GlucoGo: A Diabetic Tracking and Coaching Application for Mobile Phones

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Abstract

Diabetes is a chronic disease that requires ongoing monitoring and careful attention to diet, exercise, and other lifestyle factors. A great number of technological tools exist for helping patients to track blood sugar levels, the key indicator of successful diabetic management. Unfortunately, these tools fall short in meeting the wide ranging needs of diabetic patients including simplicity of data input, interpretation of blood sugar readings, motivation and personal empowerment, coaching and learning opportunities, portability, easy to read progress indicators, and more. This paper will introduce the disease, analyze the many challenges faced by diabetics, evaluate current products on the market, explore current related research, and make the case for a diabetic application for mobile phones that would address the deficiencies of competitor products. The proposed product, GlucoGo, will be profiled and its feature base outlined in the context of a theoretical diabetic decision cycle.

Introduction

Diabetes is a disease that affects approximately 20.8 million people. Though descriptions of the disease and its pathology could fill entire books, the American Diabetes Association offers this concise description: "Diabetes is a disease in which the body does not produce or properly use insulin. Insulin is a hormone that is needed to convert sugar, starches and other food into energy needed for daily life. The cause of diabetes continues to be a mystery, although both genetics and environmental factors such as obesity and lack of exercise appear to play roles." Complications of diabetes are wide ranging, but can include heart disease, kidney problems, circulatory issues, blindness, skin problems, depression, and gastrointestinal issues. The ADA also estimates that nearly 54 million people have some degree of insulin resistance which is often termed pre-diabetes. These people are at increased risk of developing diabetes later in life, though improvements in diet and exercise can decrease this risk. A third category of diabetes known as gestational diabetes, effects 4% or women or around 135,000 cases per year. Gestational diabetes is a form of the disease that only develops and continues during pregnancy, largely due to the drastic hormonal changes experienced during this period. Because of the short-term nature of gestational diabetes, it is not known to create the same complications as regular diabetes, but has been shown to increase the risk of birth defects, stillbirth, and over-sized babies. Like pre-diabetes, those diagnosed with gestational diabetes are more likely to develop regular diabetes later in life. **(1)**

Diabetics are often classified as Type 1 or Type 2. Type 1 diabetics are those whose bodies have completely stopped making insulin. As a result, they must inject insulin one or more times per day or risk seizures or diabetic coma. The onset of Type 1 diabetes is usually in childhood. In a Type 2 diabetic, the body still produces insulin, however the amount of insulin is insufficient or the body cannot efficiently use what is made. The onset of Type 2 diabetes has typically been in the older (60+) age range, though the disease is beginning to appear earlier and earlier. The ADA estimates that approximately half of the 20.8 million diagnosed diabetics are over 60, and the other half between 20 and 60. This change in the pattern is often attributed to the rise in obesity amongst the general population, but nobody knows for sure. **(1)** Type 2 diabetics typically keep the disease and its complications under control through lifestyle changes that may include a low carbohydrate diet, exercise, and oral medications. **(2)**

While Type 1 diabetes has been a fairly rare condition through the years, and Type 2 diabetes generally considered a complication of old age, the statistics show some significant shifts in demographics. The ADA estimates that approximately half of the 20.8 million diabetics are between the ages of 20 and 60, and about 10% of the 20.8 million are young adults between the ages of 20 and 35. There are also about 175,000 diabetics under 20 years of age, primarily with type 1 diabetes which typically has its onset between 10 and 14 years of age. Cases of pre-diabetes are rising at astounding rates as well, especially among the youth population. It is estimated that about 2 million teenagers aged 12 - 19 are already experiencing the insulin resistance that may lead to full-blown diabetes as an adult. This rise in cases of diabetes and pre-diabetes is most often attributed to the general rise in obesity. **(1)**

For both Type 1 and Type 2 diabetics, the mainstay of treatment revolves around measuring blood sugar levels one or more times a day, and using the results to decide on a course of action. Use of glucometers to measure blood sugar levels is common practice and has been shown effective in increasing a patients awareness of their condition. **(3)** A patient uses a small needle (called a lance) to prick their finger or other body part to get a drop of blood. The blood sample is placed on a special strip, and inserted into the glucometer which analyzes the level of sugar in the blood and assigns it a numerical result. ADA guidelines are that diabetics use a glucometer to test their blood sugar levels at least 3 times a day, though this may be increased depending on the individual severity of the condition. **(4)** A new category of glucometer has become available in the last few years called a continuous glucose monitor. These devices embed a sensor under the skin of the patient which automatically takes blood sugar readings at a specified interval, negating the need for manual finger pricking. The sensor relays values to an external glucometer. Unfortunately, these devices are still in their infancy and not widely used. Part of this is that insurance companies will typically only approve the device except for Type 1 diabetics and cost is prohibitive or seen as overkill for Type 2 diabetics.

