Too Many Conditions, Too Little Time: Designing Technological Interventions for Patients with Type-2 Diabetes and Discordant Chronic Comorbidities

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Abstract
Patients with Discordant Chronic Comorbidities (DCCs) either are experiencing multiple conditions that are not related in their treatment plans and management, or are dealing with the simultaneous presence of two or more chronic illnesses with opposing treatment instructions. These conditions can make it difficult for patients and health- care 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, and managing multiple treatments simultaneously. This paper highlights barriers faced by patients with type 2 diabetes and either depression or arthritis, describes a design process, and presents a design of a digital tool to support patients with DCCs in managing their health. The design ideas presented in this work were influenced by the health care management needs, barriers and opportunities suggested by patients with type 2 diabetes and DCCs.

Introduction and Background

Chronic conditions are conditions that last five or more months, such as diabetes, arthritis, and depression. Due to the extended nature of these conditions, patients typically are entrusted to play an active role in their treatments and management; however, they often require complex treatment and management routines. Patients frequently struggle to successfully achieve and/or maintain these routines, increasing their risk of developing other additional chronic conditions or severe health outcomes[1–4]. Discordant chronic comorbidities (DCCs) are conditions in which treatment guidelines are not related[2], or even conflicting, creating difficulties for providers and patients when it comes to managing their conditions. Despite the increased numbers of patients with DCCs, few studies have looked into understanding the needs and challenges these patients face[1]; furthermore, there is a shortage of tools to aid individuals with DCCs in managing their health and wellness. In this paper, we present the design of a tool to help individuals with DCCs better manage their overall health and well being.

Over 28 million people in the US have type-2 diabetes[5]. The majority of patients with type-2 diabetes have at least 1 additional chronic condition with approximately 40% have 3 or more chronic conditions[6]. These patients often need frequent general practice consultations, complex and structured care, as well as increased coordination between different health care providers to ensure the better quality of care [4,7]. In our prior work, we performed a photo elicitation interview (PEI) study with 15 patients with type-2 diabetes and a DCC (either arthritis or depression)[8]. We identified a set of barriers participants face when it comes to managing their conditions, and solutions they have developed to address their needs[8].

While these exist numerous applications to support people in managing their health, (e.g., wearable devices[9], journals[10], goal setting[11], rewards[10,12] and social sharing[13]), most of these applications were purposefully designed for patients with a single chronic condition or to achieve a single task (e.g. track physical activity routines or eating habits, or monitoring their physiological data such as heart rates and sleep patterns). Patients with DCCs typically face a multitude of tasks and routines, making these single-focus applications fall short in meeting their needs. Doyle et al. and Sinnott et al. separately explore how to encourage patients with multiple conditions adhere to complex medication management routines[14,15]. We use their work to inform the medication management portion of our design. However, their guidelines did not specifically address patients with discordant comorbidities, so may not sufficiently address the challenges associated with DCCs.

This paper presents a design case study which incorporates the findings from the literature and our prior work to address the complex needs of patients with type-2 diabetes and a DCC. We start with an overview of the most relevant findings of our previous photo elicitation interview (PEI) study of patients with DCCs. We then briefly present the

design process and wireframes of a tool to support patients with DCCs to better manage their conditions.

Barriers and Opportunities

Findings from our PEI study revealed five major barriers that patients with DCCs face while managing their health. The PEI study also highlighted the opportunities that the patients with type-2 diabetes and a DCC found useful in managing their health:

- **Coordination**: lack of communication and coordination amongst different medical providers can result in opposing treatment instructions, such as contradicting medications, conflicting diets, and overdosing. One solution that patients identified was having centralized and synchronized medical records: if all of a patients records are in one place, each medical provider could see it and recommend a treatment that does not interfere with other treatments already in place.
- **Polypharmacy**: a complex medication regime, including potential drug interactions, makes it difficult for patients to adhere to their prescribed medications. Some patients use medication management tools, such as a pillbox, but these were often not sufficient for the complexity of their regime or their ability to adhere when out of the house.
- **Prioritization**: how to prioritize different treatment and management routines for both short term and long term outcomes can be a challenge. Patients with DCCs often struggle to follow multiple strict diet and treatment protocols. If they are only capable of performing a subset of the recommendations, they must prioritize one treatment over another. Participants indicated the need to have easy-to-understand, reliable information that can contextualize the different treatment and their short- and long-term effects in order to be more informed when prioritizing them.
- **Coping**: coping mechanisms for the unique challenges posed by DCCs. 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. Participants often attempted to adjust their lifestyle to account for these limitations. They talked about having to come to terms with their new lives, and finding a sense of normalcy within their new realities in order to be able to successfully manage their conditions.
- **Financial**: dealing with the financial burden of their complex medical needs, as well as the reduced income due to health issues. While clinical costs are often at least partially covered by insurance, many patients fear that if their insurance coverage is changed, they may no longer be able to afford their treatments. In addition, patients often 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. 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.

Any technology design should attempt to address these different facets of living with and attempting to manage DCCs. The next section discusses our design process.

Iterative Design

To design a technological intervention that could effectively support patients with DCCs in managing their everyday health and wellness, we used the barriers and opportunities extracted from the PEI study to guide a brainstorming session where researchers generated, discussed, and evaluated several design ideas as they evolved.

Brainstorming

Once the research team had uncovered the main health managements barriers mentioned in the previous section, we discussed possible avenues of design to support patients with type-2 diabetes and DCCs. Researchers discussed each of these health care management barriers and their respective design opportunities and looked into the possibility of

using currently available technologies to support patient needs. We considered designing for wearable technologies, mobile devices, assisted living technologies such as smart-home devices, online support groups, and other ubiquitous and pervasive technologies. While each of these technology platforms could be used to support some of the health care management barriers that patients with DCCs face, researchers decided to move forward with a mobile application, because the majority of the participant (12 of 15) were already familiar with some features of mobile health apps such as iOS Health or Samsung Health. Twelve of the 15 patients owned a smartphone, and were somewhat familiar with using mobile applications to manage their health. Although there are many mobile application designed to support patients with the type-2 diabetes, to the best of our knowledge, there are currently no mobile applications that address the problems that arise from experiencing and managing DCCs.

