OnPoint: A Social and Mobile Platform for Optimizing Health Services for Complex Chronic Care Management

Bill Kim

Electrical Engineering and Computer Sciences
University of California at Berkeley

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Bill Kim

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Visual Computing and Computer Graphics

This **Masters Project Paper** fulfills the Master of Engineering degree requirement.

Approved by:

1. Capstone Project Advisor:

Signature: _____ Date _____

Print Name/Department: Bjoern Hartmann, Department of Electrical Engineering and Computer Sciences

2. Faculty Committee Member #2:

Signature: _____ Date _____

Print Name/Department: Dan Gillette, CITRIS

OnPoint:

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Master of Engineering Capstone Design Report

Bill Kim

University of California, Berkeley

Department of Electrical Engineering and Computer Sciences

Visual Computing and Computer Graphics

In Collaboration with:

Angela Hsueh, Department of Electrical Engineering and Computer Sciences

Zhuosi (Amy) Wang, Department of Electrical Engineering and Computer Sciences

Faculty Advisor: Professor Bjoern Hartmann,

Departments of Electrical Engineering and Computer Sciences

Faculty Committee Member: Dan Gillette

Research Specialist, CITRIS

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1. Introduction

The healthcare system in the United State is constantly in a state of flux as it attempts to balance the ever increasing needs of its diverse population, keep pace with rapid technological developments, and be fair to the multitude of healthcare professionals within the system. One of the most recent catalysts that have impacted the healthcare system is the increase in need for chronic care management. IBIS World Reports estimates over 130 million Americans suffer from a chronic disease and that these individuals are responsible for nearly 76% of all hospitalizations. Furthermore, Ibis also predicts that these numbers will increase significantly in the coming years due to the baby boomer generation developing common chronic diseases such as congestive heart failure, chronic obstructive pulmonary disease and coronary artery disease (Diment 2015: 10). Not only do chronic diseases account for a large percentage of hospitalizations, but they also account for a large part of healthcare expenses. In fact, according to a 2009 JAMA article, chronic illnesses account for 75% of Medicare spending (Peikes et al: 603). The large cost of managing chronic diseases can be attributed to the fact that they require a diverse range of medications, appointments, caregivers, and specialists to effectively manage the disease and the patient. Additionally, having only one chronic condition is a unique case, because being predisposed to one chronic condition usually leads to multiple conditions, which further increases the cost of managing the condition and complicates the care that is needed (Kim 2015:1). Trying to reduce the complexities, price tag, and prevalence of chronic conditions is the purpose of our capstone project. We aim to create a social and mobile platform to efficiently and effectively manage care of a patient in a complex interconnected web of caregivers, physicians, specialists, pharmacists, nurses and family members.

2. Problem Statement

The sudden increase in chronic diseases has exposed a gaping need in the current health care system due to its inability to effectively treat such diseases. This is due to the fact that the present system focuses on treating acute diseases which are characterized by, but are not limited to, abrupt onset, limited duration, usually a single cause, and technical interventions are usually effective for treatment (Holman et al: 118-119). These characteristics are in direct contrast to those of a chronic disease, which explains why there exists a disconnect between chronic diseases and reliable treatment. Chronic disease requires collaboration and communication between the patient and the care team. As Holman and others state, "The bedrock is continuity and integration of care by the participating health professionals" (Holman et al: 119). Therefore, our main focus in creating our application is to foster and encourage this type of teamwork within the care team surrounding the patient. With an emphasis on strengthening collaboration through our mobile solution, we will bridge the divide between the care chronic patients need and the care they receive.

3. User Needs Assessment

A chronic patient must deal with a wide array of issues, from scheduling and tracking medications and measurements to maintaining various personal and clinical goals. In order to fully understand our patient's situation and the role of their caregivers, we relied heavily on our partners at the UC Davis Health Systems to provide us with feedback from eight participants, which included patients, caregivers, and physicians. They provided us with valuable insight and a realistic care plan (Appendix A) for a patient suffering from cardiovascular disease which we used to create our storyboard and build our prototypes around. Furthermore, we were also able to consult a few of these participants and received two key insights regarding care management that

drove our prototyping phase. The first was that medications itself is a huge endeavor for patients that includes scheduling, managing, taking, tracking, and refilling medications. We needed to ensure our medications module within our application eased the process of overseeing medications, rather than complicating it. The second came from a patient telling us, "Different people need different features, don't overwhelm me with everything." This highlighted the fact that even though we wanted our application to have enough breadth to cover all aspects of a patient's care plan and enough depth for each feature to be useful, we must gradually integrate our application into patients' daily lives. Our initial planned feature list included shared care plan, medication management, symptom management, nutrition, physical activity, appointments, personal monitoring devices, and integration of data and workflow. However due to the time constraints of one year and the large scope of the project, we decided to drop the nutrition and physical activity components due to many existing applications on the market that already fulfill this purpose such as Fitbit[1], Jawbone[2] and other activity tracking monitors. Once we had a firm grasp on our user and had a list of required features, the next step was to begin the design process.

4. Design Phase 1

During the first design phase of the project, the team focused its efforts on creating low fidelity user interface mockups and imagined all the possible different situations, scenarios, and user interactions that could occur to create the most holistic, convenient and easy to use application for chronic disease management. After designing the initial wireframes, we created the initial prototypes with sticky notes to simulate the actions and workflow of our design. Once

[1] https://www.fitbit.com/
[2] https://jawbone.com/

the basic workflow was established, we created medium fidelity wireframes with Balsamiq[3], which is a rapid wire framing and mockup tool, and InVision[4], which creates presentable prototypes by linking various mockup screens together with animations, gestures, and transitions to create a clickable user interface on a smartphone or tablet. I will be discussing our initial shared care plan mockup, while Amy and Angela will be focusing on the medication tracking and medication scheduling design one phases, respectively. The work breakdown structure for design phase 1 is shown in figure 1.

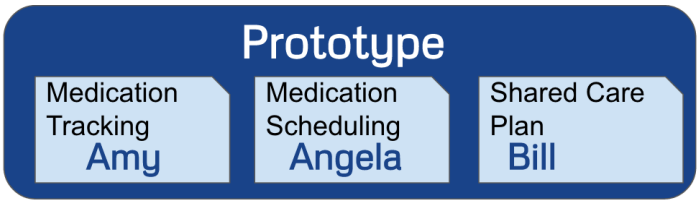

Figure 1: Work Breakdown Structure for Design Phase 1

4.1 Shared Care Plan

We identified the shared care plan module as being the most critical component of our application because it would act as the cornerstone of collaboration that would allow us to differentiate ourselves from other health care applications. The shared care plan has four main components which are goal setting, roles and contacts, self-management plan, and measures and outcomes. A simple version of the shared care plan would only include goal setting and roles and contacts, while an extended version would include the other parts as well. We initially decided to pursue a simple shared care plan that encompassed goal setting and roles and contacts; in addition to being the access point for medications, measurements, appointments and symptom management. Because our shared care plan was the intersection of all of these components we

[3] https://balsamiq.com/
[4] https://www.invisionapp.com/

decided to make it our main dashboard view and be the true meeting point of a patient's care plan. Our main dashboard presented various "cards" that gave users access to every feature of our application. Users could pin certain cards, remove others, and be able to prioritize them to reflect their own unique condition. We strove to make the dashboard as customizable as possible in direct response to a patient urging us to not overwhelm him with our application. By providing customization, a user had the power to utilize the features that were only relevant to him or her. An example view of the main dashboard is presented in figure 2 with various reminder cards that include goals, medications, appointments, symptoms, measurements, and messages. Further Balsamiq Mockups can be found in Appendix B.

Figure 2: Balsamiq Mockup of Main Dashboard View.

