

# Discordant Chronic Comorbidities: CHI SRC Paper

ProHealth REU Summer 2017

Gabrielle Cantor  
Indiana University  
Bloomington, IN  
gcantor@iu.edu

Sergio Ramirez Martin  
Transylvania University  
Lexington, KY  
sergiormrz560@gmail.com

## ABSTRACT

Discordant Chronic Comorbidities (DCCs), or the simultaneous presence of two or more chronic illnesses with opposing treatment instructions in a patient, can make it difficult for patients and healthcare providers to prioritize and manage the treatment of each individual disease. Some difficulties that arise from having DCCs include medication conflicts, social and familial dependencies, seeing multiple health care providers, etc. This research seeks to understand the hardships that patients with DCCs face in managing their health. Furthermore, this research aims to create an intervention that will effectively support these patients in managing their health. This study focused on 16 patients with DCCs, all of whom had Type 2 Diabetes and were from in and around Bloomington, IN. During interviews, the patients answered a structured questionnaire and were engaged in a photo elicitation task where they described objects and aspects of their lives that either support or stifle their health management. A qualitative analysis of the content from the patients' interviews revealed themes that guided the creation of wireframes of a potential application. In this paper we describe the problems and solutions that patients face when managing and prioritizing the treatment of DCCs, as well as the wireframes created as potential solutions to make the management of their treatment easier.

## Categories and Subject Descriptors

H.4 [Information Systems Applications]: Miscellaneous;  
D.2.8 [Software Engineering]: Metrics—*complexity measures, performance measures*

## General Terms

Theory

## Keywords

comorbidities, discordant chronic comorbidities, medication management, mobile applications, wireframes

## 1. INTRODUCTION

Chronic conditions, or conditions lasting five or more months, are becoming increasingly common in patients. Due to the extended nature of these conditions, patients typically are asked to play an active role in their treatment. These conditions often require complex treatments, and patients who struggle to successfully manage their conditions and treatments are at a greater risk for developing other chronic conditions. The development of DCCs, or multiple chronic conditions with unique and often opposing treatment instructions, has become increasingly common, and creates difficulties for providers and patients when it comes to managing conditions. Despite the increased numbers of patients with discordant chronic comorbidities, there is a lack of studies on these patients as well as a lack of tools to aid individuals with comorbidities in managing their conditions. In this study we aim to develop a tool to help individuals with DCCs better manage their overall health and well being.

The challenge in studying patients with comorbidities often arises from their compounding health issues, which often leaves these patients sicker and spending more time in clinical environments. This presents a unique challenge in understanding the barriers to successful self-management of their diseases as well as discovering what tools would potentially be useful in improving their self-management skills. As there are few papers on patients or tools for patients with chronic comorbidities, we looked for papers focusing on patients with multimorbidities, as well as papers about self-management, medication management, and apps to help manage diseases. These papers allowed us to identify the need for studies focusing on patients with chronic comorbidities, as well as the need to look at designing technology to effectively support patients with chronic comorbidities in managing their diseases. We also identified the need to develop technology that aids with other aspects of self-management in addition to medication management, as most mobile applications on the market focus exclusively on medication management while ignoring other aspects of chronic disease treatment management.

By studying patients with DCCs, and specifically focusing on patients with Type 2 Diabetes and other chronic conditions, we were able to develop a tool to help patients better manage their chronic conditions. One reason this research focuses on Type 2 Diabetes as the index disease to study DCCs is that the World Health Organization argues that at least 170 million individuals suffer from diabetes [16].

Furthermore, the Center for Disease Control (CDC) reports that in the United States about 21 million people have diabetes [1]. Studies by Thorpe et al. [25] have revealed that the number of people living with diabetes and other chronic comorbid conditions is high and drastically increasing. These patients often need frequent general practice consultations, complex and structured care, as well as increased coordination between different health care providers to ensure better quality of care. We also discovered the primary barriers these patients face when it comes to managing their treatment, and the solutions they have developed to address the needs of their conditions. In this paper, we make three primary contributions, the first of which is the study and collection of data from patients with discordant chronic comorbidities. Our second contribution is identifying the barriers faced by patients with chronic comorbidities in successfully managing their conditions. Our third contribution is represented by the tool we have developed to help patients manage their conditions.

