may be related to difficulties with controlling BG, therefore collecting and displaying this
information would be helpful for future self-management planning. Also, through feedback collected through an iteration of design discussion, it was suggested that ‘Emotion’ may be a more appropriate label for capturing how a user feels than ‘Feeling’ due to the input being a selection of emoticons (faces that depict emotions such as happy and sad). The input screens that enable the user to record their data have been included in Appendix D for reference.

4.2.2 bant Book

The purpose of the bant Book is to provide the user with a place that is familiar to them within the app. Therefore, this section was designed based on the paper logbooks that are often provided either by their clinic or packaged with their BG meter or pump. However, as one focus of the app was to represent data in a visually rich and meaningful way, a unique calendar feature was designed (Figure 18)

![bant Book screens](image)

*Figure 18: bant Book screens*

The purpose of this calendar was to show the user at a glance what their BG readings look like over the course of a month. The idea is that a heat map would be generated based on the number of readings taken and whether those readings are in or out of range. As there wasn’t a consensus on what colour represents high or low readings, any days
that are out-of-range would be a shade of red and an in-range day would be coloured a shade of green. Red was selected to depict out-of-range values because it is the colour most associated with danger. The depth of the colour would indicate how many readings were taken and the average value of those readings would determine the colour. For example, a day with five in-range readings would be a darker green than a day with just two in-range readings. Similarly, a day with five out-of-range readings would be a deeper red than a day with a single out-of-range reading. The difficulty arises on days where several readings were taken but the average is only slightly out of range. According to the given algorithm, this would result in the day being shaded a dark red which would not be an accurate representation of the users overall blood glucose that day. The alternative would be to colour the days based on BG average only. This is an area that was explored in the subsequent user testing.

The bant Book will default to the current day (Figure 18a above), which is indicated by the bold box surrounding the day (May 1). The user can navigate to any other day by touching the desired date. This interaction is consistent with calendar applications on various mobile devices. It is important to note that when a day is selected the BG average for the date is displayed near the centre of the screen with a list of the readings taken that day below it. Users will be able to access the details of each of their readings by tapping on the arrow to the right of the BG value(s). This will bring them to a screen that will look like Figure 17c above.

4.2.3 Trends

The trends section was designed to address the lack of useful and clear visual representations of blood glucose data that exist in diabetes mobile applications currently available. The purpose was to provide at a glance where a user is experiencing difficulty with regulating their blood glucose. Early iterations attempted to include carbs counts and insulin; however in order to simplify the design and place emphasis on BG, they were removed. The emotions data were also excluded in this section for the same reason. Trends proved to be the most challenging section and as a result, the designs went
through several iterations. The first version of the trends screen followed the theme of using context circles to represent data; three variations on the design were mocked up.

Figure 19: Trends Screen – Iteration 1

In figure 19a above, the screen is divided into sections by context with the average BG on the left, the percent of readings in-range in the centre, and the percent of readings out-of-range on the right hand side. The size of the circle changes proportional to the percent value that it is depicting. The user will also be able to toggle through data by number of weeks (1 to 3). Figure 19b follows a similar concept; however rather than showing every context on the screen at once, the user would be able to select the context and the number of weeks of data.

In an early design review, it became apparent that showing both the percent in and out-of-range was redundant and the screen space could be better utilized. Therefore, the percent out-of-range circles were removed and replaced with additional information such as average carbohydrates consumed by context (right hand side of figure 19c). However, upon further review, a more important flaw in this design was uncovered. When looking at the screens above, attention will likely be drawn most to the largest circle, which represents when the user has the highest percentage of readings in-range. This is problematic because one of the goals of this section is to draw the users attention to areas
where they may be struggling with maintaining healthy blood glucose. For example, in Figure 18c, it is significantly easier to notice the large green circle showing that 80% of BG readings at snack time are in-range over the small orange circle showing that 15% of lunchtime readings are in-range.

The next iteration of trends changed drastically from the first. The ability to toggle through by week remains; however, the circles concept was abandoned and a more traditional graphing theme was adopted. Figure 20a shows a scatterplot of every reading taken by context with the plot of all reading shown at the top. The parallel lines indicate the upper and lower limit of the readings, similar to the green band on the home page. Figure 20b shows a horizontally stacked bar chart that indicates by percentage the number of readings that run low (red), in-range (green), and high (blue). As this did not follow the requirement that any out-of-range readings be coloured red, the screen evolved to the one shown in figure 20c with the high readings also shown in red. Also, through a review, it was highlighted that the percentages would be more meaningful if the user was made aware of the number of readings taken for each context. As a result, this was displayed in brackets next to the title of each context.

Figure 20: Trends Screen – Iteration 2
We hypothesized that these revised screens were easier to understand than the screens from the first iteration. For example, by looking at figure 20c, it is clear at a glance that the user has better BG control when having a snack than at breakfast time. Due to both 20a and 20c being favoured through review, it was decided that both views would be included for usability testing. Users would be able to navigate from one view to the next by swiping to the left and then swiping to the right to return to the previous screen. The two dots below the top menu bar and above all reading in figure 19c indicate that there are two views. The shading of the dots would indicate what screen the user is on (black) and which way to swipe to access a different view (grey).

4.2.4 Challenges

From the identified requirements, it was clear that users set personal goals that relate to overall health and well being. The goals section of the mobile app was named ‘Challenges’ in order to stay aligned with the game-based design theme. The aim of the challenges portion of this application was to incorporate these types of personal goals and incorporate them with challenges that would encourage the user to remain engaged in the app. In the first iteration of the design, the challenges were kept to a single screen (Figure 21). Along the top were three items: the ability to log A1C, review how many challenges were achieved, and also how many more challenges remain in the app. Underneath the circles, a challenge in progress is displayed; this can be changed by tapping on any of the challenges listed below. These challenges range from encouraging more physical activity to working towards increasing the number of BG readings in range. In the bottom right hand corner, there is a box labeled ‘Create my own…”. The idea behind this was to allow users to build their own personal challenges within the app.
Figure 21: Challenges Screen – Iteration 1

Upon review of this screen, it was discussed that the title ‘Achievements’ was not appropriate given that the majority of the screen was dedicated to listing out current challenges. As a result, in the next iteration, the title was updated to ‘Challenges’. Also, although these challenges may be relevant, they were not well integrated into the application. The user would have to navigate to this tab to review their progress and the challenges they were working on. The next iteration of design took a more integrative approach with challenges being built right into each screen through the use of a pull out tray. The concept of a pull out tray is gaining popularity in the design of mobile application design.