4.2 Goals Module

The initial goals module was very prominent in our shared care plan. We designed the module to allow patients to enter and track various personal and clinical goals such as "Being able to hang out with friends" and "Taking all medications". The first iteration was oriented towards a goal tracking application, and allowed patients to define a very fine level of granularity

in their goals. For example, we broke down goals as long term goals such as “Staying energetic” and routine goals such as “Walking 30 minutes a day” and we provided different templates for each of these goal options. We gave the user options to set reminders, be able to track their goals, and whether the goal should be displayed on their main dashboard view.

After a round of feedback from our UC Davis partners, the goals module underwent a major pivot. Rather than track the goal itself, we decided to give the patient the ability to create an action plan to achieve the desired goal, based off of the logic that tracking actions was easier than tracking a goal itself. An action plan would list specific tasks to be done, in order to realize the goal. We further simplified the module by eliminating the distinction between a long-term goal and a routine goal, which effectively reduced the level of granularity a patient had in creating a goal. Following more discussion with UC Davis, we finally settled on a very simplistic purpose for the goals module; the patient would be able to view their clinical and personal goals that were configured either by their care coordinator or themselves. The simplistic model was chosen because, although goals are an important feature of a patient’s care plan, the achievement of the goals themselves can be attained through the patient following the entire care plan and therefore individual goal tracking would be redundant and cause fatigue on the user. By looking though goals, a patient and health care professional should be able to discern the big picture of the patient’s care plan.

4.3 Roles and Contacts Feature

The next portion of the shared care plan was incorporating “roles and contacts”. We wanted to integrate this feature into our application as more than a contacts list with tags indicating a role. Through “roles and contacts” we wanted to address the essential aspect of treating chronic conditions, collaboration and coordination. According to Dr. Daniel Way,

"Collaborative Practice is an inter-professional process for communication and decision making that enables the separate and shared knowledge and skills of care providers to synergistically influence the client/patient care provided" (Way et al. 33). We wanted our application to provide an avenue of "Collaborative Practice" for all types of care providers to induce the type of synergy that could produce the best patient care possible. Therefore, the "roles and contacts" feature was designed to allow patients and health care providers to create custom groups and teams such as "Diabetes Team" or "Heart Disease Team". The idea was that, through custom teams, health care providers would be able to offer patients comprehensive care and evaluation as a unified team with a unified goal. This feature, however, did not bring teamwork to the forefront as much as we had envisioned. The way we designed the "roles and contacts" feature was not a defining characteristic of our application during usage because it could be avoided completely. Therefore, this could not provide the synergy that Dr. Daniel Way mentioned is necessary to provide the most ideal patient care. To address this problem, we made collaboration our first priority in the next design iteration.

5. Design Phase 2

After completing our medium fidelity Balsamiq mockups, we re-evaluated the shared care plan and decided that a true care plan encompassed all components of a patient's health, including Medications, Measurements, and Symptom Management; which we initially thought of as separate entities in the first design phase. Through this redefinition we were able to design a new user interface that also incorporated more participation amongst the care team, which solved our issue of not placing a greater emphasis on teamwork. The new user interface was an interactive Health Timeline that served as the point of collaboration and linked to other modules as necessary. We decided to move on from Balsamiq and created medium fidelity prototypes

with Google Drive Slides for the timeline prototyping due to extreme time constraints. Google Slides allowed the team to prototype the timeline faster because the timeline did not require specific iOS templates that Balsamiq provided and we could use simple rectangles and text to construct the timeline After finalizing the idea of the Health Timeline with Google Slides, we created high fidelity prototypes in Keynote and produced interactive pdfs to show our advisors and for user testing. For this design phase, I will be discussing the details about the Health Timeline. Amy will be focusing on the Symptom Management module and Angela will be discussing our storyboard and the challenges involved with creating it. The work breakdown structure for design phase 2 is shown in figure 3.

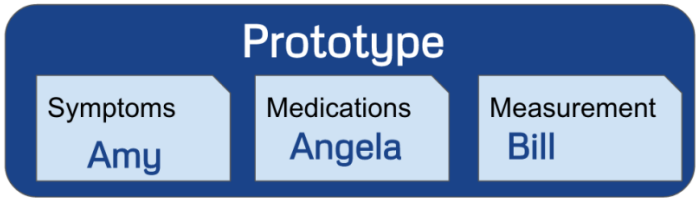

Figure 3: Work Breakdown Structure for Design Phase 2

5.1 The Health Timeline

We came up the new timeline interface because we felt like our previous designs did not address the issues of collaboration and communication in a profound way. The idea of the timeline is twofold. First, it facilitates sharing of information because it serves as the main overview of all relevant events that can impact a patient's health. Second, it also encourages contact between the patient and caregivers. The timeline view consists of action cards, reminders, and messages. An example view of the Health Timeline with a measurement card is given in figure 4. To view a detailed list of timeline features reference Appendix C.

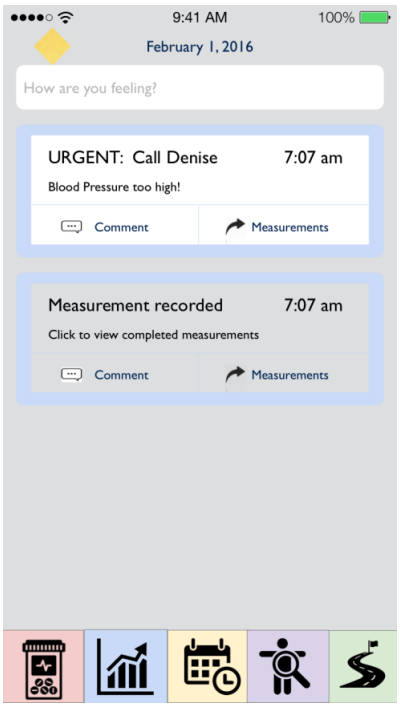

Figure 4: Keynote Mockup of Health Timeline

Each card that appears on the timeline can be commented on and viewed by anyone on the care team, thus generating discussions on specific aspects of a patient's health in order to treat the patient more effectively. All members of the care team have access to the patient's timeline and each member can filter the timeline to a subset of categories. The patient will have the ability to restrict what other people see from his or her own timeline. For detailed information about a certain health component, the patient can navigate to the specific page for the health component either through the card on the timeline or through a tab at the bottom of the screen. We initially had planned five tabs at the bottom of the screen which would be Medications, Measurements, Appointments, Symptoms, and Goals. Each action card that appears on the timeline view can be completed by simply clicking on the card, completed cards are greyed out and only greyed cards can be swiped away to avoid clutter on the timeline screen. The timeline will store all cards and comments in a database that will be easily queryable by any

combination or subset of category, user, or date. Furthermore, the app will present detailed summaries of all aspects of the patient's health. This summary will be used during appointments, so each physician within the care team will be able to see a holistic view of the patient's health. This is an especially important feature of our application because a patient will see multiple doctors and specialists and these clinical professionals rarely interact directly with each other, despite the fact that they treat the same patient. The ability of our application to provide each clinician with the same view of a patient's health related data will increase the quality of care the patient receives by giving clinicians a comprehensive view of how the patient is being treated by others in the care team. Through the new Health Timeline, we aim to solve the most pressing issue in managing chronic diseases, collaboration.