Challenges of Treating Diabetes

When a person is diagnosed with diabetes, they are typically assigned to work with a health professional known as a nutritionist or diabetic counselor. This health-care provider helps the patient to determine a custom diet and exercise plan, schedule of blood sugar testing, target blood sugar ranges, insulin doses, etc. The diabetic counselor also takes the lead in teaching the patient about nutritional values of foods, how/what to eat, how to use tracking devices, and how to give injections. To help the counselor give the best advice, patients are often asked to record all of their blood sugar readings in a log, and may also be asked to keep a food diary or record insulin amounts. Patients must send this data to their counselor on a weekly basis or other prescribed schedule. Without this data, the counselor can only offer general advice, but not specific, customized advice. It is widely acknowledged that Type 2 diabetes is best understood when long-term patterns can be assessed through detailed logs of blood sugar levels, diet, and exercise. **(5)** For diabetic counselors, getting accurate data to work with can be quite a challenge. Tracking individual actions is very difficult. Food diaries are a common suggestion by health care professionals, but are "rarely strictly followed" for a number of reasons that will be discussed later. Blood sugar testing, especially by finger, is still considered painful and inconvenient by many. Without frequent sampling and detailed food diaries it is difficult to see daily patterns. **(2)**

The challenges are even greater for the patient himself. One of the first obstacles often encountered is a denial of the disease in the first place. Newly diagnosed diabetics often display no symptoms. True complications may not show up until many years later. The impact of one's choices may not be immediately apparent with diabetes as in many other diseases. This can lead to false assumptions about the level of control a person is keeping and make lifestyle and dietary changes difficult to introduce and follow. **(6)** It has also been shown that a person's personal beliefs about diabetes largely effects what changes are made in response to it. **(7)** When left to their own devices, people tend to evaluate data or evidence in a way that supports their personal hypothesis. This is known as confirmation bias **(8)** and can lead to enforcement of incorrect assumptions and behaviors that are at odds with the patients true needs. **(2)** Health-care providers who take the time to understand these attitudes and self-defeating behaviors may be able to offer better guidance to their patients, **(9)** but often treatment focuses around blood sugar numbers and other areas that can be quantitatively measured.

For most diabetics, the disease must be thought about and managed every single day. Mamykina et. al describe 3 broad areas of diabetic management. First, is the "need to become a detective". Individual analysis of the condition is required by patients due to variability from one person to another, as health-care providers are unable to create a one-size fits all regimen that works for all patients. Patients must learn how to recognize the symptoms of low/high blood sugars and see their personal reactions to various foods, and other lifestyle choices. The second aspect of management is the "flexible negotiation of actions". Because the disease is ongoing/chronic, people try to "flexibly negotiate their actions" (ie. see what they can get away with) rather than adopting 100% risk free methods. Helping individuals find balance between deprivation and healthy habits is a chief goal of diabetic education. The third aspect of management is the "importance of motivation". Managing diabetes is difficult. Patients often get discouraged, leading to low levels of compliance with established practices and advice. Strict dietary guidelines can make travel, work, and family gatherings particularly challenging and uncomfortable. **(2)**

Additional challenges fall into the realm of logistics. Though some people have very consistent waking, mealtimes, exercise regimes, diets, and sleep times, most people experience at least some change in their schedules and habits from day to day with many experiencing drastic variances. For those in the latter two categories, simply remembering to eat or take a blood sugar reading at a certain time is difficult. It's also easy to forget to record foods eaten in a diary immediately following ingestion and it has been shown that later recall of foods eaten is unreliable, despite user attempts at accuracy. **(10)** The patient is also faced with the task of figuring out the nutritional value of foods eaten to ensure that carbohydrates, proteins, and fats are consumed in appropriate amounts. Additionally, users have the burden of relaying all this data to their diabetic counselor. Because of incompatibilities between many capture devices and inadequate software tools, the majority of patients must hand-write their data in a paper log and fax the info to their health-care provider, or call it in each week. Even if the user buys a glucometer that automatically syncs data to a PC based software program, it is unlikely that the diabetic counselor has the same program. This whole process is tedious and time consuming.