## 2. RELATED WORK

As chronic conditions become increasingly prevalent among patients, a plethora of studies have been done examining the impact of a chronic condition, how patients manage a chronic condition, and focusing on technology developed for patients with a single chronic condition. However, few studies have focused on patients with comorbidities, which are two or more chronic conditions, and almost no studies have looked at patients with discordant comorbidities, which are chronic conditions with opposing treatment instructions. Due to the inadequate amount of research on discordant comorbidities, we pulled information focusing on a variety of similar topics including multimorbidities, self-management, medication management and adherence, and mobile applications. By studying these areas, the researchers were able to identify ideas and processes used in the treatment of single chronic conditions, which can serve as the basis for developing technology designed to suit the more complex need of patients with DCCs.

### 2.1 Multimorbidities

Multimorbidities, the presence of two or more chronic illnesses in an individual, can create difficulties in managing and treating these illnesses. Bayliss et al. [2] found 15 primary challenges faced by individuals with multimorbidities which were the compound effect of multiple conditions, physical limitations, the compound effect of medications, the challenge of coordinating multiple medications, the burden of taking multiple medications, side effects of medications, lack of knowledge about their conditions, financial constraints, low self-efficacy, the burden of the dominant effect of one condition, the emotional impact of having chronic conditions, inadequate communication with health care providers, the need for social support, logistical issues, and the need to better understand their conditions. This combination of challenges not only makes the management of multiple conditions more difficult, but also leads to patients with multimorbidities being more willing to learn self-management strategies and more willing to see non-physician medical professionals such as nurses, chiropractors, nutritionists, physicians assistants, or others to supplement their care [19]. Multimorbidities can make other aspects of managing care, such as managing medications,

more difficult than if a patient only had one chronic condition.

Multimorbidity is increasingly prevalent in patients with diabetes, with several studies looking at the frequency of patients with diabetes and other multimorbidities. Teljeur et al. [24] found that 90% of patients with diabetes had at least one additional chronic condition, and more than one-fourth had more than 4 additional chronic conditions. Studies have also found that the number of chronic conditions an individual has increases with their age [8], and that these patients with multiple other chronic conditions in addition to diabetes typically placed a lower priority on their diabetes, as other conditions were more intensive, resulting in patients often being unsuccessful in managing their diabetes [12]. This leads to patients with diabetes receiving lower quality medical care for all their conditions, due in part to the limited amount of time during visits with health care providers to address all concerns they may have. However, in situations where patients are able to maintain e-mail or phone correspondence with providers in between regular appointments, patients with and without multimorbidities experienced the same standard of care as these alternative communication channels with health care providers were able to fill in the care gaps and circumvent time constraints during appointments [22].

### 2.2 Self-Management

Self-management is the process of empowering patients with the knowledge, skills, and tools to facilitate self-care, and to encourage them to be an active participant in the treatment of their conditions. For patients with chronic conditions, self-management is a necessary aspect of their care to ensure that they are taken care of, even when not frequently seeing a doctor. Self-management relies on the needs, goals, and life experiences of patients with chronic conditions to improve clinical outcomes, health statistics, and their quality of life [6]. It also often involves a collaborative health care model, where patients work with their health care providers to manage and treat their diseases. It also often focuses on holistic outcomes, including a patient's physiology, symptoms, physical and emotional functions, their personal health perceptions, and their quality of life [13]. Self-management can be broken into three main components - medical management of the condition(s), creating and maintaining new behaviors or routines, and dealing with the emotional impact of having a chronic condition. In order to successfully manage each of these components, patients need to learn skills such as problem solving, decision making, how to find and utilize resources, how to form partnerships with their health care providers, and how to take action to improve their health [14].