6. UC Davis User Test

After creating a full storyboard and creating high fidelity Keynote wireframes of our final designs we held an official user testing session at UC Davis. We met with clinicians, patients and nurses in four different combinations, a pair of clinicians, a clinician and patient pair, a clinician and nurse care coordinator pair, and a patient and family member pair. The age of our participants ranged from mid-30's to early 60's so we were able to gain a wide perspective on our prototype. Through five different scenarios, we observed how each pair accomplished a different task while navigating the prototype. The scenarios included taking morning measurements with a scale and blood pressure monitor and calling the nurse care coordinator because of an unusually high blood pressure reading; setting up a medications schedule for eight different medications and filling a pillbox with the generated schedule; and responding to a medication notification to take specified pills, while skipping a specific subset of pills. Each wireframe was customized for a specified scenario so only a subset of buttons was actually

linked to respond to user clicks. This allowed us to observe what the user's first instinct was on any screen and we were able to record what they expected to happen.

The user testing session identified a few key issues in our designs that we needed to address before implementation. The major issue was that the various cards on the timeline were ambiguous as to whether they were clickable. We have three types of cards on our timeline; actionable, reminder, and urgent cards. Users, however, were confused how to respond to actionable and urgent cards and thought of them as simply reminder messages, rather than pathways to execute the action that was specified on the card. As a solution to this problem we adopted a color code for the various cards as well as modified the wording to make the card's purpose more obvious. Another prevalent issue was that users wanted the flexibility to take more than a scheduled dose of a medication and also reacted negatively to selecting each medication to be taken at a given time. Rather they preferred to have the default action to be "take all medications" and deselect medications they did not want to take. This feedback was directly applied to our Medications modules. There was also confusion regarding the "Symptoms" tab. User's assumed that this module was where they could list daily symptoms that afflicted them, however, the purpose of this tab was to keep track of and monitor screening questionnaires for various symptoms. The form for indicating daily symptoms is the input field at the top of timeline. We replaced the Symptoms tab with a Timeline/Home tab and increased the prominence of the input field to draw attention to its functionality. The feedback we gathered was applied to the keynote wireframes so we have an up to date mockup to reference during implementation, which can be viewed in Appendix D.

7. Implementation

Before implementation we had to decide what framework to build the application in, either a native iOS app or a hybrid application with web development technologies. We decided to create a hybrid application using HTML/CSS/Javascript with Ionic Framework rather than create a native application in iOS using Swift. The main reason we chose a hybrid application was because the learning curve of HTML/CSS/JavaScript seemed to be much less steep, which would provide us with a faster development cycle. Hybrid applications are mobile applications using web development tools and are bundled into platform specific deployment packages that can be loaded onto a specific platform, such as iOS. A native application has the benefit of performance because it was built using the platforms native code and has access to all of the platforms latest APIs. Our application is not computationally expensive so the performance drop is not a factor in our application. Furthermore, Ionic Framework provides us with plugins for the necessary native iOS components we need, such as Healthkit, ResearchKit, and access to the camera. Finally, as a consequence of choosing to build a hybrid application with web technology, we benefit by having access to a much larger developer community.

In order to have a fully functioning application by the end of the year, we will be focused on creating an alpha version of the application and therefore not be placing much emphasis on the graphical elements of the application. The development of the application will be broken down into three phases and can be seen in figure 5.

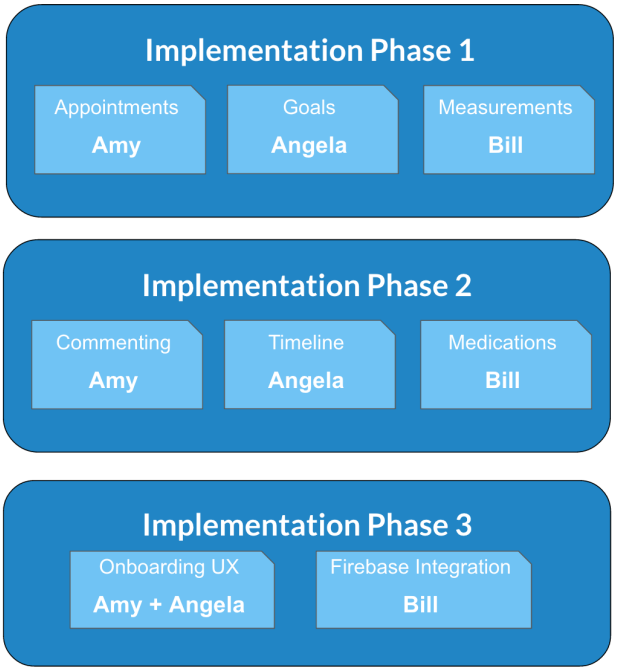

Figure 5: Work Breakdown Structure for Implementation

During the first phase of implementation, we tackled the simpler features of the application as an introduction to web development and to get our feet wet with the Ionic Framework. The second phase of implementation tackled the Timeline and Medications modules within our application which were much more complicated. Throughout the first two phases, we separated our data from the view and controller by utilizing Angular JavaScript factories. This allowed us to transition to a backend database later without having to make significant changes to the view and controller code. In the third phase of implementation, we focused on creating a cohesive experience with the application by creating the onboarding screens as well as starting to migrate data into a real time backend service. I focused specifically on transitioning all of our data into a persistent database.

7.1 Software Architecture

Because we chose to create a hybrid application with web development technologies we chose a model-view-controller (MVC) software architectural pattern. The view layer is created with HTML and CSS, which are web technologies used to create user interfaces on web pages. The controller layer is used to manipulate the data and is implemented with JavaScript. The data lives within the model layer which is implemented with Firebase which I will discuss in the next section. A general overview of the architecture can be seen in figure 6.

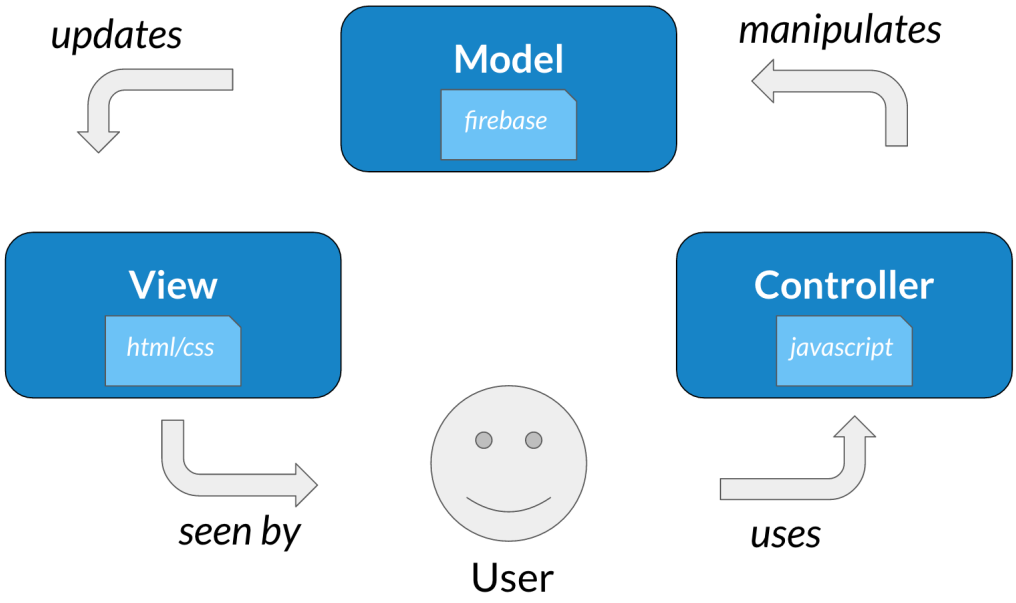

Figure 6: MVC Software Architecture

7.2 Firebase

We chose Firebase as our backend service because of its NoSQL structure which was extremely important due to the uncertainties of how we wanted to structure our data. This uncertainty meant we needed a flexible schema that was able to adapt quickly without a lot of work, which led us to selecting a NoSQL structure. Additionally, Firebase provides us with user authentication features and security rules that will allow us to protect Patients confidential

information in the future versions of the application. The Firebase API also provides useful constructs such as synchronous objects to abstract away the asynchronous nature of querying a database.

