Diabeats: Empowering Diabetics to Live Smartly

Rohan Nagesh

Electrical Engineering and Computer Sciences
University of California at Berkeley

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Rohan Nagesh

Department of Computer Science, University of California at Berkeley

ABSTRACT: The application of mobile technologies in the health and wellness sector presents exciting business and technical opportunities. In particular, diabetes, a worldwide phenomenon continuing to grow at alarming rates, lends itself well to monitoring and control through a mobile application. With the ubiquity of mobile computing and pervasive network effects in today's social networks, we believe the mobile health space is primed for disruption. This paper explores the design, development, distribution, and commercialization of a mobile application targeted for diabetes, with focus on diet management and making smart choices while eating out. We discuss our journey of product iterations along with lessons learned each step of the way in building our application in this mobile health space.

KEYWORDS: healthcare, mobile health, diabetes, glucose management, customer development, lean startup, iOS development, incentive systems, machine learning, recommendation engines

INTRODUCTION

According to the World Health Organization (WHO)[1], there are more than 1 billion overweight adults, with at least 300 million of them clinically obese. By the year 2050, 1 in 3 Americans will be diagnosed with diabetes[2]. Given, such increasingly staggering trends, it is evident that an overwhelming majority of people worldwide take little to no action to address health concerns. From eating to exercising to sleeping, we find it difficult to drastically modify our lifestyle—simply on our own volition.

Diabetes, in particular, poses some unique challenges for its patients. Affectionately known as the "Thinker's Disease" due to the constant need for data collection and decision making, diabetes is an ailment with little predictability and can severely hamper the lifestyles of today's increasingly busy adults in the areas of meal management and exercise regimens. The human body's glucose levels are in constant flux, and abnormal spikes or lows can yield extreme negative repercussions for patients, including fainting, blindness, and amputation.

At the same time, we have seen tremendous growth in mobile phone usage, smartphone penetration, and Internet applications. Social networks such as Facebook and Twitter have amassed close to 1 billion members. Mobile applications leveraging these platforms boast high engagement due to pervasive network effects. Sophisticated machine learning algorithms used in applications such as Pandora and Apple's Siri have spurred impressive advances in personalization of content and have already disrupted numerous verticals including local commerce and media.

Yet, healthcare as an industry has historically been reticent to adapt to and adopt these new technologies, and much of this is due to the numerous hurdles to overcome. Whenever a device,

service, or application relates to the health of a human being, a certain protocol must be followed. In the United States of America, the regulating organization that must approve anything hoping to be commercially implemented is the U.S. Food & Drug Administration (FDA).

There are three classes of medical devices ranging from I - III (in increasing severity and scrutiny).[24] In the diabetes space for instance, the simple task of plotting data points read from a glucometer is regarded as a Class I device. Therefore, any app wishing to display information must undergo Class I clearance. Class II devices must undergo greater scrutiny because they manipulate data, project trends, or perform an activity that could have a direct or indirect effect on a user's health. This is the category that more and more apps find themselves in. Class II devices usually possess a longer time to market because they must receive approval before any marketing efforts. A potential alternative to avoid, or at least post-pone FDA approval, would be to initially deploy in another country. Europe and Asia do not have organizations with strict protocol to follow for commercial medical devices.

While efforts must be made to ensure privacy standards and adhere to standards set forth by the Food and Drug Administration (FDA), we believe there is a tremendous value proposition in aligning with this technological shift for all parties involved—patients, physicians, hospitals, health maintenance organizations (HMO's), and insurance companies.

While there are numerous pain points for diabetics that can be addressed through technology, we focus our efforts on enabling more informed food and exercise choices. What foods will best keep a patient's glucose levels in check? What balance of carbohydrates, fats, and protein are optimal and in what situations? How far apart should meals be spaced? What exercise routines

are most effective and what duration and intensity should be maintained? With this context in mind, we discuss our journey in developing a mobile application personalized for diabetics.

LITERATURE REVIEW

We began our investigation in this space with the vision of developing an integrated hardware and software solution. As depicted in Figure 1, the current standard for diabetes care consists of a glucose meter (glucometer) to measure glucose levels, test strips, lancets, and insulin. Observing the need for a more mobile-ready diabetic kit, we looked into possibility of utilizing one's own smartphone as a glucometer.

