Impacting the Future of Diabetes Management

Nathan Collingridge

Electrical Engineering and Computer Sciences
University of California at Berkeley

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M. Eng. UC Berkeley

Abstract

To address the societal problems associated with diabetes, this paper presents a novel approach to the management of the disease. Enabled by new technology, we constructed a glucometer that provides the ability to turn your mobile device into a blood sugar sensor, transforming blood glucose testing from struggle to sensation. We also built a web application dedicated to diabetic reviewed restaurants, presented here as a way to bring this technology to market.

Introduction

Diabetes is one of the oldest diseases recorded in history. Known anciently as the "sweet urine disease", it has grown to affect over 285 million people in the world today.[1] The US alone has 25 million diabetics, and this number is steadily increasing, 7% from 2010 to 2011.[2] In consequence health care costs are on the rise, and the economic burden is shared by everyone.

Diabetes is the leading cause of hospitalizations in kids. 74% of all hospitalizations in young people are diabetes related. An even greater number of adults are hospitalized by the disease each year[3]. Complications from the disease include heart disease, stroke, kidney failure, nerve damage, and blindness. It is the seventh leading cause of death

related to disease[4]. The health risks and financial crisis due to poor diabetes management has resulted in a movement to finding a solution, including this project.

Funding is going into diabetes related research to solve these problems. Glucometers are becoming more technologically advanced, but in spite of this, diabetes is becoming more problematic. Research has shown however, that in all cases, blood sugar control can be improved through lifestyle changes, such as diet and exercise. Some cases showed such dramatic improvements among type 2 diabetics, that they were no longer considered to have the disease[5]. If science has shown that diabetes, specifically type 2, can be "cured", how is it diabetes is still such a burden?

Diabetes is an extremely personal disease. Management is remarkably intimate. Testing supplies including glucometer, test strips, lancets and lancing device are carried around at all times. To test, the user pricks their fingertip or forearm with a lancet in order to extract capillary blood and apply it to the strip. Good management practices require extraordinary effort, logging results in order to identify patterns and trends. It is also extremely expensive with testing supply costs ranging anywhere from $500-1000 per year, depending on the doctor recommended frequency of testing. Once a high sugar level is detected, the person with diabetes needs to take the appropriate steps to correct it, whether through the use of insulin, drug or exercise. For low blood sugar levels, a sugary drink like fruit juice is recommended to quickly increase blood sugar levels and prevent hypoglycemia. Although regimens are discussed and worked out with the health professional, it is entirely up to patients to stick to it and avoid burnout. Diabetes burnout is the real problem behind the costs and health risks associated with diabetes,
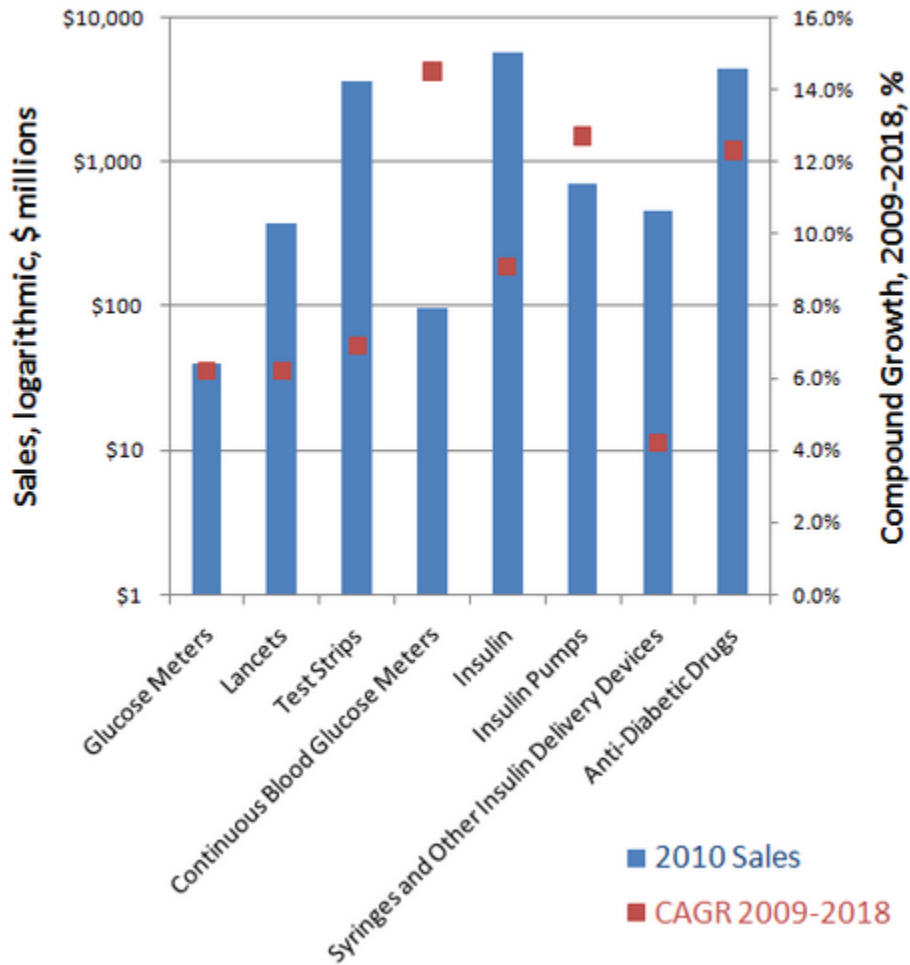
aside from the growing population. Diabetes is elusive. One may feel fine after neglecting to manage diabetes while away on vacation, after running out of testing supplies, or just too busy – but unexpectedly faint or worse due to low or high blood sugar levels. Any solution to diabetes management must prevent this from happening. It must create a way to engage the user in a way that they forget the burden of carrying their glucometer and the pain and expense of testing. It must provide confidence, and a sense of accomplishment. People will take pride in management, willingly change their lifestyle and no longer suffer from diabetes. In this paper, I review the state of the industry, identify what is missing and present a project dedicated to creating a solution that accomplishes one goal: to improve health and increase the quality of life for people with diabetes. The motivation for this product does not end here, however. By applying technology to patch diabetes, we also address universal health care costs. Costs will fall, and all people will benefit from it.