On every screen with a challenge, a small tab on the right hand side indicates the existence of a tray. When the little tab on the right side of the reading input screen (Figure 22a) is pulled out, a list of challenges that relate to that screen are displayed. In other words, the list of challenges in the tray will change dependent on what screen the user is working on. With each challenge, a progress bar is shown (where appropriate) to demonstrate how far the user is from completing the challenge. Each time one is completed, the graphic of blue circles grows by the number of challenges. Though difficult to depict on paper, imagine a brief animation that transforms the completed challenge into a circle that travels up and attaches to the collection above. Figure 22d
shows how the graphic would look with two completed challenges. Additional challenge screens have been included for reference in Appendix D.

![Images of challenge screens](22a, 22b, 22c, 22d)

Figure 22: Challenges Screen – Iteration 2a

With the challenges moved to individual trays, this freed up screen space on the challenges tab. This allowed for the introduction of a new feature; the use of *points*. The idea is that as users complete challenges, they will accumulate points and can visit the challenges tab (Figure 23 below) to review how many they have completed to date and to also see how they are performing compared to other users of the app. This can be done using a leaderboard. Although there isn’t a social community for users to directly share information, a leaderboard can provide another means to connect users with one another in a more private manner. This means that rather than sharing personal diabetes or health related information, the only data a leaderboard shares is the number of points the user has accumulated. The graphic of circles on the top portion of this screen is interactive, meaning that users can tap each circle to find out what challenge they completed to obtain it. This provides the ability for users to review their accomplishments over time.
Review of the updated challenges section revealed that the design may be too complex and could prove to be confusing with the content of the challenges tray changing from screen to screen. This was included in usability testing to determine whether this was in fact true.

4.2.5 Food Database

The decision to include a food database in the application was not necessarily driven by the requirements. In fact, what was drawn from the requirements was the need to keep track of how many carbs are being consumed, not a tool to help determine the amount. Though participants didn’t explicitly state they would want a food database in a diabetes app, they did mention that they used other food databases available either by book or via another mobile app; the three most popular being MyFitnessPal, LoseIt, and CalorieKing. It is important to note that none of these popular applications have been designed specifically for a Type 1 Diabetic patient to use. The idea is that an integrated food database would make it easier for the patient to estimate their carbohydrate intake. Therefore this screen (Figure 24) has been included as a means to measure the demand for such a feature in a diabetes app through usability testing.
If this were to be incorporated fully into the app, it would have to be well integrated. However, since the focus of this research was to explore various data visualization techniques, this portion of the design was not fully prototyped.

4.3 Final Prototype

The prototype finalized for usability testing was feature rich with an emphasis on data visualization. It had a total of five main sections, three of which are directly related to BG readings and different methods of representing the collected data. The remaining two sections were dedicated to the challenges/leaderboard and a food database. The information architecture of the final prototype has been drawn below in Figure 25.
The arrows stemming from the menu bar indicate how the screens are linked together and demonstrate how a user could navigate through the application. To reiterate, the menu bar icons from left to right are: Trends, bant Book, Home, Challenges, and Food. The goal was to keep the flow as straightforward as possible; this was accomplished by minimizing the depth to which a user can navigate within each section. Generally, the number of screens was limited to three per tab, including the ‘Challenges’ tray as a screen.

Beginning at the left side of the flow diagram, the ‘Trends’ section has 3 main screens. By touching the ‘Trends’ icon, the scatter plot view of blood glucose readings by context opens. By swiping to the left, the bar chart view of trends will be revealed. Finally, when the tab on the right hand side is pulled out, the Challenges tray appears on the
Within the two chart views of trends, the user can toggle between views of the data: 1-week, 2-weeks, 3-weeks, and All (all data collected).

The ‘bant Book’ section will always default to the view of the current day. The user can go as far back as they wish in the calendar to access their log summary and BG average for any given day. Again, if the user wishes to engage with the challenges built into the app, they pull out the tray using the tab on the right hand side at any time.

Although the ‘Home’ page appears to have several screens, when the user toggles through the centre menu bar, the layout on the top half of the screen remains consistent and the data along the bottom portion changes to represent carbs, insulin, activity, and emotions (4 screens on the bottom right). Each section within the app is fairly independent; the only cross section link exists between the ‘bant Book’ and ‘Home’ page. Users are able to drill down on a specific reading from the ‘bant Book’ by tapping on the arrow next to the reading of interest. This action will bring the user directly to the reading ‘Details’ page.

The ‘Challenges’ screen summarizes the number of challenges completed using a graphic of blue circles at the top, with a leaderboard showing the user how many points they have collected in comparison to their peers. This section is a single page deep; there are no additional screens for the user to drill down to. Similarly, the ‘Food’ section is only a single page. If this feature were to be completely mocked-up, there would be several screens and possibly a link into the reading ‘Details’ screen that would allow users to log a food with a BG reading. The goal was to collect opinions through testing regarding how useful a ‘Food’ database would be to potential users.

In the next phase of this research, usability tests were conducted using this finalized prototype. The goals, methodology, and results from testing are outlined in Chapter 5.
5.0 Usability Testing

Usability testing is an important part of user centred design, it uncovers design flaws and also validates good design features. A separate ethics submission (13-5975) was prepared for this phase, as the content of questions and style of interviewing patients was different from that of Phase 1 – Requirements Gathering. The following sections outline the methodology, the tools used to measure the usability of the application, and a summary of the results.

5.1 Methodology

Usability testing was carried out at The Centre for Global eHealth Innovation in the usability laboratories. Nielsen (1994) recommended 3 to 5 participants for a talk-out loud study. Therefore, recruiting for participants closed when a total of 6 participants were reached. Potential participants were contacted initially by an RN in their circle of care either in person or via a recruitment letter sent through email. Interested participants were encouraged to contact the Research Coordinator to schedule a time to participate in a user test either by phone or email. In order to participate, patients had to be fluent in English in order to comfortably read scenarios and provide written feedback in questionnaires. Also, it was preferred to recruit patients who had been diagnosed with T1DM for at least one year. This was to ensure that patients were reasonably comfortable with their self-management routine. Finally, patients had to be an adult (>19) as the application was designed to support a mature user.

The session was no up to 1-hour in duration. Upon arrival, participants were provided with a copy of the consent form, walked through the document, and given as much time as needed to review and ask questions regarding the study. Following a brief introduction regarding the purpose of the session and the mobile application, participants were asked to fill out a pre-test questionnaire to gather background information on the patient. Upon completion, participants were briefed on the testing method and the
prototype. At the end, participants were asked to complete two questionnaires and were debriefed on design features that may have been missed during the test. For a detailed outline of the usability study protocol, please refer to Appendix E.