Analysis of Current Diabetic Tools

As previously mentioned, glucometers are the primary tool used by diabetics to measure and track the disease. There are likely hundreds of different varieties of glucometers on the market, but most are remarkably similar. Typically they store between 100 and 500 readings and assign a date and time stamp to each reading. In most cases, one has to scroll using arrow keys on the device in order to review previous numbers. There is no way to view summaries, graphs, or reports showing trends. Most meters also give no indication on whether a test result is good or bad. Users must make this interpretation on their own or wait until their diabetic counselor reviews the numbers. Glucometers are essentially just capture devices.

A special type of glucometer known as continuous blood glucose monitors eliminate the need for painful and tedious finger pricking by diabetics. Rather, they gather blood sugar readings on a continuous basis using a small sensor embedded under the skin of the patient. These include products such as the Freestyle Monitor **(11)**, Guardian **(12)**, and The Seven System **(13).** The sensors generally test at a set interval (like every minute or every ten minutes), and send this information to an external receiver that is similar in size and function to the manual glucometers on the market. These continuous blood glucose monitors have many advantages for the patient in terms of reducing the testing burden and collecting many more readings than would be physically possible using traditional devices. Still, they are subject to the interface limitations of manual glucometers, including a focus on numbers rather than their interpretation, the inability to see trends, no mapping between diet and exercise and blood sugar levels, and no coaching on what to do about a particular reading. These devices primarily reduce the need for manual blood sugar testing.

To address some of the limitations of glucometers, manufacturers of some of the more popular devices like OneTouch **(14)** have started offering computer based software that can upload data from the device to a PC using USB or infrared technology. While this software is useful for seeing trends through charts and graphs, it does not help users deal with issues in real time. And since analysis may be happening far after an abnormal blood sugar reading, the user's opportunity to learn from the experience declines because they've probably already forgotten the circumstances surrounding the issue, what they ate at the time, etc. The lack of mobility is one of the key drawbacks for this category of software.

A long list of other companies offer software similar to what the glucometer manufacturers provide, with similar strengths and limitations. Additionally, a number of companies have offerings that work on PDA's and smart-phones such as the Diabetes Pilot **(15)** and GlucoBase **(16)**. Unfortunately, not everyone chooses to use or can afford this category of handheld device. Nor does everyone have a computer available to sync the data to, as is typically required to make use of the full functionality of these applications.

Some companies have come to the same conclusion as this researcher that mobile phones are the logical and ideal diabetic tracking tool. Unfortunately this concept is still fairly new, so there aren't as many existing products to survey. Two such products are profiled below.

DiabetesMobil is a diabetic tracking application for Nokia mobile phones available through a German company. **(17)** This application focuses mainly on numerical analysis of manually entered values for blood sugar levels, insulin taken, and carbohydrates consumed. The output is a series of graphs and charts that will appeal to scientific types with a strong grasp of statistical math, but will likely be quite overwhelming to users without this comfort level. This device addresses the portability issue and desire to use a device that most people already carry.

WellDoc is a mobile phone application for diabetics that is currently undergoing clinical trials. WellDoc seeks to provide coaching, reminders, and a way to communicate logged data to a third party health professional. **(18)** Unfortunately WellDoc is data intensive from the user standpoint. Users are required to manually enter the nutritional values of foods eaten. This puts the burden of carb counting on the patient, a process that is tedious and likely to be highly inaccurate. Because there is no food log, patients do not learn the impact of specific foods on their blood sugar. Blood glucose levels can be manually entered or uploaded from a compatible device. Users are warned when a measure is high or low, and are walked through tips on how to adjust to appropriate levels. The user can't see their progress over time, however, without the use of server software that is hosted by the developer and accessed by the medical provider (and these reports are highly numerical and difficult for a non-specialist to interpret). In general, this system is a step in the right direction and has clearly put usability at the forefront of its design, but is still too cumbersome for the patient and requires a high level of involvement from a medical professional.