Figure 1: Diabetic care kit consisting of glucometer, test strips, lancets, and insulin [25]

Project Hijack at the University of Michigan[3] focuses on "hijacking power and bandwidth from a mobile phone's audio interface to create a cubic-inch peripheral sensor ecosystem." The HiJack energy unit can supply 7.4 mW to a load with 47% power conversion efficiency, using components totaling a mere $2.34. In addition, sensorboards to detect various signals such as carbon monoxide and ozone can be built into the HiJack platform. More pertinent to the healthcare space, Kuo and Verma[4] detail in their paper an application for a phone-powered

electrocardiography (EKG) monitor. As depicted in Figure 2, three EKG leads have been configured into the HiJack node and pass the waveform data to the mobile phone and optionally the cloud for visualization and storage.

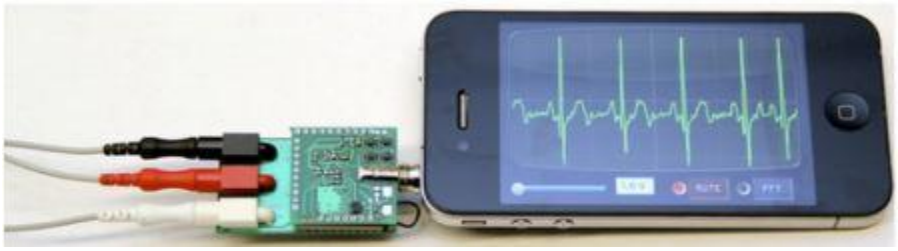

Figure 2: HiJack EKG monitor application[4]

Inspired by HiJack's potential to create a new class of low-cost and space-efficient mobile applications, we set out to adapt the HiJack platform for blood glucose detection and visualization.

On the software side of our product, we first attempted to deliver value to diabetics through glucose level prediction. Much research has been completed in the field of machine learning applied to glucose prediction. Bellazzi et al.[5] utilize a Bayesian framework with Markov Chain Monte Carlo (MCMC) chaining techniques to predict glucose measurements at a particular timestep. Bellazzi notes that deterministic state equations are unable to capture the variability of the glucose time series, and thus a stochastic description of the system dynamics is required. Unfortunately, even with these modifications, the authors note the algorithm is not suitable for real-time analysis.

On the other hand, some have argued in favor of a probabilistic approach to glucose modeling. Andreassen et al.[6] discusses an implementation of a carbohydrate metabolism model that can be adapted to an individual patient and produce 24-hour blood glucose predictions. In an experiment

conducted on a sample size of 12 patients, the system predicted glucose levels with a mean error of 3.3 mmol/l.

All in all, given the long training times, slim margin for error, and better understanding of our target demographic and market, we turned our attention away from prediction towards utilizing software to engender behavioral change. More concretely, we aimed to create a software application focused on visualization of glucose levels as opposed to prediction coupled with gameplay incentives to spur compliance (routine measurement of glucose levels) and engagement.

Given the nascency of the social and mobile health computing space, there is considerable investment and research interest in the area. The SMART[7] (Social/Mobile Approach to Reduce Weight) study, launched at the University of California at San Diego is especially pertinent to our problem statement. Funded by the National Heart, Lung, and Blood Institute (NHLBI)[8], UCSD researchers are investigating the efficacy of theory-based weight-loss intervention utilizing the Web and social media as compared to usual health care information, such as static nutritional tables publicly available.

University of Washington researchers have developed UbiFit[9], a persuasive mobile application designed to encourage individuals to self-monitor their physical activity and better incorporate exercise and varied activity in their lifestyles. The UbiFit solution consists of three main components: a display that serves as an omnipresent yet subtle reminder of a user's activity, an interactive application that functions as a journal and analytics source, and a fitness device similar to a pedometer that records and transmits physical activity to the application.

Another significant area of focus is automating data entry and monitoring from both the patients' and clinicians' perspectives. My Health, My Life[10], a web-based health monitoring application developed at North Caroline A&T State University, assists users in reaching their fitness goals by simplifying data entry and connecting them with professionals and other users with similar interests and goals. Mobile Mentor[11], a similar application developed in Australia, focuses on weight loss through real-time data collection and self reflection.