To elaborate further on the method of testing, participants were asked to complete a total of eight scenarios by interacting with a paper prototype of the mobile application. Paper prototyping is a widely used method in user-centered design because it is fast, cost effective, and encourages creativity (Snyder, 2003). In addition, when a user interacts with a high-fidelity prototype, they are more likely to become frustrated if the testing device is slow or certain links or buttons don’t function as expected. Using a paper prototype frees the participant from these expectations and also allows for more open discussion as the facilitator works through each paper screenshot.

5.2 Scenarios

Scenarios were used as the method to guide the user through the paper prototype. They were developed using the tasks that were identified through storyboarding (Section 4.1). The idea was that these scenarios would be representative of actual tasks that a T1DM patient would want to complete using a mobile application that supports them with their self-management routine. Table 6 below summarizes each scenario and categorizes them by user task.

<table>
<thead>
<tr>
<th>Task</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record Data</td>
<td>It’s dinnertime (8pm) on May 1, 2013 and you want to record your most recent BG reading along with other related information. Open the app and record the info in the following order: BG – 5.0 mmol/l Carb Count – 20 grams Insulin Bolus – 3.5 units Activity – Yoga Emotion - Happy You’ve had your doctor’s visit earlier in the day. Since your goal is to keep your A1C (8.1) in range, you’d like to record it in the app to keep as a reminder.</td>
</tr>
</tbody>
</table>
Review Recent Data
Since it’s the end of the day, you want to have a look through your carbs, insulin, activity, and how you felt throughout the day.

Review Historical Data
It’s the first day of May and you want to see how your blood sugars looked the month before (April). Have a look through your bant log book to see how you did. In particular, you want to see what happened on April 23rd.

You’ve made a mental note that your readings before breakfast have been a bit out of range lately. You’re curious what your average blood glucose at breakfast has been for the past week. Use the bant app to find out.

Now that you’ve had a glance through what your readings looked like for the past week, you want to know the percent of times you’ve been in and out of range as well.

Look for Motivation
Comment on the community blood glucose.

You’re interested in completing some of the challenges that are built into the app. Explore the various challenges for each tab and find out how far you are from achieving them.

Now that you’ve had a look through some of the challenges, you’re wondering how many you’ve completed to date in total. You’re also curious how you’re doing in comparison to others using the app; find out where you are on the leaderboard.

Share Data
You remember you wanted to share some information with your sister since she’s been bugging you for updates lately. Email her the details of your day from within the app.

As the emphasis of this research was to explore different data visualizations, nearly half of the scenarios are related to reviewing data. The prototype has four different ways of representing information: on the home page, bant book, and two views on the trends page. It’s important for the user to be exposed to each version in order to determine which visualization is preferred.

An additional scenario regarding the food database was included and reads as follows: “It’s a special occasion and you’re trying a food you’ve never had before; BiBimBop (a Korean dish of rice with mixed vegetables). Have a look through the food database in the app to try and get an idea of the carb estimate for this new dish.”
The food-based feature was included in the prototype but was not fully functional. In the scenarios outlined in the table, participants were encouraged to log their carbohydrate intake but any additional functionality such as logging a photo of the food or in-depth browsing through a food database was not included. Therefore, the purpose of including a scenario dedicated to this feature was to encourage discussion, gauge interest, and determine whether it would be an area for future research.

For the actual usability testing session, scenarios were ordered to allow for a flow of events that would make sense to the user: recording data followed by reviewing past data. As participants worked through completing each scenario, they were asked to ‘talk out loud’ and voice any opinions they have on the design, the scenario, and also share their thought process regarding their navigation choices. If an issue was encountered, or the participant was stuck, the scenario was ended and the session proceeded to the following scenario. As participants worked through each scenario, the number of ‘clicks’ off the critical path and overall task success were recorded. Once a participant had completed the usability test, they were asked to fill in two questionnaires after which they were debriefed on any screens and scenarios they had trouble with.

### 5.2 Questionnaires

Participants were presented with questionnaires at the beginning and end of the usability testing session. The purpose of the pre-test questionnaire was to collect background information on participants regarding their self-management routine and level of comfort interacting with mobile devices. There were two post-test questionnaires both focused around measuring the usability of the design; the system usability scale (SUS) was issued first, followed by a general post-session questionnaire.

The SUS (Brooke, 1996) consists of ten usability related statements, half of which are positively worded and the other half negatively worded. Using a 5-point Likert scale, participants were asked whether they agreed or disagreed with the system. The score is calculated by following these steps:
1. For positive items (1, 3, 5, 7, 9), take the scale position minus 1
2. For negative items (2, 4, 6, 8, 10), take 5 minus the scale position (reversing the score)
3. Sum all scores
4. Multiply the total by 2.5 resulting in a SUS score out of 100

The SUS score provides a usability measure of the mobile application as a whole but does not provide feedback for specific design features. Therefore, an additional post-test questionnaire was created that consisted of four components. The first section breaks down each feature and asks the participant to rate on a 5-point scale how easy it was to understand or use the features. The second section asks the participant whether they are likely to use the app and provides space to list their top three most and least liked features. The section following focused less on usability but more on the relevance of each scenario; users were asked to rank on a scale from one to five, how realistic each of the scenarios was to them. Finally, participants were given the opportunity to provide open-ended feedback.

5.3 Participant Demographics

A total of seven participants were recruited from the Toronto General Hospital Diabetes Clinic. Participants had varying levels of comfort with mobile devices and less than half had used diabetes related mobile applications in the past. Of those that participated, one was eliminated from the results due to a learning disability that hindered their ability to read and comprehend the scenarios accurately. As a result, the analysis was conducted using a total of six participants. Table 7 summarizes the demographic profile of the participants where MDI stands for multiple daily injection and the 4-point comfort with mobile devices scale was represented as follows: NC – Not comfortable, SC – Somewhat comfortable, C – Comfortable, VC – Very comfortable.
<table>
<thead>
<tr>
<th>Question</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>&lt;25</td>
<td>&lt;25</td>
<td>&lt;25</td>
<td>45-54</td>
<td>&lt;25</td>
<td>55-64</td>
</tr>
<tr>
<td>Gender</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>F</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>Years with T1DM</td>
<td>0.5</td>
<td>12</td>
<td>15</td>
<td>1.5</td>
<td>2.5</td>
<td>36</td>
</tr>
<tr>
<td>Management routine</td>
<td>MDI</td>
<td>MDI</td>
<td>MDI</td>
<td>Pump</td>
<td>Pump</td>
<td>MDI</td>
</tr>
<tr>
<td>Comfort with mobile devices</td>
<td>VC</td>
<td>C</td>
<td>SC</td>
<td>VC</td>
<td>VC</td>
<td>C</td>
</tr>
<tr>
<td>Owns a mobile device</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Uses a diabetes app</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

*Table 6: Usability Study – Participant Demographics*

The two participants that used mobile applications to help support their self-management needs had listed them out on their questionnaires. Of the seven listed, two were designed specifically for diabetes patients (Diabetes GPS, Glycemic Index), and all but one were focused on carbohydrate counting. Even the two diabetes apps were solely focused on carbohydrate counting and did not focus on helping the patient understand or visualize their blood glucose readings.