Several studies have explored the benefits of self-management, specifically for patients with one or more chronic conditions. When studying diabetes patients in an intensive treatment and education program, Polonsky et al. [23] found that, compared with individuals in a standard diabetes treatment program, those in the intensive treatment and education program experienced a greater drop in their A1c, monitored their blood-glucose levels more frequently, paid more attention to the carbohydrate and fat-contents of food, and overall had better glycemic control. Patients in intensive self-

management educational programs typically had increased levels of exercise and fewer uses of health services such as extra doctors visits or hospital stays, which contributes to lowered health care costs and higher quality of life for patients [15]. In addition, patients with self-management skills are more likely to know how to research and find information, which leads to a better understanding of their disease and treatment options, which can be especially helpful for patients who are unable to treat their conditions using the standard treatment options [17].

There are several barriers to successful self-management which are preventing patients from successfully managing their conditions. Bodenheimer et al. [3] found that the lack of trained personnel, the lack of funds for self-management education, and the current medical model, which leaves patients dependent on physicians, prevents many individuals from learning to self-manage their conditions. Financial worries, lack of awareness to self-management education programs, lack of physician or family support, and pain also prevent many patients from being able to successfully self-manage their conditions [11].

### 2.3 Medication Management and Adherence

For many patients with multimorbidities, managing multiple medications is a crucial part of successful self-management of their diseases. When it comes to managing medications, the biggest concerns of patients are the ability to obtain reliable information on medications, maintaining autonomy when it comes to medication and treatment decisions, concerns about polypharmacy, discrepancies between traditional and alternative medical therapies and treatments, and the challenge of coordinating medications lists and health records between multiple health care providers [9].

For patients with Diabetes, medication adherence is an important aspect of treatment. Nkansah et al. [18] found that diabetes patients who managed their medications with the assistance of a pharmacist had improved glycemic control, were more likely to maintain their desired weights, and were more likely to reach their blood pressure goals. Electronic monitoring systems, such as those used to monitor insulin use in diabetics, have been shown to improve medication adherence as they can help patients easily monitor blood sugar levels and identify when they need to take more insulin, as well as aid health care providers in identifying patients who need more support [4]. In studying various methods to find the best medication management system, Granger et al. [7] found that the integration of in-person contacts with electronic monitoring systems, technology based medication reminders, and pharmaceutical database monitoring interactions helped to improved medication adherence and resulted in a positive impact on overall patient outcomes.

### 2.4 Mobile Applications and Technology

Recent studies have looked extensively at mobile applications as a tool to aid with the management of chronic diseases. Apps are useful for many individuals to aid them with tracking medications and numbers such as glucose scores, but Owen et al. [20] found that apps were more helpful for individuals who were changing their routines or experienced high fluctuations in glucose scores than for stable individuals as the ability to correlate glucose scores to daily activi-

ties was useful in understanding their scores and developing healthy habits. This often leads users to use only the features of the app that they find useful, especially if they have other monitoring methods that they don't want to change, which leads patients to interpret data in a non-clinical manner as they don't store all their data in the same place [10]. In studying ways to encourage consistent interpretation of data, Pernencar et al. [21] found that wearable sensors with connected mobile apps captured clearer statistics which encouraged the user to take an active role in managing their health by providing them the tools to consistently interpret and evaluate different aspects of their health. Doyle et al. [5] found that in order to encourage patients with multimorbidities to use a long-term medication management application, the app had to have the ability to create medication lists, educate users about their different medications, manage changing medications, and support individuals in scheduling and taking medications as prescribed.

## 3. OVERVIEW OF QUALITATIVE FINDINGS

After a thorough qualitative analysis of the DCC's patients' interviews, several major themes emerged. These themes represented barriers that patients face in successfully managing their DCCs, and strategies that patients use to overcome the problems that they face.