7.3 Data Structure

The way we structured our data was extremely important because it would impact the responsiveness of the application and would reduce bottlenecks during future development. I chose to create a very flat data structure within Firebase so that each component of a patient's care plan would be a direct child of the patient within Firebase. Figure 7 visualizes the flat data structure layout within Firebase.

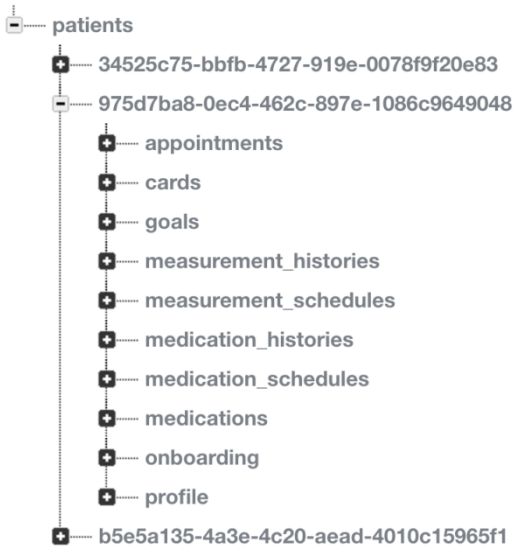

Figure 7: Data Structure within Firebase

Every item within a certain component of the care plan has a unique ID that is generated when it is added to Firebase. This unique ID is used to connect all of the different components within the care plan. For example, a medication card does not contain the information about the medication or the medication schedule that generated the card. Instead, the card contains a *medication_schedule* ID that is used to look up the medication schedule and the

medication_schedule contains a list of medication ID's that can be used to look up the specific information regarding the medication. This flat structure allows for direct references to objects within Firebase that can be queried immediately from Firebase because we are able to provide the full Firebase reference to the object we desire. In addition, the flat structure allows each component of the patient to be less complicated and only store information directly relevant to that component (i.e. a medication schedule component will only include timing information and the list of medication ID's not the information about the medications themselves).

7.4 Segmented Control

During implementation, we also redesigned the timeline, medications, and measurements tab within the application to include segmented control. An example of the segmented view on the timeline tab can be seen in figure 8.

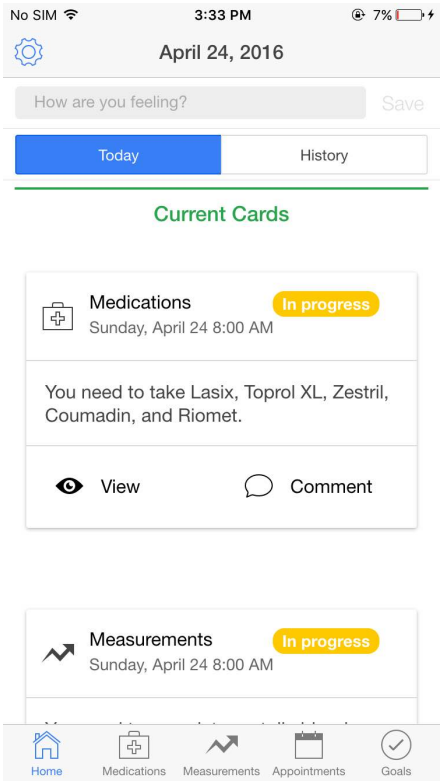

Figure 8: Segmented Control on Timeline Tab

Within the timeline tab the user can switch between a “Today” tab and a “History” tab where they see today’s/upcoming cards and archived/past cards, respectively. Within the medications tab the segmented control allowed user to see his schedule, specific mediations, and access the fill pillbox feature. Within measurements tab the segmented control allowed the user to see his schedule, measurements history and add any measurement he wanted. Segmented control was added to allow the user to do more actions that were intuitive within the specific tab without adding clutter to any individual page.

7.5 Further Development

After reviewing the application with our UC Berkeley and UC Davis advisor’s there were a few more implementation changes that were applied. We decided to create ad-hoc cards whenever a patient performed a non-scheduled task such as taking a medication cabinet medication, logging a non-scheduled measurement, or changing/editing their schedule. These ad-hoc cards would automatically be archived in the history tab and will give a more holistic view of the patient’s health status to caregivers and doctors. These ad-hoc cards can also be commented upon.

8. Conclusion

We have created an alpha version of a mobile solution to tackle the issue of chronic care management. Our application, OnPoint, allows patients to create and edit preconfigured medication and measurement schedules and track his medication and measurement adherence. OnPoint can be used to carry out research studies and user testing to see whether such an application can successfully integrate within a patient’s life and ease the burden of managing chronic conditions. Further work is required to improve the graphics and animations of the application to match the initial keynote wireframes. Additional work is also required to integrate

with Apple's ResearchKit for symptom management surveys and HealthKit to aggregate measurement data. Furthermore, because we are using pre-configured medication schedules, the application will need to integrate a medication scheduling algorithm as well as image recognition to allow patients to take pictures of medication bottle labels to input medication.

With the rise of chronic conditions in the United States there have been many efforts to help those who suffer manage their illnesses due to the complexity and cost of such diseases. Many of these efforts have focused on patient self-care with a system of healthcare interventions and communications with the patient and care team (Diment 2015: 5). Our capstone project also centers around patient self-care with a heavy emphasis on collaboration between the patient and various caregivers to help the patient's disease management take a backseat to their daily lives.

9. Acknowledgements

I would like to thank our UC Berkeley advisors Professor Bjoern Hartmann and Dan Gillette for providing us with their user interface expertise and guidance throughout the project. I am also thankful our UC Davis advisors Katherine Kim and Sarah Haynes for providing us with clinical experience and insight and also connecting us with various patients, nurses, care coordinators, and doctors within the UC Davis Health Systems. Furthermore, I would like to thank Dmitri Skjorshammer who was our project manager during the implementation phase of project. I also appreciate Hansen Lui for helping us perform user testing at UC Davis. Finally, I would like to thank CITRIS for providing us with the grant that funded this project.

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Chapter 2: Engineering Leadership Paper (Team-Written)

1. Introduction

Chronic disease is the greatest challenge facing the healthcare system in the United States. It is the leading cause of death, accounting for 7 out of 10 deaths each year, and over half of all Americans have at least one chronic condition (Chronic Disease Prevention and Health Promotion 2015, Gerteis, Izrael and Deitz 2014:4). In order to address the challenges and long-term nature of chronic illness, the healthcare system is evolving from a reactive system to a more proactive system aimed at preventative care and patient self-empowerment. Chronic diseases require a diverse range of medications, appointments, caregivers, and specialists to effectively manage the disease and the patient. This poses significant challenges for patients as they are left to self-manage their care between office visits. Furthermore, a patient who suffers from one chronic disease also typically suffers from multiple comorbidities such as depression, hypertension, and obesity. The varying number and magnitude of diseases a patient suffers from further complicates the delivery of efficient and effective care (Kim 2015:1). The management of such chronic conditions requires complex interactions between multiple health care specialists, multiple transitions between physical locations and different degrees of maintenance and surveillance (Kim 2015:1). Our project is a collaborative mobile platform for patients to engage in their care and more effectively manage their complex health conditions. We will analyze how our project fits into the industry landscape, our approach to marketing, and the challenges we face regarding health data regulations.