5.4 Results

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

5.4.1 By Scenario

There were two metrics recorded as users worked their way through completing each scenario: task success and the number of taps or gestures taken off of the critical path. The time to complete each task was not recorded because participants were encouraged to talk out loud which directly impacts this metric and would have resulted in inaccurate data. Figure 26 below depicts the percent of participants who successfully completed each scenario.
It is apparent that participants struggled quite a bit with scenarios seven and eight, and also with scenarios three and six but slightly less so. To provide context, scenario seven was related to the alternate trends view and scenario eight was the challenges task. To develop a deeper understanding of task success, the number of taps/gestures off the critical path to complete a scenario was taken into consideration. In other words, any participant that completed a task using more taps than necessary was categorized as a success with errors. Figure 27 below depicts the percent of participants that completed scenarios with no problems (green), with errors (blue), and failures (red).
It appears as though participants experienced difficulty with the first scenario since many taps were made off of the critical path to complete the task. However, this was due to participants exploring the application (visiting other tabs) as it was their first exposure and they were encouraged to interact freely with the paper prototype. The failures for scenario three were attributed to a minor design flaw in the home page. Some participants failed to read the message circled in red in Figure 28 below. For a future iteration of this design, it would be recommended that the home page eliminate this message and default to the screen on the right.

![Figure 28: Design Issues 1](image)

The errors and failures experienced with scenarios six to eight relate to the ‘Trends’ and ‘Challenges’ features of the mobile application. These issues are better explained in the following section that discusses the results and findings collected through the post-test questionnaires.

5.4.2 By Feature - Ease of Use

In the post-test questionnaire, participants were asked whether they would use this application to complement their daily self-management routine. Of the six participants, one indicated that they were ‘very likely’ to use the app, while the remaining five said that they would ‘likely’ use the application. In addition, the SUS scores for each participant were generally quite high, with scores 80 or higher (Table 8 below). Average
satisfaction scores are typically between 65 and 70 (Bailey, 2006) meaning participants
were highly satisfied with the usability of the mobile application.

<table>
<thead>
<tr>
<th>SUS Score</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
</tr>
</thead>
<tbody>
<tr>
<td>82.5</td>
<td>90</td>
<td>82.5</td>
<td>80</td>
<td>92.5</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

*Table 7: SUS Scores*

Overall, this was positive feedback but in order to determine why the majority of the participants weren't entirely convinced to use the application (selecting 'likely' over ‘very likely), each feature was examined in further detail. As part of the questionnaire, participants were asked to indicate how easy it was to use or understand each major feature of the mobile application. Figure 29 below summarizes the average rating by feature of all participants: 1 - very difficult to 5 - very easy.

![Ease of Use - Features](image)

*Figure 29: Ease of use by design feature*

It is clear that the ‘Trends - %in/out’ and ‘Challenges’ features were the most difficult to use/understand. By reviewing the comments of the things participants liked least about the mobile app, it was revealed that finding and navigating to these features was what made them hard to use. By revisiting the screenshot below (Figure 30), the source of these difficulties can be narrowed down. Both features required the use of a more complex gesture; rather than tapping on an icon/button the user was meant to either
ʻswipeʼ or ʻpullʼ to access different content. This is consistent with the large number of failures for scenarios 7 and 8, which were for ʻTrends - %in/outʼ and ʻChallengesʼ related tasks respectively.

There were also minor ease of use issues with the ʻbant Bookʼ, ʻTrends – Scatterʼ, and ʻInformation Sharingʼ, each having an average ease of use score of around four out of five. Upon reviewing the user testing recordings and notes provided by participants on the questionnaire, it was apparent that the issue was with understanding what the icons represent. The icons have been revisited below in Figure 30; note the ‘Trends’ icon on the far left and the ‘bant Book’ just to the right of it. It was suggested that the ‘bant Book’ icon should look more like a calendar than a booklet, as the tabs main feature is a heat map calendar. Also, the ‘Trends’ icon wasn’t obvious to some users. In Figure 30, below the navigation bar, note the ‘Share’ icon. This icon was hand drawn using Keynote and as a result, it didn’t appear exactly as users would have expected which caused problems. However, it is important to note that the ‘Sharing’ feature was listed in the top 3 most liked features of the application by four of the six participants.
The remaining features: ‘Logging a BG’, ‘Day view’, ‘Leaderboard’, and ‘Food Database’ were all rated fairly easy to use. In fact, by reviewing the top three things participants most liked about the app, the ease of logging information was listed by four of six participants. The ‘Day view’ summary, in particular the graphics, community blood glucose, and A1C logging feature were noted as ‘most liked’ as well. The ‘Food Database’ was never listed in most liked, in fact, only one participant commented on this feature and requested to have a sliding scale for carb counts. Finally, the ‘Leaderboard’ wasn’t listed on either list, which is important when considering gamification type design features for the adult T1DM population. The goal in this case was to leverage this feature as means to create a competitive element. However it seems the community BG (displayed on the day view) was a more effective way of doing this since half of the participants listed it as one of the features they most liked in the app.

5.4.3 Scenario Relevancy

The last section of the post-test questionnaire asked participants to rank how realistic/relevant the scenarios were to them on a scale of 1 to 5: 1 - not realistic and 5 - very realistic. Table 9 below summarizes the results with realistic to very realistic represented by a deepening shade of green. Anything below three has been indicated with a shade of red with the darkest red representing ‘not realistic’.
The purpose of this piece was to confirm what aspects of the design an adult T1DM patient might be most interested in using. The most realistic scenario for all participants was the feature that allows users to log their HbA1c. Some participants commented that seeing their A1C daily would be a helpful reminder to stay on track with their self-management routine. Logging information and the scatter plot view of trends were also rated as fairly realistic scenarios.

In comparison, participating in challenges and reviewing the leaderboard were rated fairly low across participants, with only one individual (for each feature) indicating that the scenarios were very realistic. It’s also interesting to note that sharing data was quite polarized, either a participant found the scenario to be not realistic or really realistic. The middle of the road features rated as ‘realistic’, were the bant Book and the food database. Finally, reviewing the day summary and the % in/out view of blood glucose trends were rated between realistic to very realistic by some but not all.