What Diabetic Patients Need to be Successful

Unfortunately, many of the current diabetic technologies fall short of patient needs in one or more key areas. First and foremost, diabetics need tools and processes that remove the challenges of collecting data in the first place. The more automated the process of collecting blood sugar readings, food entries, and other measurements, the less time a patient has to spend inputting data. Time is precious, and patients would be better served if their cognitive focus went to reflecting on the data and taking appropriate actions rather than gathering the data in the first place. Many diabetics don't take responsibility for reflecting on how their choices effect the daily patterns shown in the data. This may be partially due to our current system which puts much of the responsibility for diabetic analysis on the health-care provider. Empowering patients to take a much more active role in this analysis and in choosing appropriate actions would undoubtedly have a positive impact on outcomes. Patients who can see "how their existing practices lead to instances of poor health" are more likely to adapt positive attitudes and behaviors. **(6)** For both health professional and patient, diabetic management is largely a case of trial and error, since no two people respond in an identical fashion to the same treatment. Revising behaviors based on trial and error is dubbed "reflection-in-action". This reflection allows people to focus on understanding how and why their beliefs or actions are a certain way. **(19)** For diabetics, reflection is likely to occur when there is a failure of some kind, such as a high blood sugar reading **(20)** and is likely to take the form of wondering what actions led to the abnormal reading. **(6)**

Current glucometer technology is a form of "memory capture device" as it records the quantitative physiological state. These devices provide data about how a patient is doing, but no analysis of why levels are high or low. **(6)** Glucometers do not capture the qualitative aspects of the disease such as the adjustments to diet, exercise, and lifestyle that are necessary for successful management. Thus, glucometers can not address the cause, only the effect. Additionally, those that are new to the disease, may not understand what a number means, and are thus unlikely to take timely action to correct it. Many diabetics could benefit from a device that not only gave a number, but coached them as to what the number meant and what appropriate actions to take. Relevant just-in-time information may influence positive health practices. **(21)**

There are a number of great food databases available both online and for purchase for PC or PDA. Users can look up foods and get nutritional data on them. Some programs allow you to add looked up items into a food diary. Unfortunately, there are no products that compare food diary entries side by side with blood sugar readings, so that users can see the cause and effect of specific foods. Having this capability would further empower the diabetic to seek their own answers rather than relying on a third party.

Proposed Solution: GlucoGo

In order to address the many challenges of managing diabetes especially among the evolving younger diabetic demographic, a new product tentatively called GlucoGo is presented. In brief, GlucoGo is a mobile phone application (ie. virtual assistant) that will help diabetics track diet and blood sugar readings, while learning healthy habits through customized coaching and positive feedback. There are two primary goals with the creation of this application. First is to create a simple all-in-one solution that minimizes the administrative burden of tracking and monitoring the disease. The second goal is to reduce or eliminate the reliance on health-care professionals by providing users with the individualized coaching and motivation they need to be successful.

Getting Started and Setting Goals

Before users can get busy managing their diabetes using the GlucoGo system, the system will need some information about the individual. Without this, the virtual assistant would be able to offer only generic advice, and track progress against a specific set of guidelines (that may or or may not match the patients actual program). GlucoGo will collect this information via a wizard that walks users through the process. Some users may have set goals as defined by themselves or a health-care provider and simply need to type them in; others may need assistance establishing these baselines through tutorials or the system calculating targets based on recommended guidelines. Experienced diabetics may opt to skip the setup wizard altogether, and simply fill in their data via a form, but this is not the preferred method since accuracy is so important. GlucoGo will ask a few preliminary questions to determine the user's knowledge level before sending them down the simplified path. The exact flow of the setup wizard will be dependent on user responses, with many possible scenarios. Here is a likely first question with a sample of where the questions might lead. This is not a complete flow with all possible responses.

1. What type of diabetes do you have? Type 1, Type 2, Gestational, Pre-Diabetes, Guide Me
   - If Type 1, ask - How frequently do you take insulin? As needed, After Meals, Upon Waking, At Bedtime, All of the Above, Guide Me
     - If NOT As needed or Guide Me, ask - Do you inject a fixed amount of insulin? Yes (if so, what amount?), No, or Guide Me
     - If As needed, ask - By default, GlucoGo will notify you to inject insulin if a blood sugar reading exceeds your target by 20 percent. Is this okay? Yes, No, Modify Target, Guide Me
     - If Guide Me, launch Intro to Diabetes Tutorial
   - If Type 2 or Pre-Diabetes, go onto next question
   - If Gestational, ask - When is your due date?