2. Industry Analysis

The healthcare landscape is constantly evolving as it adapts and transforms to best serve the needs of an ever increasing population. Our capstone project is at the center of an emerging

industry within healthcare: the disease management industry. The number of people with chronic diseases is projected to grow over the next few decades as the baby boomer generation ages and becomes more susceptible to chronic illness. (Anderson 2010:7) Moreover, the Patient Protection and Affordable Care Act has brought wellness and long-term patient care to the forefront (Curran 2015:5-6). The potential market for a comprehensive chronic care management system is huge with such a high demand from the increasing population of potential buyers. The current state of solutions for chronic care management pales in comparison to the alarming rate at which the need for such a system is rising. Current care management revolves around infrequent checkups from a care manager and relies heavily on family members as well as self care. The disease management industry, however, has rapidly grown due to the digital revolution and technological advancements. E-patients, healthcare consumers that have taken a more active role in their own care by researching various topics online, have been a direct result of the internet and information age, (Ball and Lillis 2001:2-3). The rise of the electronic health records and the e-patient has contributed to improving information flow between doctors, patients, and caregivers. Furthermore, the propagation of medical devices and smartphone applications that pair with these devices in the realm of preventative medical care have empowered patients to monitor their own health, and have also improved communications between patients and their care network as well as strengthened patient self-care.

With the rapid pace of technological developments, there is no shortage of developers or engineers who can invent a solution for chronic care management. The disease management industry has experienced a flurry of new entrants such as CareZone, FlowHealth, Caremerge, and CareSync, which increases the rivalry within the industry. All of these companies provide smartphone solutions to lighten the load of managing the patient's chronic disease. The disease

management industry, however, is still looking for a comprehensive solution that can increase coordination and collaboration without significantly impeding the natural flow of a patient's life.

3. Market Analysis

Our project is designed to help chronic care patients understand their care plan and make the behavioral lifestyle changes necessary to improve their health outcomes; this is a central tenet to the evolving healthcare paradigm that healthcare professionals are struggling to effectively address through patient and provider training. Thus, our strategy to introduce our product to the market will be to first target healthcare professionals, who in turn, can recommend our app to their patients who have chronic diseases. Since we are partnering with the UC Davis School of Nursing, we can leverage the credibility of our partnership and proven deployment in the UC Davis Health System to market our app to healthcare professionals, and also take advantage of any network effects and connections of our partners at UC Davis. With the goal of increasing adoption rate, our product is developed on the iOS platform and will be offered in the Apple AppStore for free.

4. Regulation and Ethics

The proliferation of health-related smartphone applications, of the standalone variety and also those which pair with medical devices, has brought to the spotlight regulatory concerns over such technologies. The US Food and Drug Administration (FDA) has regulatory authority over the safety of mobile health applications and stipulates that

> "apps acting as medical devices or as accessories to medical devices will require FDA approval, whereas apps that provide users with the ability to log life events, retrieve medical content, or communicate with clinicians or health centers will not be regulated under its jurisdiction [...] the FDA has focused on safety, it has largely left the review and certification of apps to the marketplace" (Powell et al. 2014:1851).

The explosion of smartphone applications that are aimed at the healthcare industry provides convenience and ease of use for patients but also comes with various risks and security concerns. Since we are not creating a medical device, which comes with risk of liability and also requires a lengthy and complicated process of FDA approval, we must be careful to distinguish ourselves as a non-medical health management application which aggregates health data and facilitates communication and collaboration. Our challenge lies in providing enough guidance to help patients organize their health care, without crossing the line to becoming a medical device by providing diagnoses or medical recommendations. Instead, all medical advice and suggested adjustments of a patient's care plan will come from the health care professionals within the patient's healthcare team. In a nutshell, our application is an information channel, not an information generator.

Since our project centers around patient medical data, we must be mindful of regulations and laws concerning privacy. In the United States, the Health Insurance Portability and Accountability Act (HIPAA) Privacy and Security Rules establish standards governing patient health data. According to the HIPAA Privacy Rule, any "individually identifiable health information" must be protected. This includes the individual's past, present, or future physical or mental health or condition; the provision of health care to the individual; the past, present or future payment for the provision of health care to the individual and other common identifiers that could be used to identify the individual (Office for Civil Rights 2003:3-4). Because our application will aggregate various factors that describe the patient's health status and present it in a timeline view with searchable past history, we must be vigilant in the transmission and security of the information collected by the application. We will provide data privacy by creating user accounts and only giving read and write permissions to specific users designated by the care plan

and the patient. Furthermore, all information transfer, such as screening questionnaire and symptom protocol results, will be encrypted. Through these precautionary steps we will safeguard the patient's health-related data and ensure their privacy is secure.

5. Conclusion

The healthcare industry is on the cusp of a digital revolution as technology empowers patients to take charge of their own health. With the ever increasing human population combined with the aging of the baby boomer generation a more efficient and effective healthcare system is a challenge that is evident now more than ever before. Our capstone group will leverage expert advice from the UC Davis School of Nursing and CITRIS to maneuver around patient data privacy concerns and create an application to meet the rising demand for a comprehensive chronic care management system. Our focus on fostering and improving collaboration and communication will distinguish us from current solutions and will serve as the key ingredient to the solution of chronic care management.

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Appendices

Appendix A - Mrs. A's Care Plan:

Summary of problem:

Mrs. A is a 72 year-old woman who has been living with type II diabetes for 12 years. She developed cardiovascular disease and was recently informed that she has heart failure. She has noticed greater difficulty in walking with hip and leg pain. Mrs. A takes eight prescription medications: Metoprolol (beta-blocker), Lisinopril (ace inhibitor), Coumadin (anti-coagulant), Lasix (diuretic), Lipitor (statin), and Losartan (angiotensin receptor blocker), as well as Metformin for diabetes and Ativan for anxiety. All are taken daily but on different schedules, e.g. before going to bed, 1 hour before taking food, or with food. Mrs. A sometimes doesn't take Lasix if she plans to go out for the afternoon because it causes frequent urination. Several medications cause Mrs. A to be dizzy and fatigued. She describes them as making her feel "loopy" and prevents her from driving. She's not sure they are working so she sometimes decides to take a break from them. Mrs. A needs to limit intake of vitamin K-rich foods, e.g. kale/collards/grapefruit, pomegranate, as vitamin K can make Coumadin less effective as a blood thinner. She is also on a low-sodium and diabetic diet and restricted fluid intake. Mrs. A's healthcare team includes a primary care doctor, cardiologist, diabetes educator, dietician, and pharmacist who are located in four different facilities. She has visits with her doctors around every six months. She's met with the diabetes educator and dietician once. She sees the pharmacist to get her refills. She lives alone in a two-story home. Her son lives in the same town and although he works full-time and has a family, he frequently helps with her healthcare and daily living needs. Her daughter lives in another state and checks in regularly with both of them. Mrs. A's greatest concerns are remaining independent and having the energy to visit with friends and family.

<u>Mrs. A's Care Plan:</u>

I. The care team
II. Goals
III. Medications
IV. Measurements
V. Symptoms
VI. Nutrition
VII. Access and changes to the care plan