These findings, as well as the ease of use results, will help guide the discussion around the contributions this research has made to the T1DM mobile application design space.
6.0 Conclusions

Type 1 diabetes mellitus (T1DM) is a complex disease that requires constant monitoring and active patient participation in the development and maintenance of their daily self-management routine. Every individual is unique and has varying needs which makes designing a mobile application to provide support to these individuals a challenging project. This research involved exploring existing diabetes mobile applications and design features, developing a better understanding of user requirements, translating those requirements into a paper prototype, and collecting feedback on the final design.

6.1 Contributions

6.1.1 Design Contribution

The primary contribution of this research is the design of several different and unique methods of visualizing the data that is typically collected and tracked by T1DM patients. In the final design, there were four different ways to review blood glucose and other collected information. The home page of the application provided a visually rich representation of the current day while the bant Book and Trends tab provided alternate views of data over extended periods of time ranging from one week to a month. Through usability testing, feedback was gathered to determine which visual representations were the most easily understood. The scatter plot view of blood glucose data was found to be the favoured design both with respect to ease of use and relevancy. This screen clearly displayed the target range by context with each blood glucose reading taken for a context overlaid on top resulting in several mini scatter plots (ie. Breakfast, lunch, snack etc). The user would be able to select how many days of data they want displayed on the screen; by increasing the number of days, more dots of blood glucose readings would be added to each plot. By looking at this screen, in a glance a T1DM user would be able to tell at what time of day they were having trouble maintaining in-range blood glucose. This screen also includes the blood glucose average to the left of each mini scatter plot.
It was uncovered through requirements gathering that this value is a number that many T1DM patients are interested in being aware of.

### 6.1.2 User Research Contribution

Through conducting requirements analysis and usability testing with adult T1DM patients, this research helped to develop a deeper understanding of the patient population and their expectations and attitudes towards mobile applications. Therefore, the secondary contributions of this research are the findings related to understanding T1DM user needs. There were three key findings related to social networks, frequency of reviewing data, and motivation.

The first finding, related to online social networks, found that although T1DM patients were connected to various social networking sites such as Facebook and Twitter, they rarely used them as avenues to communicate any diabetes related information. However, they did share their health information often with family members and close friends either in person or over the phone. This helped to shape the design of the ‘share’ feature of the mobile app in an important way. Rather than having a separate tab to house a social network where users could share publically with an online community, users would be able to share any information in the app privately using the ‘share’ button accessible from almost every page in the app. Tapping on this share icon allows users to either email or SMS info directly to someone they intend to share with. Interestingly, the majority of patients were interested in having access to the community blood glucose. This figure would display to the user the average blood glucose measurement for all users throughout the day when the user is logged in. This meant that although patients weren’t willing to share detailed personal info, they were happy to contribute to a figure that wouldn’t identify them independently.

Another finding from requirements gathering was that patients were generally interested in their most recent blood glucose information only. They really only wanted up to a
month of data; anything past that wasn’t considered to be very helpful. This helped guide the design of the app since the data visualization of trends really only needed to support a week or two worth of BG readings and other related info. The other key finding was that patients looked for motivation to stay on track with their self-management by being aware of how they were feeling (general health). Related to this, patients also mentioned that keeping or getting their A1C in range was an important motivating factor. This guided the challenges side of the design; some of the challenges were focused on health related goals. In addition, the A1C was included on the home page, which can be seen by the user every time they open the app. It’s important to note that from usability testing, it was found logging and being able to easily view the A1C was the only feature of the app that was very relevant for all users.

To summarize, throughout the user-centred design process, copious user feedback was collected which contributed to the understanding of adult T1DM patients and helped guide the design of novel data visualizations. These visualizations were tested and validated by the user. The feedback was positive and overall, the patients enjoyed the experience of using the mobile app. The hope is that applications like this can help to lower the burden of care on diabetes patients.

6.2 Limitations & Challenges

Several challenges and limitations were faced throughout the course of this research. In the requirements gathering phase, interviews with potential users were conducted. There are inherent flaws with using this method to collect data. No matter how well trained or prepared, the interviewer may unintentionally guide the interviewee with certain behaviours and social cues in an unrelated direction (Opdennaker, 2006). Also, because the interview was semi-structured with some fixed and some open-ended questions, participants might have felt as though they needed their answers to fit within certain categories (Ziniel). This could have led interviewees to provide answers that they thought the interviewer wanted to hear. In fact, upon reviewing the collected interview data, several contradictory statements were discovered. To provide an example, one
participant stated they didn’t use a logbook, but when asked later in the interview how far back they looked through their logs, the participant then stated they had a logbook and looked through it at the end of each week. In addition, the design was based on what people said in these interviews versus what they might actually do which may have limited the design in some ways.

Designing for a mobile interface presented a different set of challenges. With the many different sizes of mobile device screens, selecting an appropriate device and designing for a single screen size can be a limiting success factor in the event the design were to go live. Since Apple iPhones were kindly provided by the Centre for Global eHealth Innovation to conduct research with, it was selected as the device of choice when designing the prototype. In addition, there are a limited number of mobile design guidelines currently available and there exists a lack of consistency of design elements between various mobile applications. For example, by looking at two popular apps currently available on the iPhone: ‘Google Maps’ and ‘Facebook’, they both use a pull out tray for the user to access additional functionality. However, ‘Google maps’ clearly indicates that a tray is available by using a small tab in the bottom right hand corner of the screen (Figure 32 below). The Facebook app, on the other hand, doesn’t have a clear marker; the only way the user would know that there is a tray with more info is through accidental discovery or if another user shows them.
There are also limitations with using a paper prototype for usability testing. Although participants were encouraged to use their imagination and interact with the prototype as though it was an actual mobile device, the actual mobile interaction experience can’t actually be created. This may have impacted the willingness for participants to attempt different gestures such as ‘swipe’ or ‘pull’. Tapping an icon is a relatively common interaction, however swiping across the screen or pulling out a tray are unique and specific to mobile device screens, therefore a user may only think to try these when using an actual mobile device. Using the paper prototype may have also affected participant ratings with respect to ease of data entry. However since inputting data is a feature more of the device and/or operating system than the prototype itself, data entry wasn’t evaluated when testing.

Lastly, there were also limitations of the usability procedures applied in this research. Every participant followed the scenarios in the same order, which may have influenced the results due to learning, novelty, and exploration. As noted in the results, participants clicked through more of the app during the first scenario and this was attributed to exploration. The reason for the set order was two fold: first, participants were given the scenarios in the order in which the interactions would typically occur when using the application (ie. Load reading and then review the data). Second, using a paper prototype made it difficult to allow for randomized scenarios because the number of potential screenshots and flows would increase significantly. This would have negatively impacted the testing experience, as the facilitator would have been spending a lot of time shuffling through the screenshots.