One major concern faced by DCCs patients is the lack of communication among the medical providers whom they see and the resulting problems such as contradicting medications, diets, etc. DCCs patients feel that their medical providers prescribe them medications and treatments without considering other medication and treatments prescribed by their other providers. In the words of a patient "Okay, so I'm talking to my kidney doctor, and he sees... he goes, 'Why are you taking B-vitamin? And cinnamon?' And I go, 'Well, my diabetic... He suggested that I take this.' 'Oh, you don't need that,' you know? He's going based on what his labs say, you know? 'You don't need that. That's not going to help.' And then you go, 'Oh... okay!'" -P13. Many of the patients interviewed mentioned a lack of communication among medical providers as a concern in one way or another. As the same patient pointed out "You know? But your diabetic doctor's not going to prescribe insulin based on your kidney schedule..." -P13. One strategy used by some patients is carrying a list of the medications they take every time they go to the doctor, that way the provider is aware and, if needed, can prescribe a new medication that does not conflict with the ones the patient is currently taking. As a patient shares, "I always keep a list of medications, a list of all my doctors, a list of how long I've been in the hospital, etcetera... And I provide that to every medical professional that I go to" -P13. However, other patient do not take such initiative. Patients who do not take such an active role in communicating with their medical providers are more most likely to take conflicting medications, which can be harmful.

Another major issue that emerged is polypharmacy. DCC's patients often end up on many medications as a result of having multiple conditions that require medications as a part of treatment. One patient explains, "So all of my medications are basically production. What I have in my hand there, I have a couple of fluoxetine, which is an SSRI, an anti-depressant, there's quetiapine, which I take both at night to

sleep, and as a mood stabilizer, there's some clonazepam, which is benzodiazepine, which I take for anxiety, that one I do take pure... And there are 2 vitamins there, there is a vitamin D capsule which low levels of vitamin D can contribute to depression, so I take that. And then, an iron supplement, because I have had anemia, and anemia contribute to depression" -P9. The routine of taking so many medications can become a daunting burden. A strategy used by patients to manage so many medications is using pill planners and schedules. A patient who wishes to have a more specific pill planner than the one they already owned said, "A much more specific pill box. Like 'take these on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday.' I would have—and maybe this exists, I don't know—the Monday column would have a box for wakeup and a box for morning, before lunch, lunch, after lunch, before dinner, dinner, after dinner, sleep. And every day would have however many boxes that was for those specific times" -P7. Having a well structured schedule for medications helps DCCs in taking the right medication at the right time, which reduces the risks of misusing medication or overdosing.

Another problem that emerged from the analysis is prioritizing illnesses and treatments. Patients with multiple chronic conditions often have to follow specific diets, exercise routines, medication regimes, and other treatment protocols. In many cases patients may find themselves struggling to follow two very different diets. In the words of a patient, "But on a renal diet, you have to look at the vegetables and say, 'Oh. I cannot have raw spinach. You know, I have to limit raw spinach.' But, you know, diabetic doctors: 'Oh! Eat a big spinach!'" -P13. In many cases like this, patients are faced with a decision that results in favoring one condition while disfavoring others. A strategy that patients often use to help them make such decisions is finding reliable information. They seek advice from peers, medical sources, and others. DCCs patients may also have medical support from case managers or health coaches who help them learn how to prioritize their treatments. For example, "My health coach handles swimming and exercising, and anything to do with my health. My case manager is there so for example my son wants to move out, well what's available to him or if I couldn't get to the grocery store I needed to get there my case manager take me. Or she could take me to the doctor." -P3. In situations where DCCs patients have access to easy to understand and reliable information they are more likely to have a better understanding of their conditions and treatments and be more successful in managing and prioritizing the treatment of multiple conditions.