Upon enrolling in Steve Blank's Lean Launchpad course offered through the Haas School of Business at UC Berkeley, our team began a 10-week deep-dive into the world of customer development. Through completing a more exhaustive competitive analysis of the mobile health space, we analyzed five solutions: Glucose Buddy, Yelp, CalorieKing, Livestrong, and Crohnology.

Glucose Buddy[12] is a free application that affords users the ability to manually store and visualize glucose levels, carbohydrate intake, insulin dosage, and exercise. Rated the #1 app on the iOS market by diabetes forums as well as by user reviews and downloads, the application is most definitely an improvement over traditional pen and paper logging methods. However, how much of an obstacle is manual entry of glucose readings? How useful would advanced analytics and visualizations prove for the broader audience of diabetics?

Yelp.com[13] is a social network focused on sharing dining experiences. With over 70 million registered members, the site has built up quite a collection of local reviews and enables users to better tradeoff taste, price, and location when deciding where to eat out. Much research has poured into analyzing the possible correlation between Yelp reviews and reputation. Luca[14] discusses in his paper the ability of user reviews on Yelp to shape consumer behavior and affect

restaurant demand. Utilizing a dataset combining Yelp reviews with revenue data for Seattle restaurants from the Washington State Department of Revenue, Luca finds that consumers are more responsive to changes in aggregate metrics (mean restaurant rating, overall restaurant rating distribution, total number of reviews, etc.). Additionally, a one-star increase in the Yelp rating of a local restaurant translates to approximately a 9% increase in revenue.

While Yelp does provide a rich database of reviews to aid in decision making, the site does lack ailment-specific or even health-specific content. CalorieKing[15] is a leading provider of calorie-centric education tools for food awareness. From goods found at a local supermarket to popular fast food chains to quaint cafes, CalorieKing features a massive foods database with complete nutritional facts, including fat content, carbohydrate count, and protein. In efforts to spur awareness for diabetes and more rigorous diet management, CalorieKing partnered in 2008 with Joslin Diabetes Center, the world's largest diabetes clinic.

While CalorieKing focuses exclusively on food, Livestrong[16] features an integrated food and exercise platform. Allowing users to set personalized food and fitness goals, log meals and workouts, and share or compete with friends, Livestrong builds a sense of community support for its users and is versatile enough to adapt to a variety of ailments—including diabetes.

Lastly, Crohnology[17] is a Berkeley-based startup aimed at creating a patient-to-patient information sharing platform for people with chronic medical conditions. In meeting with founder Sean Ahrens, we learned of Crohnology's success in leveraging patients' altruism in delivering value to other patients. The classic chicken-and-egg problem faced by social networks was somewhat mitigated due to benevolent cause and the founders' decision to target the application specifically towards Crohn's or Colitis disease.

METHODOLOGY

In accordance with the preaching of Steve Blank[18] and the Lean Launchpad class at Haas, we observed and implemented the lean-startup methodology, with emphasis on customer development, to rapidly drive our product development. As Eric Ries[19] and Steve Blank both eloquently explain in their respective books, a startup is not a scaled-down version of a large company. Continuous innovation and proactive, systematic customer outreach must fuel the product development cycle.

Early-stage startups unlike large companies do not have the luxury of abundant resources. From cash to brand to number of employees, startups must leverage every little bit of their resource pool to ship high-quality products to market rapidly. In an increasingly competitive Internet space with fewer and fewer barriers to entry and lower cost of development, time to market is of essence. Additionally, many early-stage startups are operating in new markets with vague problem spaces and few to no customers. Validating pain points and value propositions is an essential task for such startups and served as the main learning for our team from Professor Blank's class.

To maintain organizational structure and document our progress week to week, we utilized a business innovation tool known as the "Business Model Canvas", which can be seen in Figure 3. Conceived by world-renowned researcher Alexander Osterwalder in his book *Business Model Generation*, the business model canvas represents an innovative tool designed to create, deliver, and capture value for a business organization.