6.3 Future Research

This research is the first iteration of an ongoing design process. Future research should include another iteration of design making changes using the feedback collected from usability testing. More specifically, changes should be made to account for issues users
faced when interacting with the paper prototype. Features such as the ‘Challenges’ pull out tray and swiping to access another view of trends should be tested using a high fidelity prototype where the interaction would mimic what it would actually be like using a mobile device. With a high fidelity prototype, the design could be further tested with a pilot study with potential users to determine whether using the app can impact real health outcomes such as improving blood glucose readings over time.

In addition, the food database portion of the app was not fully developed. This was done intentionally to act as a preliminary investigation into a food/carbohydrate related feature. The feedback collected from participants could now be used as a basis for future work in this area. Measuring and tracking carbohydrate intake can be an onerous task for many T1DM patients making this an area where creative research can be quite helpful. Overall, it was found that patients currently use apps focused on diet and weight loss to measure and track their carbs. Therefore, it would be extremely helpful for them to have an integrated tool built into an app designed specifically for T1DM users.

Related to future research on a food database was the concept of a photo journal; this was also explored briefly in the literature review. The idea was to encourage users to log photos of their food along with their carbohydrate estimates. The hope would be that this would raise self-awareness of what is being consumed and also help keep track of portion sizes. To take this a step further, if users are taking photos of food, a future design of the app could leverage a social network and crowd source the carb count to measure accuracy of the users estimate. Ultimately, since the focus of this research was on creating rich data visualizations, a carbohydrate counting/food photography feature was left out of the design.

To conclude, the need for creative solutions to help support Type 1 diabetes patients is endless. It is the hope that this research can inspire new and fresh ideas for future researchers to build from.
Glossary

A1C – See HbA1c below.

bant – Originally, bant was the name of the mobile application designed and developed by the Centre for Global eHealth Innovation. As research in diabetes applications continued to expand, the name ‘bant’ was extended to be the umbrella term for all mobile applications developed for persons with diabetes.

Basal – Used to describe slow-acting insulin; a continuous dosage of insulin intended to cover the glucose output of the liver.

Bolus – The administration of a drug (insulin in the context of diabetes) that raises the concentration of it in blood to an effective level.

Gamification – The use of game based designs and thinking in non-game based applications.

HbA1c – Glycated hemoglobin. This is a form of hemoglobin that is used to measure average blood glucose over a prolonged period of time. It is primarily measured at each doctor/clinic visit.

MDI – Multiple daily injections: a manual method for administering insulin.

T1DM – An acronym for Type 1 Diabetes Mellitus.
References


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Type 1 Diabetes, 2010; Prime Group for JDRF, Mar. 2011


Ziniel, S. *Avoiding Bias in a Research Interview* (powerpoint slides). Harvard Medical School. Retrieved from:
http://www.childrenshospital.org/cfapps/research/data_admin/Site2846/Documents/Avoiding%20Bias%20in%20the%20Research%20Interview.pdf
Appendices

Appendix A – Sample Clinic Observation Notes

Notes from Observation (Sept 17, 2012)

Two patients today: Grade 10 and Grade 8 both male

Grade 10 patient: Traveled to Bulgaria for the summer. had a lot of morning and lunch time highs. Physician tried to create awareness over the lunch time highs. Asked what he usually eats for breakfast. Patient seemed uncertain in his response: Sandwiches was the only thing he mentioned. Difficult to remember all the foods he ate. The father often spoke up on his behalf by defending the challenges he faced over the summer with control. The father also seemed hesitant to make any changes to his insulin regimen, especially concerned about going low overnight. (Pump patient). In this visit, the patient was much more interactive with their log readings, often referring to the chart with the patient. Made changes to the pump meter on his own without help from the doctor. Wasn’t overly involved with the decision making of changing the insulin dosage. When asked, he would just agree and program the changes in the pump. It seemed the Dad was more in control of the care. Patient was not given his HbA1c due to the slow system, historically runs high and was expected to be >8.

Grade 8 patient: Divorced parents. Mom kept talking about how much food he’s been eating, thought he was going through a growth spurt. Physician didn’t seem that interested in relating food to readings. Mom kept bringing it up saying how he eats stacks of packaged cold cuts as a bread-less sandwich, does the same with cheese. Numbers were all over but still had an in-range HbA1c value (<7). Waking up with morning highs, doc upped the overnight insulin and also increased the carb ratio since the patient had so many high readings. Suggested putting him on a 24 hour blood glucose reader for 3 days to get a better idea of what’s happening with blood sugars since the highs/lows didn’t match with the in-range HbA1c. (Injections patient). The patient in this case did not interact with the log at all and when asked about awareness of
highs/lows, the patient did not seem to know when he was experiencing either. Mom noted that when he was high, he was grumpy and when he’s low, he stops making sense. Overall observations, doctors always refer to the printout provided by either the pump or glucometer. The pump patient brought in a paper based log (loose leaf sheets) as well that appeared to have more readings on it than the pump itself. The injections patient also brought in a paper log, maintained by the mother, in the form of a small blue booklet. She had recorded the readings and written the out of range ones in red to make them easily distinguishable from the rest. The pump patient was asked to share the log while the injection patient wasn’t asked to show it, but was shared by the mom voluntarily. The physician didn’t really give much notice/time to the paper log. In both cases, both physicians placed greater emphasis on the printed out log from the meter.

Notes from Observation (Sept 27 2012)
Grade 10 male HbA1c 8, visit with mother, went to summer camp, had Ok control and a bad high at camp with vomiting etc. Talked about amount of food being consumed due to really high carb estimates and accompanied bolus. Said that he was taking a course on nutrition and healthy eating and was trying to make healthier choices as a result. Admitting to having really large portions of food. High nighttime readings. Ate Wendy’s and ice cream the night before the visit to the clinic. Had better control at camp than he does at home which could be due to the transition from summer to school. Used the blue log book, appears to be managed by mom. Grade 10 male HbA1c 8.5, avid hockey player (daily) and visited with father. Having a hard time keeping BG’s in range and typically runs high. Does not carb count but was encouraged to do so as he has expressed interest in switching to the pump. When he’s low, he typically drinks milk and/or keeps other snacks in his bag (granola bar) to fix the problem. Usually low at night due to physical activity. Takes at least 4 readings a day but skips his lunch reading due to timing at school and still has problems with BG control. Uses the blue log book to keep track of readings. Almost entirely self-sufficient when it comes to care. Referred to the paper print out of BG reading for the entire appointment.
13 yo female HbA1c 8 (down from 8.5), avid dancer (4 days a week), divorced parents. Food not the focus of the conversation though some discussion around the timing of snacks and number of meals taken per day was asked. Have poor-ish control with trouble dealing with lows now that dance has started. Used meter print out to guide the discussion, no paper based log was shared by patient/parents. Overall notes: Doctor expressed interest in having an app tied into bant that would provide a means for patients to enter foods eaten and calculate carb estimates.
Appendix B: Preliminary Sketches & Screenshots
### Appendix C – Interview Data Analysis