An additional barrier that many patients with DCCs face is coping with their vulnerabilities and dealing with the mental implications of having multiple chronic conditions and the impact they have on an individual's life. For many patients each condition has its own set of difficulties to contend with, and varying mental and physical limitations which a patient must learn to overcome. Many patients discuss the need to come to terms with an altered life view, and the importance of realizing the impact that chronic conditions will have on one's life. Patient 7 discussed the importance of "Learning how to re-contextualize your life, things you enjoy and you have been doing for a while was immensely important to me. I didn't realize that's what I was doing at the time, but find-

ing a different set of parameters for something that I have been doing." -P7. Once patients come to terms with their new lives, it is important that they find ways to reach a sense of normalcy within their new realities in order to be able to successfully manage their chronic conditions.

One thing patients often do to help them adjust and thrive in their new life styles is establishing and maintaining various support networks. For most patients, their support networks have multiple components and can include friends and family, social networks, other patients with similar conditions, online support groups, and the support of their medical network. Friends and family help to provide a patient with emotional support in understanding their conditions, physical support in maintaining their independence and ability to complete daily tasks, and support in adhering to a medication or treatment regimen. Social networks have the ability to provide patients with a distraction from their conditions, and a way to focus on something else such as crafting or video games. For some this network can intersect with their network of other patients who they turn to for treatment advice and support in understanding the difficulties of living with chronic illnesses, such as Participant 11, who when discussing their knitting group said, "So, a lot of the people I knit with, the vast majority of them are women. About half of them also do have other forms of anxiety or depression. So, I can kind of commiserate with them. We can talk about, you know, things that have been frustrating for us in the last week. Sometimes, I talk to them about some frustrations I've been having with schoolwork or just work, and they can kind of empathize with that. Sometimes, they rant and I listen." -P11. Groups that intersect multiple types of support often allow patients to find support in others who can understand the challenges of their specific conditions, as well as help them to realize that they are not alone in facing the challenges associated with their conditions. It is also important for patients to develop a medical support network, which is often comprised of medical professionals other than their physicians, such as therapists, health coaches, pharmacists, and other who can help patients develop skills to manage the treatment of their chronic conditions. Developing this network is a crucial part of a patient being able to successfully manage and prioritize the treatment of their chronic conditions, as this network can help to provide advice, serve as a resource and source of reliable information, and help a patient to determine strategies that they can use to better manage their conditions. A strong medical support network, in combination with other networks of friends and family, social networks, and other patients can help to provide a patient with the emotional, physical, and informational support that they need to successfully manage their DCCs.

Another strategy that many patients use to help them adjust to their new lives is learning how to adhere to the non clinical aspects of their treatment, such as diet, exercise, and monitoring their conditions. Many chronic conditions require patients to change their diet and exercise in order to improve their overall health, such as Type 2 Diabetes. This can be a difficult transition for many patients, as it may require them to learn new skills such as limiting the amount of a type of food they eat or tracking the number of carbohydrates they eat in a day. Once patients are able to

find the diet and type of exercise that they enjoy and that fits in their daily lives, they often begin to see health benefits such as weight loss, lower blood pressure, or a reduction in symptoms. While the rewards are high, it is often difficult for patients to make this transition and learn how to eat healthier and exercise. While doing this, patients also often have to become accustomed to monitoring their symptoms in order to help manage and understand their disease. For Type 2 Diabetics this often takes the form of monitoring one's blood sugar, which typically involves a patient sticking themselves in order to record their glucose levels. It can be difficult for some patients to get into the routine of watching what they eat, exercising, and monitoring their glucose levels. Patient 9 discussed how *"...the sooner [patients] realize that it's a full time job and you are gonna have to dedicate so much time to controlling it. The faster you realize that, the faster you can do it and the faster you can take control of your health."*-P9. Once a patient is able to get into this routine, they are often able to better manage their conditions and better handle any medical situations that may arise. Incorporating non-clinical aspects of treatment such as diet and exercise are an important part of a patient adjusting to their new lives, and can help patients learn to manage and prioritize the treatment of their DCCs.