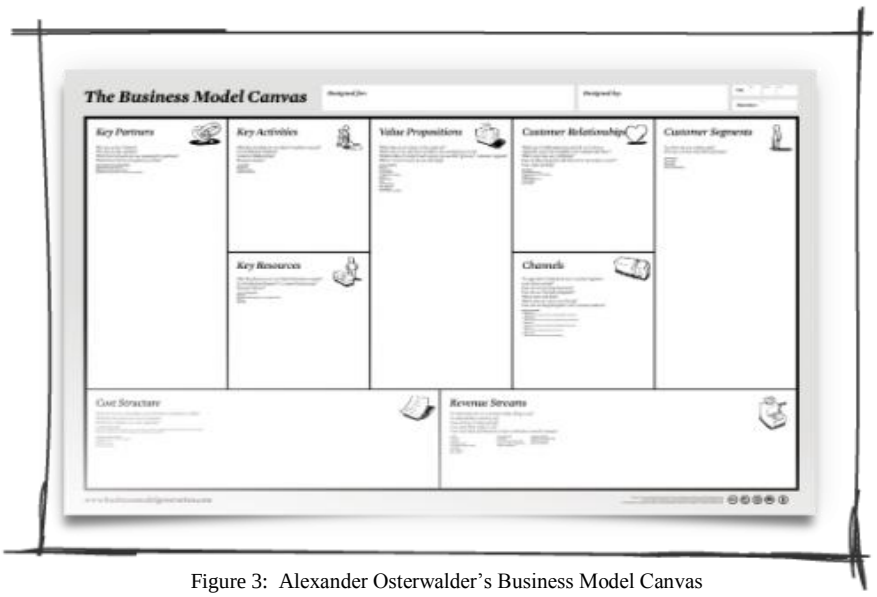

Figure 3: Alexander Osterwalder's Business Model Canvas

The canvas consists of nine essential building blocks: Customer Segments, Value Propositions, Channels, Customer Relationships, Revenue Streams, Key Activities, Key Resources, Key Partners, and Cost Structure. Each of these building blocks evolves over time in response to changes in the market and customer needs. Our team's methodology focused on validating or invalidating our key hypotheses in each of the above building blocks, each of which will be described in more detail below.

Customer Segments requires a business to analyze for whom it is creating value and which customers are most important. Careful consideration must be placed in outlining each key stakeholder group. For healthcare companies in particular, analyzing who really is the customer is pivotal and quite challenging. Is it the patient, physician, hospital, HMO, or insurance company?

Value Propositions encapsulates what value a business delivers to each of its customer segments. Which of the customers' problems does a business solve? What products or services is a business offering each of its customer segments?

The *Channels* building block describes how a business delivers its value propositions to its customer segments. How can a particular group of customers be reached? How can these methods be integrated with the day-to-day routines of customers?

Customer Relationships describes the process by which an organization acquires, maintains, and grows its customer base. Will the business provide dedicated customer support or an automated service?

Revenue Streams analyzes the various value propositions each customer segment is willing to pay for and outlines what structure of payment can be expected. Will the service be free or ad-supported or subscription-based? What about dynamic pricing?

Key Activities enumerates the essential functions a particular business must perform to ensure prompt delivery of its value propositions to its customer segments. For a consulting organization, this may be hiring top talent. For an engineering firm, this may be producing high-quality software efficiently.

Key Resources discusses the various physical, intellectual, human, and financial resources an organization requires to sustain its operations.

Key Partners outlines a firm's use of outside resources. In particular, which key resources or key activities is a firm acquiring from its partners?

Lastly, *Cost Structure* lays out the most important costs inherent in a firm's business model. Which key resources and activities are most expensive, and where is there room for optimization?

We applied this structured approach to business model innovation to our project and additionally utilized an online tool, LeanLaunchLab[21], to electronically save and update our canvas week to week. Each week consisted of our team "getting out of the building" and talking to real customers to gain real feedback on our business model.

We utilized a variety of techniques to obtain enough sources of validation to iterate our business model canvas. At the beginning of the project, we relied more heavily on in-person visits to get a more personal feel for our customers and their pain points and to build up an early adopter user base for our eventual product. We began by paying a visit to the University of California at San Francisco (UCSF) diabetes center. As can be observed in Figure 4, we utilized classic, old-school marketing techniques as my partner Kevin Yien and I set up outside the building's entrance with an easel, poster, and table and proactively approached passers-by to discuss our service.