#### Information Sharing Practices

<table>
<thead>
<tr>
<th>Theme</th>
<th>Sub-Themes</th>
<th># Of Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motivation</strong></td>
<td>Sharing information and helping others with diabetes makes patients feel good and helps them develop a better understanding of the disease and their bodies.</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Patients share information because they want to help others emotionally, and to raise awareness.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Information is only shared when prompted.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sharing information doesn’t help in any way.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Recipient (Who)</strong></td>
<td>Share information with parents and significant others</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Share the majority of information with caregivers</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Share experiences with support groups</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Don’t share information with strangers</td>
<td>1</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>Information is shared approximately once a month</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Information is shared a couple times a week</td>
<td>1</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>Displaying the community BG average, or setting other community goals can be motivating</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Face-to-face interaction in the form of mentorship programs, camps, etc is preferred</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Not interested in a social community for support; don’t want to know how others are doing</td>
<td>2</td>
</tr>
<tr>
<td><strong>Questions</strong></td>
<td>Use Google, or ask someone (i.e. Friend, Nurse etc) to answer questions about diabetes between scheduled doctors visits</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Hold questions until the scheduled doctors appointment</td>
<td>1</td>
</tr>
<tr>
<td><strong>Online</strong></td>
<td>Have an online presence (i.e. Twitter, Facebook, Blog, etc) but don’t use it to communicate diabetes related information</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Don’t feel the need to participate in online communities</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Contribute regularly to online communities</td>
<td>1</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td>Share BG readings, experiences, and activities</td>
<td>4</td>
</tr>
</tbody>
</table>

#### Data Visualization

<table>
<thead>
<tr>
<th>Theme</th>
<th>Sub-Themes</th>
<th># Of Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tools</strong></td>
<td>Don’t use any tools to support self-management practices</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Use a hand written log of BG, activities, insulin, and nutrition</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Use a mobile app such as ‘Lose it’ or ‘My Fitness Pal’ to track foods consumed</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Use an online tool that comes with the pump</td>
<td>3</td>
</tr>
<tr>
<td>Data Tracked (Content)</td>
<td>Frequency of Data Loads</td>
<td>Reflection Period</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Record carbohydrate and/or food intake</td>
<td>Recording data is time consuming, only download/record in anticipation of a clinic visit (every 3-6 months)</td>
<td>1 week to a month is the furthest back logs are reviewed</td>
</tr>
<tr>
<td>Record BG readings</td>
<td>Load data from pump once a week</td>
<td>Occasionally look back a year to verify odd trends</td>
</tr>
<tr>
<td>Record insulin dosage</td>
<td>Record data only when required to do so</td>
<td>Look back through data with Physician only (every 3-6 months)</td>
</tr>
<tr>
<td>Record exercise and activities</td>
<td></td>
<td>Never look back through logs</td>
</tr>
<tr>
<td>Don’t record BG readings at all</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Track A1C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design Elements</th>
</tr>
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<td>Theme</td>
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<tr>
<td>Colour Meanings</td>
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<tr>
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<td></td>
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<tr>
<td>Important Statistics</td>
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<td></td>
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<tr>
<td>Desired Features</td>
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<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Data Organization</td>
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</table>
### Historical Data

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Monthly view of readings isn’t helpful, however, drilling down to outliers is helpful</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Looking at data past a month is not useful; 7, 14, and 21 days is all that is required</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Going as far back as 90 is important</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

### Rewards and Motivation

<table>
<thead>
<tr>
<th>Theme</th>
<th>Sub-Themes</th>
<th># Of Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>Fear of future complications motivates patients to stay on track with self-management practices</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>General good health and feeling good motivates patients to stay on track with self-management practices</td>
<td>4</td>
</tr>
<tr>
<td>Goals</td>
<td>Set goals around A1C</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Set goals around general health (i.e. being active, maintain good health, etc.) and aim to meet them</td>
<td>4</td>
</tr>
<tr>
<td>Rewards</td>
<td>Receiving rewards would help keep patients stay on track</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Immediate positive feedback would be motivational</td>
<td>1</td>
</tr>
</tbody>
</table>
Appendix D: User Input & Challenge Screens
Challenges

**A Day in Range**
(minimum of 3 readings/day)

- 60%
- Sa great! Try again tomorrow

**A1C**
Keep HbA1C in range for next Dr's visit

---

**Challenges**

**All In Range**
>80% of all readings are in range

- 19%
- 12%
- 53%
- You did it!
Appendix E – Usability Testing Protocol

Introduction

Hi, my name is Lisa. I’d like to thank you for participating today. We’re in the process of designing a mobile diabetes self-management application and we would like to get some input from you. I’ll be presenting you with several scenarios that I’d like you to complete using a paper prototype. There are no right or wrong answers. Feel free to ask questions for clarification. Your comments are very important and they will help us understand your experiences. As outlined in the consent form, this session will be recorded so we can clearly record your comments.

Before we get started, please fill out this brief pre-study questionnaire.
<Provide a copy of the questionnaire for the participant to complete>
Part 1 - Pre-Study Questionnaire

1. In what age range do you belong?
   <25 years    25-34 years    35-44 years    45-54 years    55-64 years    >65 years

2. Are you?
   Female    Male

3. How long ago were you diagnosed with Type 1 Diabetes? ______________________

4. How are you currently managing your diabetes?
   Pump    Subcutaneous Injections    Other: ______________________

5. How comfortable are you with using mobile devices and/or mobile applications?
   Not Comfortable    Somewhat Comfortable    Comfortable    Very Comfortable

6. Do you currently own a mobile device (ie. Cell phone, iPod touch etc.)?
   Yes    No

7. If yes, do you currently use mobile apps to help you manage your diabetes?
   Yes    No

8. If yes, please list the app(s) below:
Part 2 - Scenarios

Bant Description

The purpose of this mobile health application is to provide support for adult T1DM patients. It is to be used multiple times per day to track various diabetes health measures such as blood glucose, carbohydrate intake, insulin etc. Additional features in the app are to be used to support self-management related decision-making and provide motivation to maintain overall good health and wellbeing.