- What kind of glucometer are you using? Continuous, Manual, Guide Me.
  - If Manual, ask - Does your Glucometer have a method for sending data wirelessly? Yes, No, Guide Me.
    - If Yes, say - Put your glucometer into the send mode (consult manual if necessary). When ready, click here. GlucoGo will attempt to communicate with your device.
    - If No, say - That's too bad. You'll have to manually enter your blood sugar readings into the GlucoGo application. You may want to consider changing to a glucometer that can transmit data, such as the one's listed here:
    - If Guide Me, launch Glucometer Tutorial

and so on and so forth .....

Once users have completed the setup wizard, they will be presented with a summary screen where they can modify responses or go back and view tutorials if they are still uncertain.

Due to the detailed setup requirements, it may be best to run through the setup wizard at the website where patients download the GlucoGo software. Then a configuration file could be pushed to the phone. The advantage of this is that user's would have a backup of the configuration stored online in case of loss or damage to their phone. Also, the tutorials that are accessed when a user chooses "Guide Me" from a question's responses would have to be dumbed down and lack graphics in order to work with the memory limitations of most mobile phones. The logistics of this will still need to be worked out.

Using the GlucoGo Virtual Assistant

Mamykina et. al found through a series of qualitative studies with diabetics, that success in managing the disease greatly depends on the patients ability to see correlations between their activities and resulting blood sugar levels. This reasoning generally follows a cyclical decision making process. The cycle is as follows:

1. monitoring blood sugar level
2. noticing the change in blood sugar
3. attributing the change to a particular action(s)
4. modifying behavior based on learned inferences
5. keeping track of performed actions
6. monitoring blood sugar level (loop to step 1) **(2)**

Since correlating cause and effect is a key goal of the GlucoGo system, this cycle will be used as the model and structure for describing the different features and how they align to the application's purpose.

Monitoring Blood Sugar Levels

The GlucoGo system will allow a flexible infrastructure for obtaining blood sugar readings in order to work with the various glucose meters commercially available. Users can manually enter readings if they choose, but may also obtain readings automatically from glucometers that can send information wirelessly through Bluetooth or infrared technologies or through continuous glucose monitors. A fourth option will allow users to measure blood glucose from within the phone itself using HealthPia's Glucopack. **(22)** Though it will not be possible to support every glucometer on the market, efforts will be made to offer a variety of choices.

Noticing the Change in Blood Sugar

There are several different ways that users may want to see the results of their readings and GlucoGo will allow users to set preferences in this regard. A person who gets their readings from a continuous blood glucose monitor is not going to want to look at the readings or be notified of every reading collected, as these devices may collect over one thousand samples per day. A person in this circumstance may only want to be notified when a reading is abnormally high or low, based on a range they have set in the preferences. Users who test only periodically will probably want to see the number each time, but this too is flexible. Experienced diabetics who have their diet largely under control may only want to be informed of abnormal readings, but a new diabetic will probably want to see each reading.

As previously discussed, simply reporting a value is insufficient information for many diabetics who may not understand what a number means. This is also compounded by the fact that the meaning of a blood sugar value is dependent on when it was obtained. Acceptable ranges will be lower if the person has fasted for 8-12 hours, than if they had eaten one hour ago, or two hours ago. GlucoGo will attempt to determine the context of the number, and present it in a format that indicates to the user how close to target ranges the number falls. For example, if the patients target fasting range is a value between 75 - 95, the number would be returned with a green box if it was within the middle 25%-75% of the range, with a yellow box if it was in the top or bottom 25%, and red, if it was outside of the defined range. This will give the user a quick visual indicator to let them know if they are on track. For color blind users, an appropriate symbol or word will accompany the numerical value to provide this same kind of information.

GlucoGo users will also be able to pull up graphical charts that show trends in blood sugar readings over time. Users can choose whether to view these graphs manually, or to have the application notify them when an interesting trend is identified. For example, dinner readings for the past five days may have been consistently 20% lower than those for lunch or breakfast. While this could be a good thing, it could also signal a problem. If a user is only seeing individual numbers, however, they will never have the opportunity to reflect on this trend to determine whether some modification should be made.

Users of the GlucoGo system will have a third option for viewing blood sugar readings through the use of ambient display technology. An ambient display makes use of changeable mobile phone wallpaper that conveys information about the user's performance against predefined goals. For example, the phone could track performance against target blood sugar ranges over the course of a week. Each day, a portion of a rainbow might show on the phone background. If the user is doing well, the rainbow would grow in length and become brighter in color. It would stay faded and almost disappear if the user is not doing so well. At the end of the week, a pot of gold may appear at the end of the rainbow if the user has met the week's goals. Use of such an ambient display will provide users with a quick view of their progress in a way that does not demoralize, and that may motivate them to do better. "Visualization of information related to communication can help to increase the user's awareness and hence make it a persuasive technology to push for a certain behavior." **(23)** And each time the user glances at their phone display to pick up a call, place a text message, or check their calendar, they will be subtly reminded of their progress.