An additional barrier that many patients face in successfully managing and prioritizing the treatment of their discordant chronic comorbidities is the financial difficulties that are associated with treating multiple chronic conditions. While clinical costs from seeing multiple health care providers or taking multiple medications are often at least partially covered by a patient's insurance, many fear that if their insurance coverage is changed that they may no longer be able to afford all of the medications in the amount that they need. This can lead some worried patients to not take medication as prescribed, such as Participant 9, who cited concern that she may lose her insurance coverage as a reason for *"...trying to stockpile all of my supplies. I use infusion sets and cartridges longer than I should. I try to use less insulin, I refill my insulin as soon as possible."*-P9. This can lead to complications, which can often lead to increased hospitalization and costs. In addition, patients also often have to worry about the costs of non-clinical aspects of their treatment, such as the cost of a gym membership, the higher prices of healthy food, or transportation to medical appointments. Concerns over the financial aspects of their treatment can often deter a patient from trying new treatments, and can prevent them from successfully managing their conditions. While patients were not able to provide any potential solutions for this challenge, it is important to recognize it and keep it in mind as a significant challenge patients with DCCs must overcome.

## 4. TECHNOLOGY DESIGN PROCESS

### 4.1 Brainstorming

Once the main problems and solutions mentioned in the previous section emerged, researchers discussed possible avenues of design to support patients with DCCs. Researchers decided on a mobile application because it would allow to address the most problems faced by these patients. To devise the features for the application that would meet the needs of patients with DCCs, researchers engaged on a cognitive walkthrough, where they navigated through a series of ideas

from a patient's perspective. Some of the main features that surfaced from this cognitive walkthrough include a pillbox option where patients can see the dates and times they need to take medications; a medications option where patients can see a list of all the medications and information about them; a share option where patients can send their medical information to members of their support network; the ability to add a new medication by taking a picture of the pill bottle; a diary option where patients can keep track of routines such as appointments; a goals option where patients can set goals for themselves; and the ability for a patient to look up medication information. More detailed information about each feature is presented in the Wire-frames subsection. Researchers also discussed how these features would fit into the application.

### 4.2 Paper Prototypes

After deciding on the features for the mobile application, researchers started creating paper prototypes. As a starting point, only two features were implemented in paper prototypes, pillbox and medications. Each of two researchers implemented both features separately with the purpose of performing a Yours Is Better exercise and a Task List exercise. In the Yours Is Better exercise, two participants navigated through the prototypes of each researcher and gave feedback about what was better about one over the other, the purpose of this exercise is to extract all the ideas that are good from each prototype. In the Task List exercise, two different participants tried to guess what they would see when a button was "clicked" in the prototypes, and compare it to what they actually saw after "clicking", the purpose of this exercise is to find out if the icons and names are representative of what is "underneath". After performing this exercise, researchers met and discussed the input received by the participants. The next step was to upgrade from paper prototypes to wire-frames.

### 4.3 Wireframes

After analyzing the results of the user studies conducted with the paper prototypes, researchers began the process of creating digital wireframes of the application, which are described below.

#### 4.3.1 Features and Tasks

Within the application users will have the ability to view and manage their medications. In the Pillbox section of the app, users will have the ability to view their medications by the time they need to be taken, and view what medications are taken at the same time. They will also have the ability to add new medications to their list by either manually entering the information or by taking a picture of their pill bottle or medication container. These features will help users adhere to their medication regimen, and help them better keep track of and manage the medications that they are prescribed.

In the Medication section of the app, users will have the ability to view a list of the medications they are currently taking and have taken in the past. They will also be able to learn about the medications, compare the prices of their prescription at nearby pharmacies, and see a list of questions they may want to ask their doctor if they are taking that medication. This section will help to provide users with

easy to understand, reliable information about their medications which will help to improve understanding of their treatments, as well as provide them with the tools to communicate with their providers about their medications.