I. The care team

Name	*Role/relationship*	*Responsibilities*	*Nature/frequency of communication*
Geeta Patel	Cardiologist	1. Prescribe list of medications for heart failure and adjust as needed 2. Answer questions about symptoms, problems, and issues with medication related to heart failure during visits 3. Set clinical goals based on existing guidelines 4. Monitor Mrs. A's heart failure, including assessing symptoms and physiologic parameters 5. Set clinical goals based on existing heart failure guidelines	After diagnosis, will see Mrs. A every 1-2 weeks until it is certain that all paramters are stable (BP, kidney function, heart rate, potassium levels). Then she will move to once a month and if after 3-4 months she is doing well, she will move to every 4-6 months.
Bob Smith	Primary care physician	1.Monitor Mrs. A's diabetes, including assessing symptoms and physiologic parameters 2. Monitor Mrs. A's general health and well-being 3. Communicate with Geeta about any information relevant to Mrs. A's heart condition 4. Adjust diabetes medications as needed 5. Set clinical goals based on existing guidelines	Sees Mrs. A during primary care visits every 6 months and when she has an issue or problem
Denise Myers	Nurse care coordinator	1. Help Mrs. A understand the causes and management of heart failure 2. Check in on Mrs. A's progress regularly, including viewing	Sees Mrs. A during cardiology visits every six months; communicates with Mrs. A weekly regarding

		summaries of measurements and symptoms 3. Make sure Mrs. A understands her clinical goals 4. Help Mrs. A set personal goals related to her treatment 4. Answer questions about symptoms, problems, and issues with medication related to heart failure as needed by phone, MyChart, or in person through a clinic or home visit 5. Send Mrs. A symptom management decision aids according to results of screening tool 6. Checks Mrs. A's medications against her medical chart 7. Reconcile medication list at every visit	measurements and labs (more often when a problem arises). Available by phone when a question or concern arises. Views Mrs. A's data weekly; if something looks wrong, Denise verifies with Mrs. A that the data of concern is accurate. Then, she contacts Geeta for guidance, especially if it will require medication adjustment
Ken Rodriguez	Pharmacist	1. Fill and dispense Mrs. A's medications 2. Ensure that Mrs. A understands her medications, their instructions, and their restrictions 3. Medication reconciliation 4. Coumadin monitoring: The Coumadin clinic is run by pharmacy at UC Davis. They do their own follow ups for blood testing and dosing. A critical component and definitely a goal of therapy and monitoring is to have the Coumadin clinic alerted every	Does not make contact with Mrs. A directly; explains medications and instructions to her son when he comes to pick up the medications

		time a medication is changed. There are a lot of medications that affect the levels of Coumadin and sometimes the dosing needs to be adjusted. The physicians do not do this.	
Nicole Graham	Dietician	1. Help Mrs. A understand her dietary restrictions and needs 2. Create a diet plan for Mrs. A 3. Teach Mrs. A about tracking certain nutrients, such as sugar, potassium, vit K and salt 4. Check in with Mrs. A around nutrition	Met with Mrs. A when she was diagnosed with diabetes diagnosis and again after her heart failure diagnosis. Since the heart failure diagnosis, follows up with Mrs. A monthly by phone
Alan Moore	Diabetes educator	1. Help Mrs. A understand causes and management of diabetes 2. Educates on lifestyle modifications 3. Educates on sign and symptoms of complications i.e. hypoglycemia, wound healing, eye exams, etc.	One-time visit with Mrs. A; no subsequent communication
Roger Anderson	Son	1. Pick up meds from pharmacy 2. Drive Mrs. A to appointments 3. Help Mrs. A understand her condition and care plan 4. Help Mrs. A understand her symptoms and determine if she needs to see a clinician 5. Learns about the data needed for monitoring (BP, sugar, weight, etc.)	Regularly looks at Mrs. A's measurements and symptoms. Speaks daily with Mrs. A by phone and in person about how she is doing. Knows and communicates with all of the members of the care team.
Allison Thomas	Daughter	1. Check in on Mrs. A and ensure she is getting the care she needs	Regularly looks at Mrs. A's measurements and symptoms. Speaks

		2. Provide emotional support	daily with Mrs. A by phone about how she is doing but is not actively involved in delivering her care or speaking with her care team.

II. Goals

Personal goals:

1. Remain independent
2. Keep visiting with friends and doing my daily activities
3. Be able to visit out-of-town family by plane
4. Feel healthy

Clinical goals:

1. Control systolic blood pressure to lower than 130/80 mm Hg but not less than 90 mmHg
2. Home glucose monitor to avoid hypoglycemia- this is what kills diabetics in the short term!
3. Keep HbA1C levels at 7% or less
4. Keep heart rate between 60-80 bpm
5. Tolerate all heart failure medications
6. Lower LDL cholesterol levels to below 100 mg/dL
7. Weight- we usually define a dry weight and then monitor 3-5 Lb. changes from it to modify medications (i.e. diuretics) and diet (i.e. salt).
8. INR measurement for Coumadin goal is 2-3
9. Oxygen levels with ambulation or while sleeping – keep O2 saturation at >91-92%
10. Decrease anxiety levels
11. Due to a risk of hyperkalemia with the Losartan, move Mrs. A off of losartan; if blood pressure increases, switch to carvedilol instead of metoprolol

III. Medications

Medication	*Description*	*Dose*	*Timing*	*Instructions*	*Purpose*
Furosemide (brand name Lasix)	Diuretic	40 mg	Twice daily: first in morning and then 6-8 hours	Orally	Treats salt and fluid retention and swelling caused by heart failure

			later		
Metoprolol succinate (brand names: Toprol, Lopressor) extended release tablets	Beta-blocker	25 mg; double dose every 2 weeks to highest tolerated dose up to 200 mg per day	Twice a day, morning and night	Orally	Used to treat heart failure, and high blood pressure
Lisinopril (brand name: Prinivil, Zestril)	ACE inhibitor	40 mg	Twice a day, morning and night	Orally	Used to treat congestive heart failure
Warfarin sodium (Coumadin)	Anticoagulant	2 mg	Once a day, morning	Orally	Used to treat and prevent blood clots by acting as a blood thinner
Atorvastatin (Brand name: Lipitor)	Statin	20 mg	Once a day, best given at bedtime because liver deals with cholesterol during sleep	Orally; do not take with grapefruit	Used to treat cholesterol and triglyceride levels
Losartan	Angiotensin II receptor antagonist	25 mg	Twice a day, morning and night	Orally	Used to treat high blood pressure
Metformin (Brand names: Glumetza, Riomet, Glucophage) immediate release	Oral hypoglycemic agent Antidiabetic	500 mg	Twice daily	Orally; with meals	Used to treat type 2 diabetes
Lorazepam (Ativan)	Benzodiazepine	0.5 mg	One tablet, as needed	Orally	Used for the short-term relief of the symptoms of anxiety

IV. Measurements taken at home

Measure	*Unit*	*Frequency*	*Purpose*	*Instructions*
Weight	Kg (if possible); can use lbs if more comfortable	Daily; in the morning before eating or drinking (after urination)	Sudden weight gain can be a sign that heart failure is worsening	Weigh on the same scale at the same time each day. If you gain more than 1.4 kg or three pounds in one day, call Denise.
Blood pressure	mm Hg	Twice daily, in the morning before taking medications, and 4-6 hours after morning meds	Controlling blood pressure is important because heart failure can get worse if the heart is pumping too hard or not hard enough.	For both measurements, use the digital blood pressure/heart rate monitor. Take measurements at the same time every day, while sitting down and resting. If you see a reading that seems too high or low, try again twice more. If you get the same reading two more times, call Denise. Target blood pressure: 90-130/60-80 mm Hg Call if blood pressure is above 160 (systolic) or below 90 systolic
Heart rate (pulse)	Beats per minute (bpm)	Daily, in the morning, before getting out of bed	Monitoring heart rate is important because a fast or slow rate can indicate that something is wrong with the heart.	Target heart rate: 60-80 bpm Call if heart rate is above 100 bpm or below 45 bpm

V. Symptoms

Currently, we are only going to focus on anxiety and constipation. We will add more symptoms later.