Attributing the Change to a Particular Action(s)

For most diabetics, food items consumed will have the greatest impact on blood sugar readings. It is at this point that having a food diary becomes most helpful. GlucoGo will present a number of options that will ease the logging of food items so that these can be compared side by side with blood sugar readings. This is essentially looking at both cause (food) and effect (blood sugar level).

First, users will have the option of using bar-code technology to scan food items into their food diary. At the present time, this is best achieved using a phone add-on called Socket Scanner, though bar-code scanning via the phone's built in camera is currently being researched by a number of parties. All canned, boxes, and packaged food items contain a UPC bar-code that is a unique identifier for that food item. When a user scans in a UPC code, that food item will be looked up against the Internet UPC database , an open-source collection of over 600,000 food items. **(24)** Optionally, the nutritional values of these foods can be pulled into GlucoGo for analysis.

Naturally one cannot obtain a bar-code from a head of lettuce or from an item purchased at a restaurant. Users have the option of taking a picture of the food consumed using the camera phone in order to add it to the food diary. The photo can serve as a reminder to manually look up the food in an appropriate database at a later time if nutritional value is desired, scan the bar-code for it later (if they have taken their lunch for example and the package is at home), or simply keep the photo as a reminder of what was eaten in the event that an abnormal blood sugar reading comes about as a result.

GlucoGo will also support voice recording food items into the food diary. Like the photos, this can be used as a reminder to input a more detailed record later, or to serve as a place holder in case an abnormal reading needs additional data to interpret. Lastly, users can manually look-up foods in a food database through a simple search interface and add them to their food log.

In all cases, users can choose the degree of food tracking appropriate for their lifestyle, severity of diabetic condition, and their experience with the disease. Foods entered will receive a time/date stamp and the application will attempt to associate with a particular meal of the day based on user preferences/history. Users can over-ride these time stamps if they are logging foods at a later time because they forgot to do it at the appropriate time. With every abnormal blood sugar reading reported, users will be able to view the food item(s) eaten in the time periods closest to the reading in question. For some users, simply seeing the food eaten will be enough to create understanding of why it caused a problem. In other cases, further explanation might be needed by the user to understand why the food might have been problematic. This will be explored further in the next section.

GlucoGo will also offer users the ability to track physical activities and to keep a short journal entry each day that might cover areas such as mood, amount of sleep, or whether medications were skipped. All this data can be pulled up and reviewed when analyzing a trend or a specific blood sugar reading.

Modifying Behavior Based on Learned Inferences

This stage of the cycle will demonstrate the most powerful features of GlucoGo, and also the most complex. All of the previous steps have focused on the collection of data and association of that data to particular actions. For the user, the real learning comes about from individualized coaching that has traditionally fallen to health-care professionals to provide. GlucoGo users will be able to obtain a great portion of this coaching from the device itself, and only escalate to a diabetic counselor when the issue cannot be resolved satisfactorily or if trends are showing a condition that is consistently and/or dangerously high or low.

Take the following example. A user is reviewing a chart showing their progress for the current week, and notices a value highlighted in red (which signifies a high reading). They ask GlucoGo to analyze the data for possible causes. GlucoGo pulls up the food diary and reports that a bowl of clam chowder was recorded one hour before the reading in question and may be the culprit. The user is surprised by this, as they had assumed that soup was a healthy food. GlucoGo offers to return a nutritional analysis of the soup. The application may then report back that Clam chowder is traditionally made with lots of potatoes which are high in carbohydrate and thus cause blood sugar spikes. GlucoGo might further suggest to the user that if they eat this item again that they eat around the potatoes. Or if making the recipe themselves, leave this ingredient out or increase the amount of clams as the high protein content will help to counteract the effects of the potatoes. If that kind of detailed information about clam chowder is not available to GlucoGo, it can at minimum report back on the high carbohydrate value of the food, and suggest that this be examined before the user consumes this food again.