Users will also have the ability to communicate with others and share aspects of their medical information through the app. In the Share Information section of the app, users will be able to text, email, or download data they store in the app, including a list of their medications, side effects they experienced, health measurements they recorded, upcoming appointments, a list of their doctors, and a list of questions they have for their health care providers. As DCCs patients struggle to communicate information between multiple health care providers, having a central communication hub will make it easier for patients to facilitate communication between their entire support network.

Users will also have the capability to use the application as a diary and record side effects, various health measurements, upcoming appointments, and more. By allowing users to keep this information in one place they will be able to easily and efficiently share it with their health networks, and access it wherever they may be which will encourage them to record their symptoms and side effects, as well as share those with their doctors so that they can take an active role in managing their conditions.

Within the application users will be able to search and find easy to understand, reliable information about their conditions and treatments. Within the Information section of the app, users will have the ability to search and learn about conditions, see questions that they may want to ask their doctor, and learn about other possibilities for treatment that they may want to discuss with their doctors. This section of the application will allow patients to learn more about their conditions and have a better understanding of them, which is an important step in the process of learning to self-manage their conditions. When patients are able to access reliable information, they are better prepared to meet with their doctors and advocate for themselves.

The app will also provide users the opportunity to set goals, which will enable them to focus on other aspects of their health and well being, and take a holistic approach as they adjust to their changed lifestyles. The app will walk a patient through the process of setting a realistic goal, breaking it down into small, achievable steps, and working to reach that goal. The app will provide a patient with tips and motivations, which will allow them to achieve their goals and make strides in improving their quality of life.

## 5. REFERENCES

- [1] A. D. Association et al. Standards of medical care in diabetes—2014. *diabetes care* 2014; 37 (suppl. 1): S14–s80 diagnosis and classification of diabetes mellitus. *diabetes care* 2014; 37 (suppl. 1): S81–s90. *Diabetes Care*, 37(3):887–887, 2014.
- [2] E. A. Bayliss, J. F. Steiner, D. H. Fernald, L. A. Crane, and D. S. Main. Descriptions of Barriers to Self-Care by Persons with Comorbid Chronic Diseases. *Ann Fam Med*, 1(1):15–21, 2003.
- [3] T. Bodenheimer. Patient Self-management of Chronic Disease in Primary Care. *Jama*, 288(19):2469, 2002.
- [4] J. Cramer. A Systematic Review of Adherence With Medications for Diabetes. *Diabetes Care*, 27(August 2003):1218–1224, 2004.
- [5] J. Doyle, E. Murphy, S. Smith, C. Hannigan, J. Kuiper, and J. Dinsmore. Addressing Medication Management for Older People with Multimorbidities : A Multi-Stakeholder Approach.
- [6] M. M. Funnell, T. L. Brown, B. P. Childs, L. B. Haas, G. M. Hosey, B. Jensen, M. Maryniuk, M. Peyrot, J. D. Piette, D. Reader, L. M. Siminerio, K. Weinger, and M. A. Weiss. National standards for diabetes self-management education. *Diabetes Care*, 32(SUPPL. 1), 2009.
- [7] B. B. Granger and H. B. Bosworth. Medication Adherence: Emerging Use of Technology. *NIH Public Access*, 6(9):2166–2171, 2008.
- [8] A. Gruneir, M. Markle-Reid, K. Fisher, H. Reimer, X. Ma, and J. Ploeg. Comorbidity Burden and Health Services Use in Community-Living Older Adults with Diabetes Mellitus: A Retrospective Cohort Study. *Canadian Journal of Diabetes*, 40(1):35–42, 2016.
- [9] L. M. Haverhals, C. A. Lee, K. A. Siek, C. A. Darr, S. A. Linnebur, J. M. Ruscini, and S. E. Ross. Older Adults with Multi-Morbidity: Medication Management Processes and Design Implications for Personal Health Applications. *Journal of Medical Internet Research*, 13(2):1–12, 2011.
- [10] K. Huckvale and C. Morrison. How People Use Smartphone Apps to Manage Long Term Conditions. pages 5–9, 2014.
- [11] A. F. Jerant, M. M. Von Friederichs-Fitzwater, and M. Moore. Patients’ perceived barriers to active self-management of chronic conditions. *Patient Education and Counseling*, 57(3):300–307, 2005.
- [12] E. A. Kerr, M. Heisler, S. L. Krein, M. Kabeto, K. M. Langa, D. Weir, and J. D. Piette. Beyond comorbidity counts: How do comorbidity type and severity influence diabetes patients’ treatment priorities and self-management? *Journal of General Internal Medicine*, 22(12):1635–1640, 2007.
- [13] K. Lorig. Patient Self-Management : A Key to Effectiveness and Efficiency in Care of Chronic Disease in Care to Effectiveness of Chronic Disease and. 119(June):239–243, 2013.
- [14] K. R. Lorig and H. R. Holman. Self-Management Education: History, Definition, Outcomes, and Mechanisms. *Annals of Behavioral Medicine*, 26(1):1–7, 2003.
- [15] K. R. Lorig, D. S. Sobel, A. L. Stewart, B. W. Brown, A. Bandura, P. Ritter, V. M. Gonzalez, D. D. Laurent, and H. R. Holman. Evidence Suggesting That a Chronic Disease Self-Management Program Can Improve Health Status While Reducing Hospitalization. *Medical Care*, 37(1):5–14, 1999.
- [16] E. M. Magnan, M. Palta, H. M. Johnson, C. M. Bartels, J. R. Schumacher, and M. A. Smith. The impact of a patient’s concordant and discordant chronic conditions on diabetes care quality measures. *Journal of Diabetes and its Complications*, 29(2):288–294, 2015.
- [17] J. Mankoff, K. Kuksenok, S. Kiesler, J. A. Rode, and