Literature Review

Smart phones are personal, powerful and pervasive; yet they have only recently begun being used for health and medical purposes. The reasoning behind this slow adoption is not entirely clear. Mobile devices are prevalent among the underprivileged[6]. One study shows that 80% of internet users look for health information online[7]. There are also substantial financial opportunities; diabetes management is a multi-billion dollar

industry.

Diabetes Market, U.S., by Segment, 2010

It is composed of glucometer and supplies manufacturers and pharmaceuticals.

Pharmaceutical companies focus primarily on the development and delivery of insulin

and other diabetes medication and are well beyond the scope of this project. The leading

glucometer and supplies makers are: Roche, Lifescan, Bayer, and Abbott. Each of these

industry leaders focuses on innovation, but the innovation that has made them their

success is not driven by touch screens or API's. This is because the glucometer itself

accounts for only a small portion of their revenue, with many of them being subsidized or

given away for free.[†] Their profits come instead from the consumables, primarily blood glucose test strips. At the core of these test strips are a number of patents. These inventions declare the method of testing, the size of blood sample required, the location to extract blood from, duration, and whether manually coding the strip to the device is required. Each of these firms owns the license to these patents or license patents from their counterparts for their own use. All of these firms own the bulk of the patents in this scene. Consequently, the strip patent leaders do not innovate as much as some of the younger and upcoming companies as far as technology is concerned. Why take the risk? It is better for these companies to invest in proven methods rather than pioneer unproven ones. Until someone pioneers through these challenges will they be compelled to compete and bring smarter, more technologically advanced solutions to market.

There are over 70 glucometer devices produced by over 20 companies and over 100 applications across all mobile platforms. This is a saturated market, both hardware and software. How can an industry sustain this? The number of diabetics increases by nearly 10% each year in the US. If test strips cost $.45 and a person with diabetes tests 3 times a day, this is nearly $500 a year. With 25,000,000 people currently affected by diabetes, this equates to $12,000,000 in revenue growth for a company holding only 1% of the market. Now imagine a large company that holds much more than 1% of the market, this number is enormous, and its guaranteed revenue growth, year over year! The question is not how can the industry support this, but rather why are not there even more players? Which begs the question, why would I want to create a product that solves the problem and

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[†] This follows the "razor blade" model. Losses are absorbed through strip sales

cannibalize this market? A large firm would not unless it proved more profitable. This task is better suited for a starving startup.

There are smaller companies competing for this. Their target: mobile devices. Mobile devices have proven user interfaces, sophisticated API's, staggering numbers and anticipated growth to boast. AgaMatrix released their iPhone compatible iBGStar[8] which recently received FDA approval. iHealth Labs is scheduled to release a duplicate product (pending FDA approval). Glooko provides there MeterSync Cable to connect Apple devices to 7 existing glucometers with plans to support even more[9]. Other glucometers support Wi-Fi/Bluetooth communication protocols. Telcare adds a large color display and 3G to their recent FDA approved glucometer[10]. The movement is here. Glucometers are becoming more like smart phones.