The user in this case makes a mental note to leave the potatoes out of their clam chowder recipe, and flags the food item in their food diary for future reference. The next time this food is consumed, GlucoGo can remind the user that it was a suspicious food last time it was eaten. The user can compare the currently associated blood sugar reading to see if the reading went down as a result of the change in ingredients. If so, the user has learned a valuable lesson about the role of potatoes in their diet. It is a proven educational concept that learning by experience is more effective than simply being told that something is true.

In another scenario, a patient may have consumed entirely too much sugar at their last meal and the corresponding blood sugar level is considered dangerously high. Rather than simply noting it, GlucoGo may suggest actions to the user on how the situation could be corrected. In the case of an insulin dependent diabetic, the application might suggest an injection of a certain amount of insulin and then prompt the user to take another blood sugar reading in fifteen minutes. If the blood sugar level still has not gone down, the patient may be advised to contact their doctor. For the Type 2 diabetic, the application may suggest taking a brisk 30 minute walk, as exercise has been shown to lower blood sugar levels. The user may choose to accept or ignore the suggestions made by the application, but over time, they will learn how to effectively manage situations as they arise without the help of the application. This kind of empowerment is the ultimate goal of GlucoGo. Though patients could get this information from health care professionals, the information may not be timely enough to be relevant or helpful and diabetic counselors are rarely available to their patients during weekends, nights, or holidays.

Because behavior modification is even more likely to come about from positive feedback rather than from pointing out problems or errors, the GlucoGo virtual coach will offer spontaneous positive reinforcement as well. Research has shown that praise elicits positive changes to attitudes and behaviors, and computer generated praise can be as effective as that from live people. **(25)** This feedback may take a variety of forms depending on the individual case, but could be messages such as:

> "Congratulations, you've met your target blood sugar levels consistently for the past 5 days. Keep up the good work!"
> "I see you've eliminated your typical afternoon snack of cookies and chocolate milk for

> the past 3 days and your afternoon readings have been lower than normal since. This dietary change seems to have had a positive effect. Good for you."

For this virtual coaching model to work, patients and health care providers must put their trust in the virtual assistant in order to "delegate part of their responsibilities to the electronic device". To foster this trust, the interaction between the user and device must be in a format and contain content that is comfortable to the user. **(26)** Additionally, cooperation between people and virtual assistants requires some predefined method of "what to expect from whom". For example, should a user be asked to do something (such as to redo a blood sugar reading), or should they be told to contact their diabetic counselor? We must keep in mind the trade-offs such that patients do not become overwhelmed by the software. **(27)**

Keeping Track of Performed Actions

When GlucoGo suggests an action or a user decides on an independent course of action, the user should be able to record the decision that was made. This creates a kind of knowledge base that the user can consult at a later time should the same situation arise again. This is another key factor of the diabetic learning process.

Additionally, users must have the ability to create reports that show patterns and trends over time. Much can be learned from analyzing data over weeks or months that cannot be seen in daily records. GlucoGo users will have some custom reporting options and the ability to send the corresponding data via email in either PDF or CSV format (for uploading into database applications or Microsoft Excel). This will allow users to share data with health care professionals and other caregivers, or simply to keep a long-term record of progress. This step will also be important because mobile phone memory is finite and somewhat limited, therefore the application will not be able to maintain data indefinitely.

Related Research

Sick et. al evaluated the use of PDA's to collect food intake in chronically ill patients for the purpose of analyzing nutritional values to ensure the condition's strict dietary guidelines were being followed. Users of the prototype device scanned food items using a third party bar-code reader that plugs into the PDA (the Socket In-Hand SDIO) and nutritional values were pulled from the Internet UPC Database **(24)** an open-source repository of over 600,000 bar-codes. Participants also had the option to verbally record what they ate.

There were several key findings of this study that relate to the GlucoGo project. First, it had been assumed that people would know how to locate and scan bar-codes on food products, but it was found that many actually needed instruction on this task. Additionally, low income users who shopped at discount grocery stores were less likely to find bar-codes in the Internet UPC database, presumably because higher educated and more financially solvent people are the main contributors to this resource. Perhaps as a result of these difficulties, users said they preferred voice recordings, but the low literacy level of some participants also negatively affected their ability to describe foods or read the names on food packages for voice recordings. Lastly, the study showed that users often forgot to record their food intake, especially on weekends, and would attempt to back-fill their info just before meetings with the researcher. **(28)** These findings demonstrate the need for bar-code tutorials, alternatives to bar-code input, and reminder messages.