Scenarios

1. It’s dinner time (8pm) on May 1, 2013 and you want to record your most recent BG reading along with other related information. Open the app and record the info in the following order:
   BG – 5.0 mmol/l
   Carb Count – 20 grams
   Insulin Bolus – 3.5 units
   Activity – Yoga
   Emotion - Happy

2. You’ve had your doctor’s visit earlier in the day. Since your goal is to keep your A1C (8.1) in range, you’d like to record it in the app to keep as a reminder.
3. Since it’s the end of the day, you want to have a look through your carbs, insulin, activity, and how you felt throughout the day. Also, comment on the community blood glucose.

4. You remember you wanted to share some information with your sister since she’s been bugging you for updates lately. Email her the details of your day from within the app.

5. It’s the first day of May and you want to see how your blood sugars looked the month before (April). Have a look through your bant log book to see how you did. In particular, you want to see what happened on April 23rd.

6a. You’ve made a mental note that your readings before breakfast have been a bit out of range lately. You’re curious what your average blood glucose at breakfast has been for the past week. Use the bant app to find out.

6b. Now that you’ve had a glance through what your readings looked like for the past week, you want to know the percent of times you’ve been in and out of range as well
7a. You’re interested in completing some of the challenges that are built into the app. Explore the various challenges for each tab and find out how far you are from achieving them.

7b. Now that you’ve had a look through some of the challenges, you’re wondering how many you’ve completed to date in total. You’re also curious how you’re doing in comparison to others using the app; find out where you are on the leaderboard.

8. It’s a special occasion and you’re trying a food you’ve never had before; BiBimBop (a Korean dish of rice with mixed vegetables). Have a look through the food database in the app to try and get an idea of the carb estimate for this new dish.
### Part 3 - System Usability Scale

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

(Brooke, 1996)
Part 4 – Post Test Questionnaire

1. Please indicate how easy it was to use/understand the following features of the mobile application:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Very Difficult</th>
<th>Difficult</th>
<th>Normal</th>
<th>Easy</th>
<th>Very Easy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging a BG &amp; related info</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day View Summary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bant Book – Calendar view</td>
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<tr>
<td>Trends – Scatter plot view</td>
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<tr>
<td>Trends – % in/out view</td>
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<td></td>
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<tr>
<td>Challenges</td>
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<tr>
<td>Leaderboard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information Sharing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food/Carb Feature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Would you use this application to complement your daily self-management routine?

Not Likely  Somewhat likely  Likely  Very Likely

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

________________________________________________________________________

________________________________________________________________________

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

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________
5. Please rate the scenarios below on a scale of 1 to 5 for how realistic they are to you:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>It’s dinner time (8pm) on May 1, 2013 and you want to record your most recent BG reading along with other related information. Open the app and record the info in the following order: BG – 5.0 mmol/l, Carb Count – 20 grams, Insulin Bolus – 3.5 units, Activity – Yoga, Emotion - Happy.</td>
<td>5</td>
</tr>
<tr>
<td>You’ve had your doctor’s visit earlier in the day. Since your goal is to keep your A1C (8.1) in range, you’d like to record it in the app as a reminder.</td>
<td>5</td>
</tr>
<tr>
<td>Since it’s the end of the day, you want to have a look through your carbs, insulin, activity, and how you felt throughout the day. Also, comment on the community A1C.</td>
<td>5</td>
</tr>
<tr>
<td>You remember you wanted to share some information with your sister since she’s been bugging you for updates lately. Email her the details of your day from within the app.</td>
<td>5</td>
</tr>
<tr>
<td>It’s the first day of May and you want to see how your blood sugars looked the month before (April). Have a look through your bant log book to see how you did. In particular, you want to see what happened on April 23rd.</td>
<td>5</td>
</tr>
<tr>
<td>You’ve made a mental note that your readings before breakfast have been a bit out of range lately. You’re curious what your average blood glucose at breakfast has been for the past week. Use the bant app to find out.</td>
<td>5</td>
</tr>
<tr>
<td>Now that you’ve had a glance through what your readings looked like for the past week, you want to know the percent of times you’ve been in and out of range as well.</td>
<td>5</td>
</tr>
<tr>
<td>You’re interested in completing some of the challenges that are built into the app. Explore the various challenges and find out how far you are from achieving them.</td>
<td>5</td>
</tr>
<tr>
<td>Now that you’ve had a look through some of the challenges, you’re wondering how many you’ve completed to date in total. You’re also curious how you’re doing in comparison to others using the app; find out where you are on the leaderboard.</td>
<td>5</td>
</tr>
<tr>
<td>It’s a special occasion and you’re trying a food you’ve never had before; BiBimBop (a Korean dish of rice with mixed vegetables). Have a look through the food database in the app to try and get an idea of the carb estimate for this new dish.</td>
<td>5</td>
</tr>
</tbody>
</table>

6. Please share any other comments in the space provided below:
## Appendix F – Usability Test Raw Data

<table>
<thead>
<tr>
<th>Feature</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging a BG &amp; related info</td>
<td>E</td>
<td>VE</td>
<td>VE</td>
<td>E</td>
<td>VE</td>
<td>VE</td>
</tr>
<tr>
<td>Day view summary</td>
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<td>VE</td>
<td>VE</td>
<td>E</td>
<td>VE</td>
<td>E</td>
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<tr>
<td>bant Book – Calendar view</td>
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<td>VE</td>
<td>N</td>
<td>VE</td>
<td>E</td>
</tr>
<tr>
<td>Trends – Scatter plot view</td>
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<td>N</td>
<td>VE</td>
<td>D</td>
<td>VE</td>
<td>E</td>
</tr>
<tr>
<td>Trends - % in/out view</td>
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<td>E</td>
<td>VD</td>
<td>N</td>
<td>D</td>
<td>N</td>
</tr>
<tr>
<td>Challenges</td>
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<td>VD</td>
<td>D</td>
<td>N</td>
<td>D</td>
<td>VE</td>
</tr>
<tr>
<td>Leaderboard</td>
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<td>VE</td>
<td>VE</td>
<td>E</td>
<td>VE</td>
<td>VE</td>
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<tr>
<td>Information sharing</td>
<td>VE</td>
<td>VE</td>
<td>N</td>
<td>N</td>
<td>VE</td>
<td>E</td>
</tr>
<tr>
<td>Food database</td>
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<td>VE</td>
<td>E</td>
<td>E</td>
<td>VE</td>
<td>E</td>
</tr>
</tbody>
</table>