Figure 4: Rohan at UCSF Diabetes Center with team poster

We also hosted more intimate "customer discovery" sessions in which we invited a group of one to five diabetics in the area to our office in Berkeley to share their experiences with the team. These sessions allowed our team to dive deeper into very specific pain points for our customers and even afforded the opportunity to gain feedback on our software mockups and product prototypes as can be seen in Figure 5. We noted our subjects' reactions to various details, including general user interface look and feel, navigation, button placement, and ease of use.

Figure 5: Customer Discovery session with a Type 2 Diabetic

Lastly, we deployed surveys through online tools such as SurveyMonkey and Facebook to gain quick and inexpensive customer research data. While in-person visits proved wildly helpful in understanding our customers, our group was able to reach over 1,500 diabetics through our survey and social media blasts. This type of scale allowed us to validate high-level value propositions and demographic information, such as the age, gender, geography, and general level of technology savvy among our users.

DISCUSSION

The Lean Startup methodology calls for rapid iteration. Over the past nine months, we have pivoted our product idea several times to better address our customers' pain points and build a scalable, repeatable business model. This section will document our journey of pivots, provide business and technical rationales behind each pivot, and end with our current product vision, Diabeats.

As stated earlier in this paper, we began our investigation in this space with the vision of creating an integrated hardware-software solution. HiJack would be used to transform the mobile phone into a glucometer, and we would develop a simple mobile software application to integrate with HiJack and visualize blood glucose level readings. Several challenges in the areas of scale, competition, and regulations surfaced regarding this strategy.

In terms of scale, the beauty of pure software is in its ability to scale at almost zero marginal cost and at very little upfront cost. Adding one more user to a cloud service such as Facebook or Google costs virtually nothing, given the already immense cloud structure established as well as the inexpensive nature of memory. HiJack would involve a significant upfront hardware investment in addition to a non-trivial marginal cost for each diabetic kit produced. The

hardware space has largely become commoditized with large-scale players such as Johnson and Johnson and Bayer maintaining a stranglehold on prices; thus, we felt more comfortable with a pure software solution.

In terms of competition, several startups in the space released similar solutions while we were in the process of development. In particular, a startup known as Glooko[22] provided a sync cable to connect an iPhone with a glucometer and automatically transfer readings into the Glooko software application, circumventing the need for manual input. Our application would provide similar functionality as Glooko and several other apps including Glucose Buddy and Vree, and we felt the need for more differentiation.

Lastly, and perhaps most importantly, numerous FDA regulations dampened our hopes of shipping to market in a timely manner. Upon researching the FDA procedures in more detail, we discovered the need for extensive clinical trials for any Class 2 device, which a HiJack solution would most certainly fall under. These trials are instated to prove efficacy and monitor potential hazards before deploying to scale. Clinical trials can take up to two years in time and $1M to $5M in funding. Given our team's objective of pushing a solution to market within our nine-month Master's program, we had to make our first pivot.

We decided to focus exclusively on building a software solution. Our next major product iteration involved delivering a glucose prediction and visualization platform. As detailed earlier in this paper, we looked at Bayesian inference utilizing MCMC chaining techniques to predict blood glucose responses over a 24-hour timeframe. This iteration proved to be a classic instance of taking on a challenging engineering problem without close regard for actual customer needs. Upon getting out of the building and conversing with customers, we learned that predictions

would not be fast or reliable enough for users and weren't addressing the main pain point: how can I as a diabetic make more informed food and exercise decisions? A predictive tool would output a number to a user representing a glucose reading, but in reality what does that number really mean? Is it too high, too low? What next steps should I take, as a diabetic?

Seeking answers to these aforementioned questions, we launched a SurveyMonkey campaign to a group of diabetics in the San Francisco Bay Area. As can be seen in Figure 6, the majority of respondents do not use any tool to manage diabetes.