However, any additional features to glucometers are risky business. They require company resources and increase the costs associated with the device. There is no guarantee that customers will receive any additional benefit from the device and that insurance companies will reimburse them for the extra costs. When released they only appeal to cash paying customers, but with a large price tag, it is difficult for them to justify the cost. Who is willing to pay for a glucometer that costs more than an iPod? New companies lacking branding are unable to attract the attention of medical experts and insurance companies and lack the channels of older, larger firms. Combined with the capital costs to manufacture, prove efficacy and market the devices while waiting for FDA approval, these medical devices are behind the curve in comparison to consumer electronics. As tech savvy solutions are introduced, large firms will attempt to drown

them out by lowering test strip prices. This is happening today. A quick Amazon search of glucose test strips will show average savings of 50-70% of even brand name supplies. In order to overcome these barriers to entry, a new product needs to be more than just a good idea. It requires a clear strategy and an edge to enter into this complex, multi sided market, with careful, timed and calculated execution.

However, the difficulty ahead is not enough to prevent new comers from chasing after the spoils. After Telcare's 3G glucometer was approved they waited months generating hype before releasing to the market. They understood the market and created a new approach to breaking down these barriers. In fact, they "borrowed" a proven method from none other than the telecom industry. This makes sense considering their name and the technology they are leveraging. In order to appeal to the insurance paradigm and address the expensive technology they have introduced, they sell it at 3 levels, premium, discounted and free. Each level requires a contract whose term duration is dependent on the discount received. Instead of signing up for minutes diabetics sign up for strips. As for the insurance companies, they are working tirelessly to onboard more providers. They do not release the number of insurance companies, but an interested customer can submit a form to see if theirs is covered. If not, Telcare will bill out your insurance as an out of network provider.

Glooko has taken a different approach. They currently develop sync cables that connect existing glucometers to iPhones and iPods plugging them into their app. This is a no resistance path – virtually no one is doing this, not even the glucometer makers that put the Stereo Jack ports in their devices! They are after hardware placement, but unlike

larger companies know who their users are. Acquiring users may set the stage for some future transition with their own tech savvy brand.

Despite all the activity, innovation, research and business models it has yet to be decided which of these companies will address the problem presented in this report - a product that makes a difference in the lives of the diabetics it serves. There is massive potential for large players to make a tremendous impact, but will they forego better financial decisions to address this problem and risk cannibalizing the market? Will new comers find ways to attract the attention of the market and scale quickly in the face of adversity? With millions of people struggling to control their diabetes and overcome challenges they face on a daily basis, there is a tremendous opportunity to create a product that makes a difference - an opportunity to impact the world.

Methodology

Unsatisfied with the existing glucometer solutions I knew I needed one that was capable of tapping into the smart phones resources without compromising affordability. I began searching immediately and stumbled upon a project completed at University of Michigan called Hijack. Built with cost effective mobile sensing in mind, Hijack utilizes the mobile devices resources for remote sensing applications. It uses all three channels (Left, Right and Mic) of the standard 3.5mm audio jack to accomplish this, 2 for bi-directional communication and one for power harvesting[11]. The schematics and source are free and open source making it easy to produce a prototype for validating its use as a glucometer, or any application. With it, I was able to detect the presence of a test strip