Symptoms	*Evaluation*
Anxiety, Constipation	Mrs. A will use the screening tool every two weeks. If she selects that yes, she is experiencing the symptom, she will automatically receive the symptom decision aid tool for that symptom. Depending on the resulting score, Denise will either send self-care materials or reach out to Mrs. A to make another plan for care

VI. Nutrition

Foods to avoid or limit	*Reason to avoid*
Grapefruit	Interacts with Lipitor
Alcohol, cranberry juice	Can increase the effect of Coumadin
Large amounts of kale, spinach, brussel sprouts, parsley, collard greens, mustard greens, chard, green tea	These are rich in Vitamin K and can lessen the effect of Coumadin; you can still eat small amounts of these foods ; the most important thing is that the amount of Vitamin K *stays consistent from week to week*
Alcohol	Have no more than 1 drink per day; drinking large amounts of alcohol can cause cardiomyopathy or bleeding

	(interaction with Coumadin)
Caffeine (coffee, tea, chocolate)	It can increase heart rate or give you palpitations.
Salty foods (canned and processed foods, condiments, olives, pickles, soups, gravy, instant cereal, cured meats, cheese, sports drinks, fast foods, and frozen foods)	Aim to eat 1500 grams or less of salt each day; watch out for hidden salt
Fluids (don't forget about foods that contain a lot of fluid, like ice cream, juicy fruits, and soups)	Limiting fluids can help you feel better and lower risk of going back to the hospital; limit fluids to 8 cups (2,000 mL or 2 L) per day
Added sugar (ingredients listed as granulated sugar, cane sugar, corn syrup, glucose, dextrose, maltose, galactose, fructose)	Carbohydrate intake should be limited to 250 grams of complex carbs per day (for 2,000 calorie diet). Try to have around 50 grams of carbs per meal and 20 grams for snacks.

VII. Access and changes to the care plan

Mrs. A can grant different types of access to her care plan to members of the care team. For those with the ability to make changes, the change has to be approved by Mrs. A. When a change is made, members of the care team with viewing privileges should receive a notification. The following shows privileges:

Person	*Can make changes*	*Goals*	*Meds*	*Measures*	*Symptoms*	*Nutrition*
Geeta Patel	X	X	X	X	X	X
Bob Smith	X	X	X	X	X	X
Denise Myers	X	X	X	X	X	X
Ken Rodriguez			X			X
Nicole Graham		X	X	X	X	X

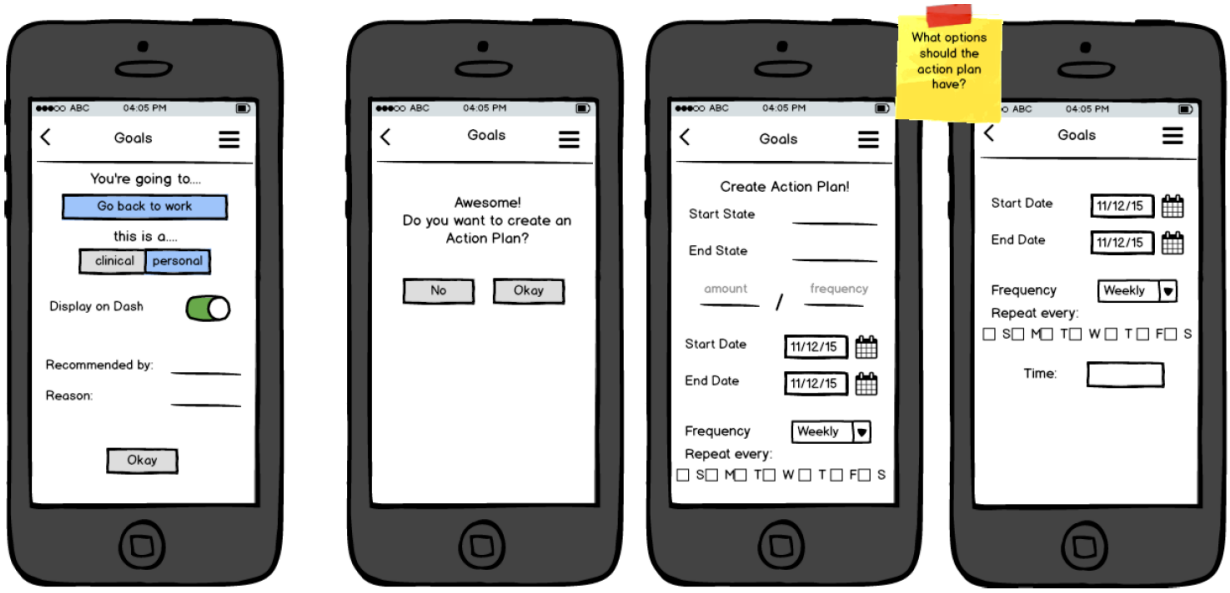
Alan Moore						X
Roger Anderson	X	X	X	X	X	X
Allison Thomas		X	X	X	X	X

Appendix B - Balsamiq Mockups for Shared Care Plan

I. Main Dashboard View

II. Roles and Contacts Feature

III. Goals Module



Appendix C – Timeline Details

- The timeline will consist of action items, reminders, and messages
- Users can filter the timeline to a certain subset of categories/items/users
- Users can customize what displays on the timeline view through settings for each item category. This will allow users to determine what information is more important and relevant to themselves, and prioritize which messages, action items, or reminders to display more prominently.

Setup:

- The timeline will be populated with actions items, reminders, and events during a setup process by the patient that can also be amended to by the care team
    - Contact list can be pulled from the existing contacts that a user has on their phone. Contact lists can also be shared between users.
    - Medications can be populated through 3 methods: (1) pulling it automatically from the pharmacy, (2) taking pictures of the medication bottle labels, and (3) manual entry.
    - Medications will be scheduled through a tablet application that allows the user to drag-and-drop the different medications into time slots throughout the day.

Access

- Everyone can have access to the same timeline view. This gives patients and their care team members an overview of the patient's health status and upcoming action items. The main patient can control what level of access other secondary users have to their information.
- The tasks/action items on the timeline view cannot be modified by anyone besides the patient or the healthcare professionals on the care team once they are set

Action Items:

- Different aspects of the health care plan will produce action items for the patient to do, such as an action to take a medication. The action items will be of a specific type i.e. medication, goals, symptoms. For example, a care coordinator can generate an action item for the patient to take a symptom management survey.
- Users can comment on the action items, messages, and reminders, similar to a message thread. These action items, messages, and reminders with comments can be expanded into their own individual feed.
- The timeline needs to differentiate between missed actions that require resolution vs missed actions that do not require further action. Actions requiring resolution will be highlighted according to urgency.

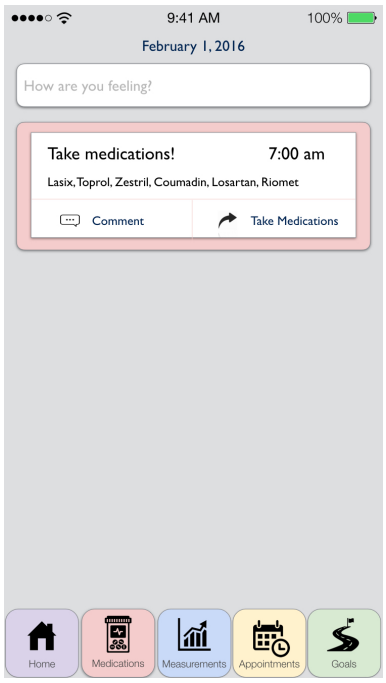
Reminders:

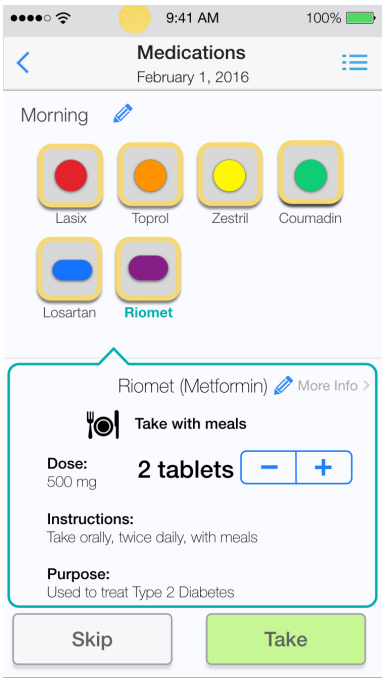
- When a user clicks a reminder the app will remove the reminder and mark it as an action that has been accomplished and finished. It will appear in the timeline feed as part of the history. i.e. reminder to take medication → took medication at 3:12 PM.