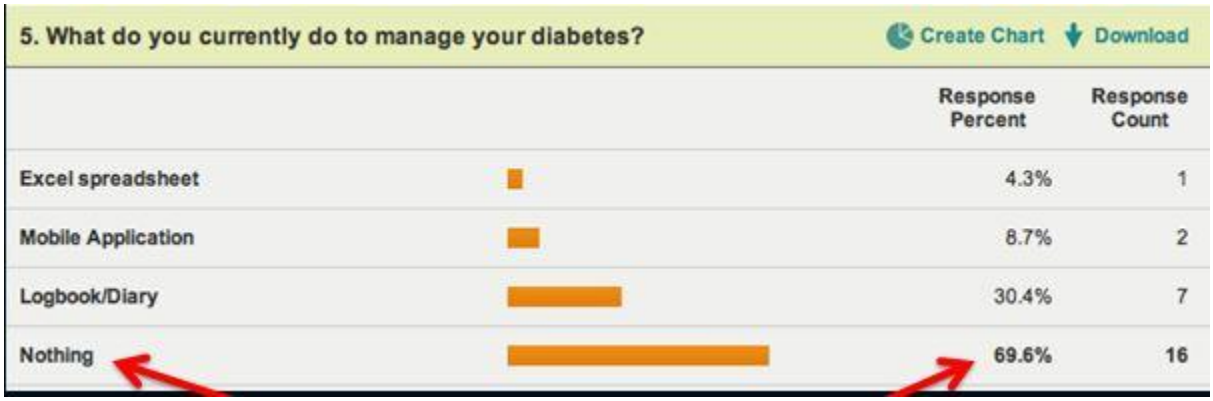

Figure 6: SurveyMonkey survey results to determine most popular current diabetes management tools

We knew from our engineering leadership module that adoption of new technologies follows more or less a bell curve, similar to that of Figure 7.

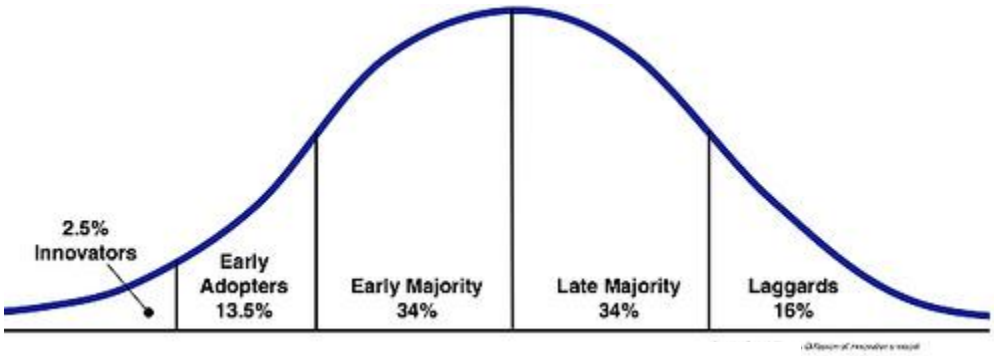

Figure 7: Technology Adoption Curve

Given the staggering number of patients not using any form of technology to manage diabetes, we recognized the nascent nature of our market and the need for us to capture the mindshare of the innovators and early adopters. We would have to offer much more than a logbook to defray the switching cost, and with these insights, we set off on our next product iteration: Siri[23] for diabetics with game mechanics for enhanced engagement.

Siri is Apple's voice-activated personal assistant. It seemingly handles all requests, from sending messages, scheduling meetings, placing phone calls, to providing step-by-step directions. Inspired by Apple's success with this product, we wanted to bring a similar personal assistant engine to the space of diabetes. We focused on aiding users in making more informed eating and exercise decisions, but also scoped functionality for medicine reminders and notifications. On the gameplay side of things, we imagined users earning points the more they engaged with the platform. We scoped functionality for allowing users to compete with their friends and earn badges as they achieved personal milestones. An example mockup of our vision can be seen in Figure 8 below:

Figure 8: Mockup for game dynamics component of our application

In accordance with our lean startup doctrine, we rushed to gain customer insight on this latest product iteration. Initial feedback was highly positive, though we did encounter some difficulty in explaining the full functionality of our application and all the pain points we could address. In somewhat of a mirror image occurrence to our experiences with the HiJack iteration, this iteration proved to be addressing the correct set of user problems, but perhaps addressed too many problems and wasn't technically feasible in our short project timeframe. To distill our vision one step further, we made our most recent pivot to Diabeats.co (Figure 9), an information-sharing network to help diabetics eat out smartly.