and read the reaction during an actual blood sugar test – two of the basic functions performed by all existing glucometers.
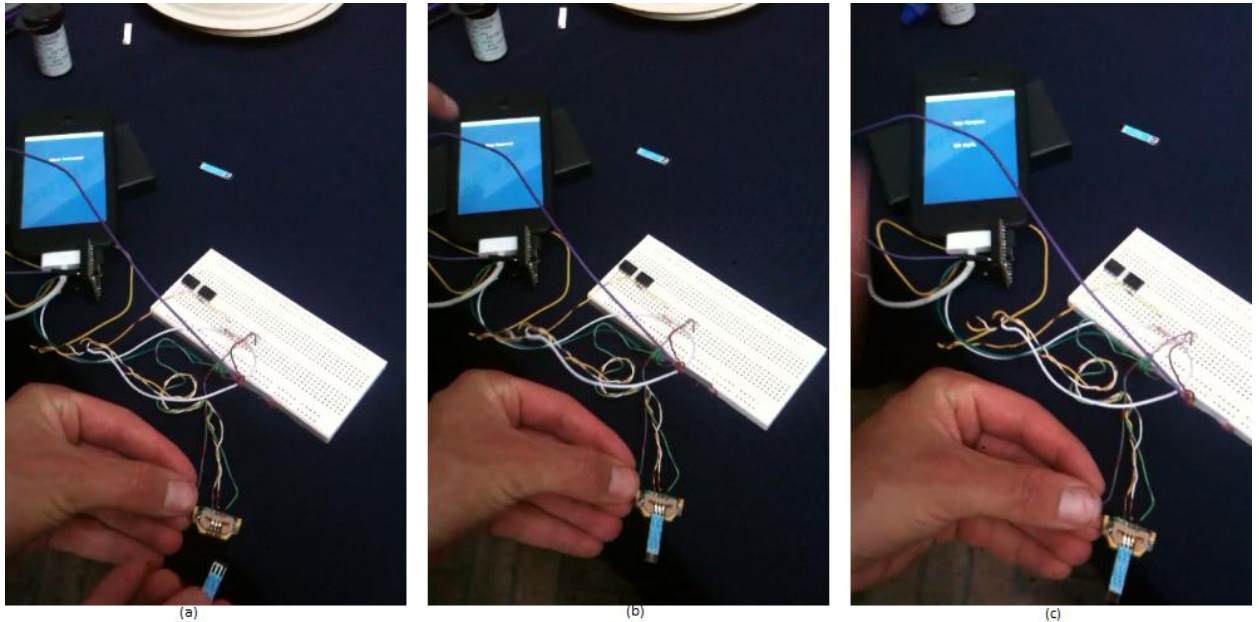

Figure 1: Hijack Prototype, (a) "Hijack Connected", (b) "Strip Detected, (c) "Test Complete; 126 mg/dL"

A Hijack based glucometer addresses the problems associated with large scale user adoption. The first is cost. The bill of materials for hijack is $2.34 for the power circuit[12] plus around $10 for the microprocessor and a few capacitors/resistors.[‡] The device itself can be sold for a profit at the same price point as some of the low end glucometers on the market. The reason is that it completely utilizes the smart phones resources, including the battery and display – two of the largest and most expensive components, and does not go through any proprietary connections! The next problem is portability. Taking up less than a square inch, this device can be easily placed on a key chain or embedded in a phone case. No one forgets their keys or phone behind, and people with diabetes should not leave their glucometers either. Marrying the glucometer with either of these in a

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[‡] The components required for accurately reading the glucose test strip were intentionally omitted. This is covered at the end of the paper

sleek, barely there fashion is ideal. Finally, by connecting with the smart phone we have access to rich development platforms, like iOS, for creating an engaging environment for users to better manage their disease.

I began working immediately on app design and development for Hijack, due to its dependency on it. Automatic input came inherently, but this was not the only thing that required logging for diabetes management. Diet and exercise are major influences that needed to be accounted for. I was able to create a component that could be incorporated to the app that eased the burden on the user for exercise input, while another team member worked on food input. Because people generally follow an exercise routine it seemed unnecessary and complicated to have them search through a scroll wheel with every exercise I could think of. Instead, I made a way to add "hot keys" to a customizable view that persists over the life of the app. When the user logs the first input they will be presented with an add button. They then select the exercise from a scroll wheel and add the icon image of the exercise to the view. They return to the new view that contains the icon for the selected exercise and the add button shifted to a new location. They can continue to add exercises until the screen is full. After touching the clickable icons representing the exercise they wish to log from the hot key view, they can use a slider to enter the duration and intensity of the exercise.

Figure 2: Illustration of Exercise Input Feature

This addresses more of the pain points with getting users to log activity and sets the stage for a recommendation engine completed by another team member; however it does not correlate to engagement. In order to provide something fun for diabetes, we need to "gamify" the disease.

Since diabetes management is inherently "gamey" (maintaining a tight blood sugar level, avoiding dips and spikes), this did not sound too difficult to pull off, rewarding points for keeping steady levels. However after talking to a number of diabetics I gained the following insight. By changing the way score is presented using an experience bar with level ups, the app opens up to a new level of engagement. Now users feel good about themselves as they manage diabetes better, and they can look at other people who also have diabetes, those who have attained higher levels and "copy" their strategy – much like a player

Figure 3: Player's Level View

in a role playing game. By incorporating simple game mechanics, the attitude toward

diabetes management changes.

As the team approached our customer segments about their greatest challenges

and shared with them our solution we discovered one thing, they all shared the problem

of where to go and what meals to choose when eating out. This decision generally is made

at the last minute and while on the go. Having this information on their mobile device

would be beneficial. A health professional also reported this problem being the most

commonly asked question during checkups and diabetes educational sessions. Downloads

and installations were also an area of concern as many people with diabetes are not

technical. This led to a major pivot, one that focused in on a much smaller problem with

the potential to quickly reach every diabetic.