- K. Waldman. Competing Online Viewpoints and Models of Chronic Illness. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 589–598, 2011.
- [18] N. T. Nkansah, J. M. Brewer, R. Connors, and K. M. Shermock. Clinical outcomes of patients with diabetes mellitus receiving medication management by pharmacists in an urban private physician practice. *American Journal of Health-System Pharmacy*, 65(2):145–149, 2008.
- [19] P. H. Noël, M. L. Parchman, J. W. Williams, J. E. Cornell, L. Shuko, J. E. Zeber, L. E. Kazis, A. F. S. Lee, and J. A. Pugh. The Challenges of Multimorbidity from the Patient Perspective. *Journal of General Internal Medicine*, 22(SUPPL. 3):419–424, 2007.
- [20] T. Owen, J. Pearson, H. Thimbleby, and G. Buchanan. ConCap: Designing to Empower Individual Reflection on Chronic Conditions using Mobile Apps. *Proceedings of MobileHCI '15*, pages 105–114, 2015.
- [21] C. Pernencar and T. Romão. Mobile Apps for IBD self: management using wearable devices and sensors. *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct*, pages 1089–1092, 2016.
- [22] J. D. Piette and E. A. Kerr. The impact of comorbid chronic conditions on diabetes care. *Diabetes Care*, 29(3):725–731, 2006.
- [23] W. H. Polonsky, J. Earles, S. Smith, D. J. Pease, M. Macmillan, R. Christensen, T. Taylor, J. Dickert, and R. A. Jackson. Integrating Medical Management With Diabetes Self-Management Training: A randomized control trial of the Diabetes Outpatient Intensive Treatment program. *Diabetes Care*, 26(11):3048–3053, 2003.
- [24] C. Teljeur, S. M. Smith, G. Paul, A. Kelly, and T. O’Dowd. Multimorbidity in a cohort of patients with type 2 diabetes. *European Journal of General Practice*, 19(1):17–22, 2013.
- [25] C. T. Thorpe, J. M. Thorpe, A. J. Kind, C. M. Bartels, C. M. Everett, and M. A. Smith. Receipt of monitoring of diabetes mellitus in older adults with comorbid dementia. *Journal of the American Geriatrics Society*, 60(4):644–651, 2012.