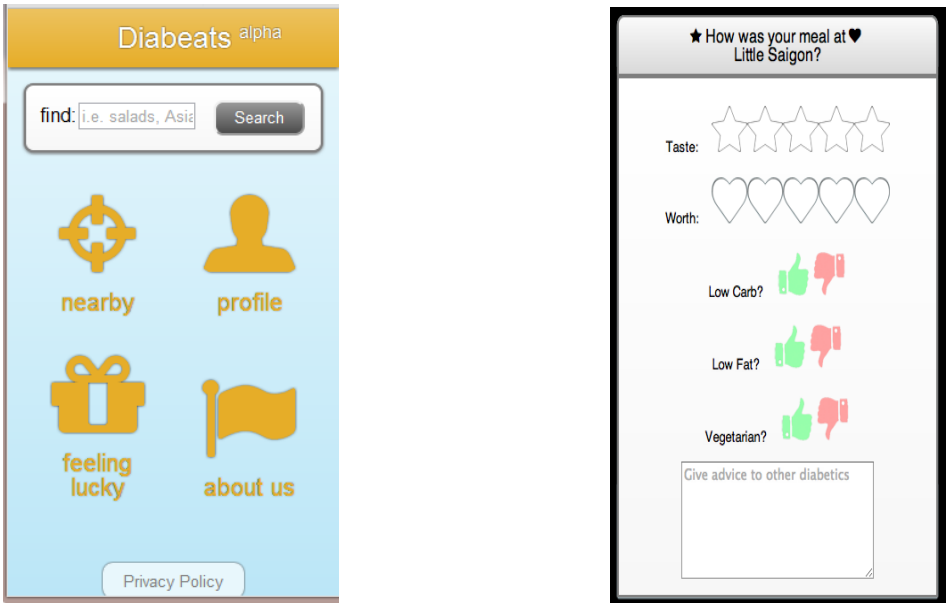

Figure 9: Left: Home screen for Diabeats mobile application. Right: Review screen

Diabeats was born from numerous customers requesting a "Yelp for Diabetics". While Yelp offers great information to help optimize for taste and location while eating out, the lack of diabetes-specific content and a trusted network makes Yelp searches futile for diabetics. With

Diabeats, we start with a closed network for diabetics, by diabetics. Profile information is gathered to ensure we can provide recommendations to our users from diabetics with similar backgrounds—ethnicity, activity level, experience with diabetes, and more. Then, users can search for nearby restaurants, filter by diabetes-specific metrics such as low-carb or vegetarian, and make more optimal choices while eating out. As seen in the right image of Figure 9, our review screen has functionality to capture more metrics than merely taste. From our initial interviews with customers, we have found seasoned diabetics to be very eager to pass along their knowledge to others, and we are hoping to capitalize on this altruism to build a Wikipedia-like community of devotees.

Figure 10 lays out our final business model canvas:

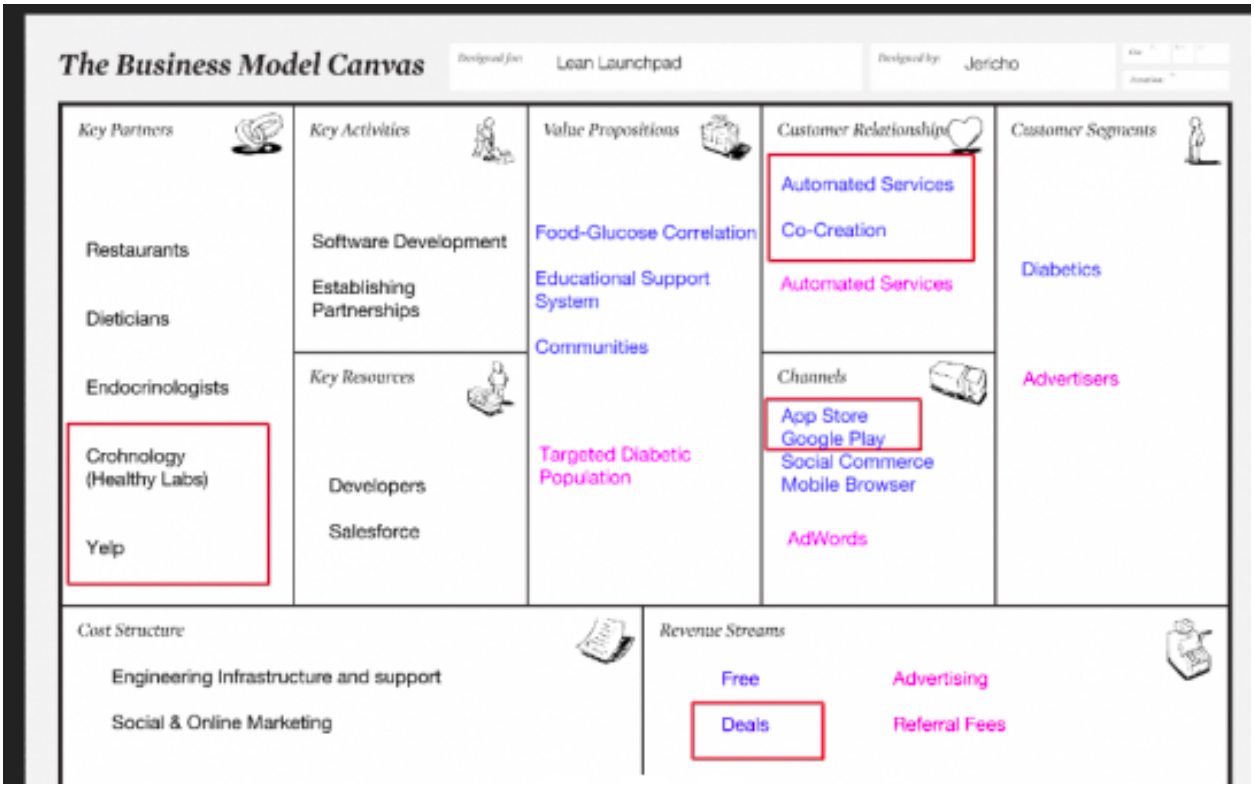

Figure 10: Final Business Model Canvas for Diabeats.co application

As seen from the canvas, Diabeats.co deals with a two-sided market of diabetics and advertisers. Value propositions focus on creating a sense of community and education while channels are now aimed at mobile Internet devices. Lastly, social networks tackling other chronic ailments have been added as potential partners.

Eating out is a massive problem for diabetics. In conversing with potential users regarding Diabeats, we found it very easy to communicate our value proposition. Likewise, users were very easily able to relate to the application and could see its potential in soon becoming a trusted information hub and community for diabetics to make smarter food choices.

CONCLUSION

In this paper, we discussed our journey of product iterations in developing a mobile application for diabetics. The past nine months have been an absolute blast for me as I have internalized the value of customer development, rapid iteration, and ultimately failing fast in the world of startups. Indeed, a startup is not at all a smaller version of a large company. From customer acquisition to development to project management, startups come with their own unique challenges.

Engineers-turned-entrepreneurs often have the mindset that they can simply "engineer" a product and customers will buy it. Worse, if customers won't buy the product, some engineers will propose adding more features! My biggest learning from these past nine months is the following: initial product intuition is almost always wrong. Customer development ensures organizations stay nimble, fail fast, and innovate their business models.

As of today, we have deployed our beta release at http://www.diabeats.co/ to a small testing group in the San Francisco Bay Area consisting of about 30 members. We hope to address data acquisition and distribution challenges over the coming weeks through targeted marketing campaigns and direct outreach to various diabetes support channels, such as the American Diabetes Association (ADA) and UCSF.

It remains to be seen whether Diabeats will pan out and achieve the scale we are hoping for. Some might question the low barriers to entry in this space, lack of pure intellectual property, and continued woes of Yelp's business model itself. Social networks routinely have trouble with the chicken-and-egg problem of acquiring users and content, and Diabeats is not an exception to this. Yet, we are optimistic that tackling one set of problems at a time will prove far easier both for us and our customers. We will continue development on our "Siri for Diabetics" on the side and look forward to integrating a personalized recommendation engine into Diabeats in the near future.

My father has been living with Type 2 Diabetes for over 15 years now. Although he runs about five miles each day, practices vegetarianism, and watches his diet attentively, I have firsthand seen how frustrating the disease can be for him. It is our sincere hope Diabeats can positively impact the lives of my father and the numerous other diabetics worldwide and empower all to live smartly.

ACKNOWLEDGMENTS

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