The idea was to create a web application identical to Yelp!, but contains only

restaurant reviews shared by people with diabetes. I worked on producing templates and

key components such displaying the star ratings and presenting the restaurant lists.

Other members of the team worked on components on both the UI and backend. One

teammate recommended using Factual[13], a database containing all US restaurants, which

is where we get our data. All authentication is done through Facebook and the site itself
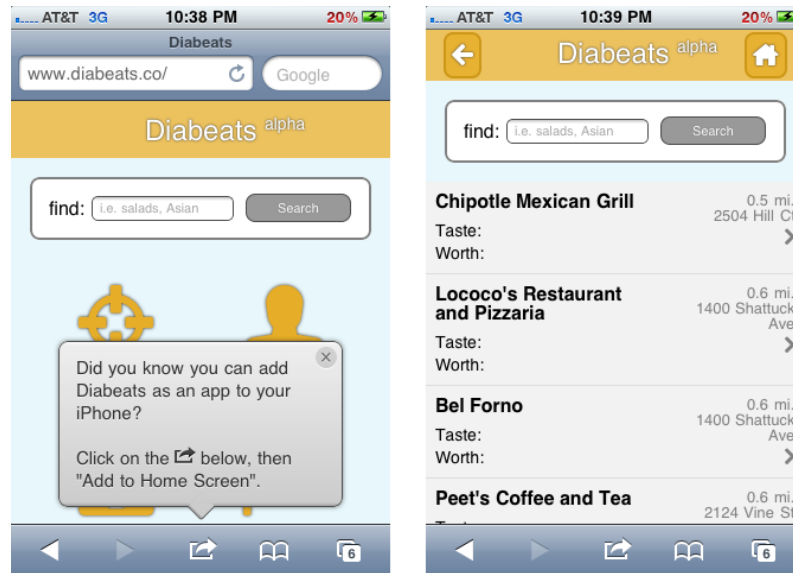
is closed (only for diabetics).

Figure 4: Diabeats landing page and nearby restaurants

Conclusion and Future Work

Diabeats went live mid April 2012. We are finding that it is extremely difficult to get users activated. The reason is that although it creates value for the user, it only becomes valuable when people use it. This is an example of the classic "chicken vs. egg" problem. We will continue to search for zealous users to create this value for Diabeats; however this is a marketing issue, not a technical one.

Due to project pivots, new discoveries and market validation, I was not able to develop the Hijack based glucometer and iOS app as much as I would have liked. It currently is and always will be a novel prototype of the future of blood sugar testing, and I will continue to push it forward. I have reserved this section in conclusion as a future roadmap for this technology as well as that for Diabeats.

At Hijack's core is the MSP430F1611IPM microprocessor. MSP430 is a family of ultralow power microprocessors, perfect for Hijack's implementation as a general purpose, low-power sensing platform. However, the F1611 lacks a few key features that are

needed in an accurate glucometer application – basic op amps for reading the reaction on a test strip and a temperature sensor, necessary to knowing the speed of the reaction of glucose in the blood with the test strip substrate. Both are built into the MSP430F22x4 chips and would be better suited for this application. These chips are nearly 1/3 the cost, contain fewer pins and can be purchased in smaller quantities. In the future, a suitable test strip that can be licensed should be selected and then an accurate sensor built to read it.

There is a lot that can go into the application. However, the more that is in there the harder process of FDA approval. Starting with a simple logbook and adding features as the hardware rolls out is the best way to go for an initial hardware launch. Alternately, a fully functioning feature rich app can be released independently with no need for FDA approval, or to raise excitement for the future of the complete product. Diabeats also provides a unique way to introducing such a product. It is a web based and only addresses a single problem: where to eat out. It has virtually no learning curve making it easy for less technical people to start using. There are no competitors and it provides opportunities to partner with and advertise for other diabetes related companies and organizations. As it becomes popular, features such as native app install, product recommendations and eventually glucometer support can be introduced, ending with a complete product that satisfies all of a diabetics needs.

Diabeats targets only people with diabetes. But there are a number of people and businesses that live and promote healthier lifestyles. Future efforts will extend this platform to other diet related diseases and the health conscious. Yelp!, the successful

business review site that Diabeats was mirrored from also allows "expert" reviews. In the future Diabeats will have health professional/dietitian profiles so experts can also weigh in and help assist people who want to make better choices while dining out.

Summary

There is no shortage of interesting problems to work on in diabetes. The growing population is evidence that these problems do exist. Scientists and engineers will continue to address societal problems like disease. Through creative thinking solutions like the ones presented in this project will become a part of everyday life and change the way we live for the better.

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