To devise a set of features for the application that would meet the needs of patients with DCCs, the research team engaged in a free form design exercise where we utilized the barriers identified in the PEI study to ground the process. We compiled a list the features found on a set of best-in-class mobile applications (targeted at patients with type-2 diabetes) and attempted to map those features to the barriers to care. This process exposed several design opportunities which the research team then explored by rapidly iterating through a set of design ideas always keeping the patient experience as the focus for the exercise.

Ultimately the research team decided to focus our efforts designing a digital pill organizer interface where patients can see the dates and times they need to take medications; a medications information interface where patients can see a list of all the medications they are using and information about them including potential side effects; a sharing interface 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 interface where patients can keep track of routines such as appointments; and a goals interface where patients can set and track progress towards a series of health goals.

From Paper Prototypes to Digital Wireframes

Figure 1: Paper Prototypes and Digital Wireframes

After deciding on the features for the mobile application and brainstorming interface design opportunities, the research team started creating paper prototypes. As a starting point, only the digital pillbox organizer and medications features were created in paper prototypes. Two members of the research team sketched and designed these interfaces separately and then performed a "Yours Is Better" exercise and a "Task List" exercise to informally evaluate the potential interactions and usability of the interfaces. To conduct these preliminary formative evaluations the research team recruited university students to participate in the informal studies. During the "Yours Is Better" exercise, two participants navigated through the interfaces and compared using a "Think aloud" protocol the prototypes designed by members of the research team. A think aloud gives feedback to the research team about which aspects of the designs worked well and which could be improved. The purpose of this exercise was to generate diversified thoughts, opinions, and suggestions for improving and/or consolidating design ideas exhibited in the different paper prototypes. During the "Task List" exercise, two different participants walked through the prototypes to see whether they could successfully navigate through the app. In this task the participants would see when a button was clicked in the prototypes, and compare the

perceived action to what they actually saw after clicking buttons as they continued to navigate through the prototype. The researchers adopted this informal formative evaluation approach to assess whether the various interface element used in the design did a good job conveying design intent. After performing these exercises, researchers met and discussed the input received from the participants. Participants suggested improvements to the look and feel, as well as suggested improvements to the overall aesthetics of the designs. Suggestions on the App functionality including adding a Facebook messenger for sharing information and allowing users to customize reminders were also mentioned during the formative usability evaluation. A large number of the suggestions that emerged from the brainstorming and design exercises as well as the design and preliminary evaluation of the paper prototypes conducted by members of the team were incorporated into

Features and Tasks

The first iteration of the mobile app design focused on clarifying the features that afford patients the ability to navigate barriers related to polypharmacy and the coordination of multiple health providers. Features that support patients to prioritize their medications and achieve effective coping mechanisms were also included in the initial design, but still require further iterations to better support patients with DCCs. Below is a list features supported in the current version of our mobile application:

Medication Management
Our wireframes include several features to address the challenges of polypharmacy. To assist with adherence, the Digital Pill Organizer (see Figure 1B) displays current medications by the time they need to be taken, and view what medications are taken at the same time. To assist with prioritization, the Medication section of the app displays all current and past medications, with links to more details, including potential side effects and price comparisons for nearby pharmacies. Finally, to assist with coordination with providers, there is support for recording reactions and questions the patient may have for their health providers.

Health Tracking
To support prioritization of their various health routines, our design allows patients to record diaries, keep a history of medication side effects, various health measurements and upcoming appointments.. By allowing users to keep this information in one place they will be able to easily and efficiently share it with their health networks including their doctors so they can take an active role in supporting effective and informed health decisions.

Sharing
To assist with coordination between multiple providers, our design supports the ability to communicate with others and share aspects of their medical information through the app. In the Share section of the app (see Figure 1C), users can text, email, or download data, 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 healthcare providers. As patients with DCCs struggle to communicate information between multiple healthcare providers, having a central communication hub will make it easier for patients to facilitate communication between their entire support network. In addition, patients may choose to share some information with social networking sites that connect them to peer groups (e.g., other patients). By sharing directly from the application, patients may receive social support that helps them prioritize management routines or develop new coping mechanisms.

Health Resources
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. Within the application users will be able to search and find easy to understand, reliable information about their conditions and treatments.

Goal Setting
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.

Conclusion and Future Work

In this paper, we synthesized the health care management barriers faced by patients with type 2 diabetes and a DCCs based on our PIE study that involved 15 participants, and identified the five key barriers that our participants faced: coordination, polypharmacy, prioritization, coping mechanism, and financial burden. Patients in our study suffered from type 2 diabetes and either depression or arthritis, and the treatments associated with these chronic conditions are often conflicting and difficult to manage. We took these challenges into consideration and designed a digital tool through an iterative design process. We carried out an ideation and formative evaluation of the initial paper prototype, then incorporate participant feedback into a high fidelity digital wireframe design. Our design is capable of facilitating coordination, helping patients organize multiple treatment plans, providing a space for patients to share, discuss, and co-discover coping mechanisms, and pointing them to tips and resources that could help them financially. Having an integrated platform that focuses explicitly on DCC management will allow the patients and healthcare professionals be more aware and cognizant of prioritization issues relating to treatment and lifestyle changes. We plan to implement the digital tool and conduct a deployment study with patients with DCCs in the future.

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