Students at the University of Oregon, created a paper prototype of a system they call NutriStat. This is a cellphone based application for tracking the diet of children in one's care, such that the information could be shared among all the people responsible for the care of that child. Users would enter a food item on the phone associated with a particular meal, that would in turn be looked up in a nutritional database. The application would put the nutritional values into a graphical representation of the USDA food pyramid, so that caregivers could instantly see data such as how many servings of vegetables or grains had already been consumed today. The idea was that caregivers could make more informed choices about what to feed a child when they could see what had already been eaten.

Relevant findings show that the cell phone was perceived as a difficult device for entering food items due to the small (and often numerical) keypad. Participants also liked the graphical representation of nutritional values using the food pyramid. One major problem discovered was that the client-server infrastructure needed to deploy this system would be cumbersome due the need to upload, sync, and/or share data between phones of different caregivers. **(5)** These findings also reinforce the need for data entry methods on the GlucoGo system beyond manual entry, and show why a stand-alone client deployment would be best.

Silva et. al conducted a field study to observe users of a national program for the prevention of malnutrition and obesity (PREVENIMSS). This program focuses around individuals meeting with specialists over a period of weeks to create custom diet and exercise plans. Silva et. al hoped to take this information and use it to build a mobile virtual specialist solution.

The study found that the number one motivator for staying on a plan is the weekly communications with a specialist as this helps participants to feel "personally attended". Some users stated, however, that making it to all these live appointments was difficult at times. Most users responded positively to the idea of a technological "virtual specialist" solution. Another finding was that users tended to keep their food logs close to where they primarily ate. **(29)** These findings demonstrate the importance of motivation and coaching and patient receptivity to a virtual assistant rather than a live one (presumably for the convenience factor). Also, since the target audience for this product is constantly on the go, the fact that users want their food logs where they eat reinforces that the mobile phone is a good device for tracking that and similar info.

Ahamed et. al are studying the challenges of implementing wireless wellness assistant technology that would gather health information about a person via sensors and relay that information to a PDA or mobile phone device. Patients and caregivers could in turn use that data to make decisions about the patients care. Though they hadn't yet achieved any results at the time of publication, they bring up a number of points to consider that are relevant to the GlucoGo project. First, the memory constraints of mobile and PDA devices make extensive data crunching not feasible. Since GlucoGo is intended to be a stand-alone application, food and bar-code databases will not be able to be stored locally so that maximum memory is available for storing and recording user data. Database data will have to be looked up and only what 's relevant copied down. Secondly, security and authentication must be considered if data is being relayed to a remote location. GlucoGo will need to encrypt data that is sent by email from the phone to the user's own account or to a third party. Third, the ability to display information in different ways is important depending on whether it is a patient or caregiver reviewing the data. Therefore, GlucoGo should be able to strip out data that is irrelevant to one audience when reports are formulated and sent via email. The research team also noted that reporting should be automated and scheduled, as the device should require only minimal interaction from the user. With this in mind, any wearable sensors must seamlessly record data to the mobile device. Patients should however, get reminders and periodic updates of their status and data should be presented graphically whenever possible for ease of analysis by the user. **(30)**

Future Directions

GlucoGo is still in the early conceptual phases, and much work remains to make the vision a reality. The next steps will be to clarify the target audience and develop detailed user personas for the product. Most likely these users will be younger diabetics (perhaps 15 - 40 year olds) who have a high degree of technical literacy and for whom mobile phones are a way of life and extension of themselves. This audience has been greatly overlooked in terms of diabetic care and many are without health insurance, which intensifies the need for smart diabetic coaching devices.

Following the creation of personas, a series of use cases will be created to guide the design direction. A series of wire-frames will then be created that follow the flow of the use cases. These wire-frames will be suitable for use in a paper-prototype user study, for which real diabetics will be recruited and asked for their feedback.

The creation of a functional prototype and a second round of usability testing would be ideal, but will be dependent on resolving a number of technological constraints. The direction this takes will be dependent on factors such as the outcome of initial studies, funding, and availability of engineering resources.

Conclusion

Diabetes is a complex disease and treatment must be individualized for each patient, often through trial and error. Technology has much available to assist in the ongoing monitoring and management of the disease, but these tools often fail to look beyond numerical values to ensure that the entire scope of patient needs are being addressed. A mobile assistant that runs from a standard cell phone is likely the best mechanism for collecting relevant data, informing the user of issues and trends, and providing ongoing coaching and motivational support in a way that empowers the diabetic to succeed in their self-care efforts.

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