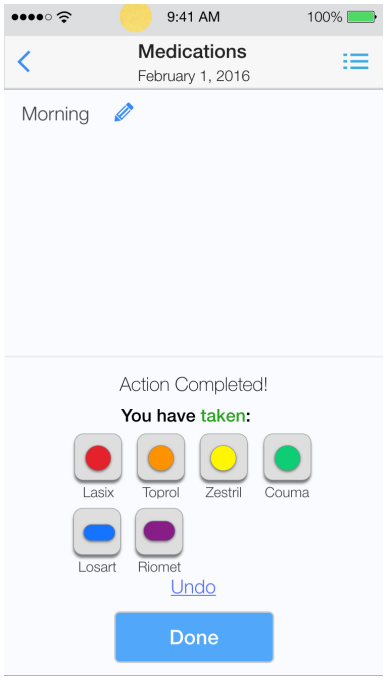
- A user can highlight a specific item on the timeline to see a history of comments made on that item and also enter the specific category of the item.
- By scrolling upwards, the timeline will load past history. By scrolling downwards, the user can view upcoming items.
- The timeline will be the main view of the application but there will be navigation buttons at the bottom of the screen to go to the specific pages for medications, goals, symptoms, contacts, etc.
- When a licensed medical professional comments on an event/task we will indicate that the comment has been made by a professional.
- The app needs access to the user's contact list, calendar, reminders, internet
- The app will provide templates for certain frequently used comments/queries such as responding to yes/no query from a care team member
- All information will be stored in a database, for query and retrieval and to look at past care plans.

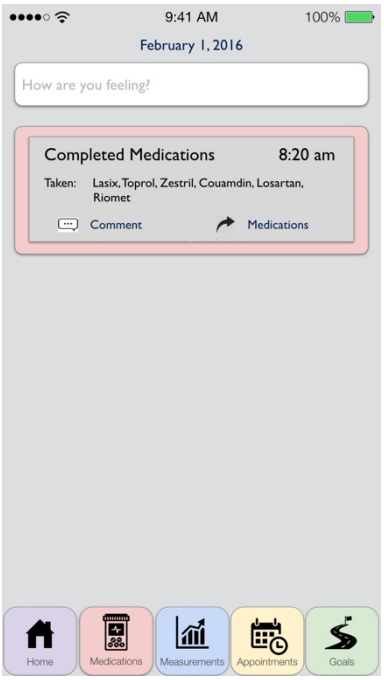
Appendix D – Keynote Wireframes

I. Medication Tracking

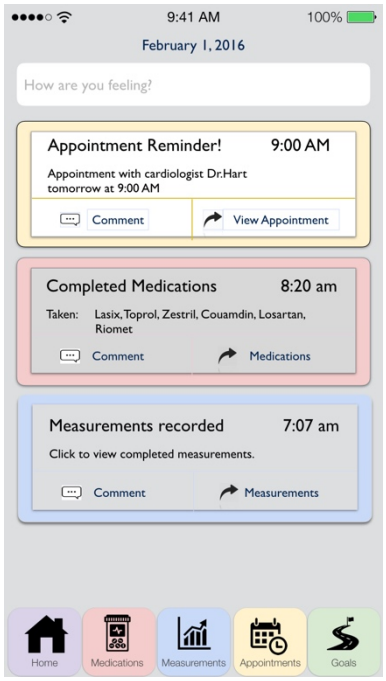


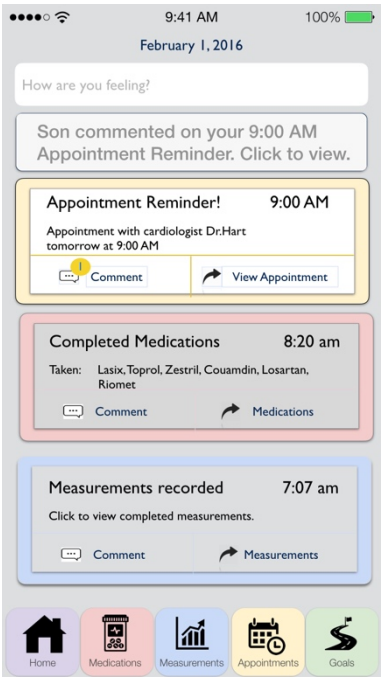


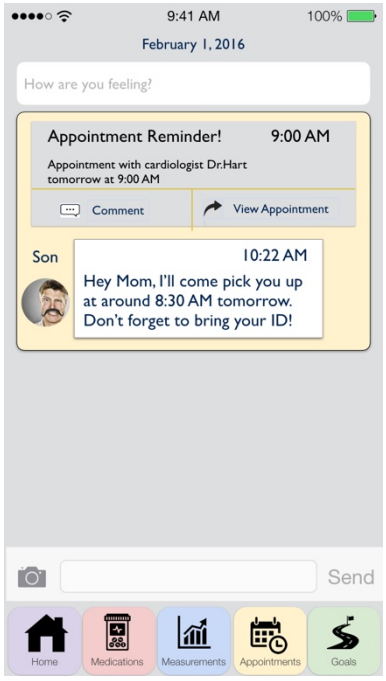


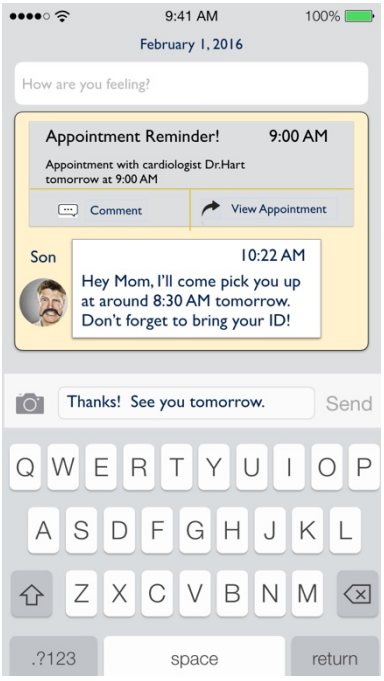


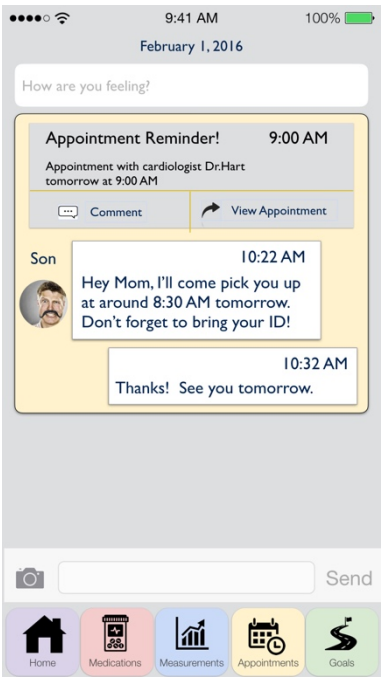
II. Timeline and Commenting







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100%
February 1, 2016
How are you feeling?
Appointment Reminder!
9:00 AM
Appointment with cardiologist Dr.Hart tomorrow at 9:00 AM
Comment
View Appointment
Son
10:22 AM
Hey Mom, I'll come pick you up at around 8:30 AM tomorrow. Don't forget to bring your ID!
10:32 AM
Thanks! See you tomorrow.
Send
Home
Medications
Measurements
Appointments
Goals