ManageMyCondition: A Standard Framework for the Development of Cloud-based Medical Condition Management Applications

Cristiano Tapparello*, Wendi Heinzelman*, Kelly Conn†, Craig A. Mullen‡
*Department of Electrical and Computer Engineering, University of Rochester, Rochester, NY
†Department of Pharmacy Practice and Administration, St. John Fisher College, Rochester, NY
‡Department of Pediatrics, University of Rochester Medical Center, Rochester, NY
*{ctappare,wheinzel}@ece.rochester.edu, †kconn@sjfc.edu, ‡craig_mullen@urmc.rochester.edu

***Abstract*—Given the increasing availability and accessibility of mobile devices, there is enormous potential to transform how healthcare is administered through the creation of highly customized smartphone-based applications for effective medical condition management. Such platforms can offer improvements for both patients and healthcare systems. For patients, advantages include improved health management as well as satisfaction, enabling them to better understand their medical condition and improve their compliance with medication regimes. For healthcare systems, advantages include more effective patient management and increased pay-for-performance reimbursements, enabling real time tracking of critical patient specific data to provide comprehensive, effective medical condition management. However, a critical barrier to achieving these tantalizing benefits in healthcare management is the current paradigm of medical software design. Development and deployment of enterprise-wide applications is generally slow and expensive. Furthermore, each application is developed independently, even if several functionalities overlap between different applications. In this paper, we present ManageMyCondition, a framework for the rapid creation and standardization of medical condition management applications. The framework defines different building blocks for the creation of cloud-based mobile applications, defines a common format for data acquisition and presentation, and is easily customizable and extendable to meet the needs of different medical conditions. Finally, we present three mobile applications for medical condition management developed using the ManageMyCondition framework.**

I. Introduction

Medical care is rapidly being transformed by the introduction of new information technology and computer science approaches. New and exciting opportunities exist for improvements for both patients in terms of health and satisfaction, and healthcare systems in terms of effective patient management and pay-for-performance reimbursement. For patients, it is possible to develop computer based tools to increase patient understanding of their medical condition and to improve compliance with medications. As an example, a computer-based personal health support system named Comprehensive Health Enhancement Support System (CHESS), showed clear benefits for improving the patient's quality of life and promoting more efficient use of health care more than 15 years ago [1]. For healthcare systems, instead, computer based tools allow the integration of multidisciplinary care and real time tracking of critical patient specific data, which are functionalities very important in providing comprehensive and effective medical condition management. From this perspective, several studies showed that computer systems enable improved quality of patient care and patient safety, prevent medical errors and reduce costs, as well as helping patients manage their conditions [2].

Additionally, there is an increasing availability of mobile devices; nowadays, this includes people of all ages and socioeconomic statuses who are almost always carrying or within range of at least one mobile device. This rapid uptake of personal mobile technology has opened the possibility for new smartphone-based healthcare solutions. As recognized by the joint NSF and NIH Smart and Connected Health Program, these novel solutions have the potential to "transform healthcare from reactive and hospital-centered to preventive, proactive, person-centered and focused on well-being rather than disease" [3].

A critical barrier to the achievement of these appealing possibilities is the current paradigm of medical software design. The development and deployment of enterprise-wide applications is generally slow, expensive and requires advanced programming knowledge. As a consequence, customization for specific conditions or specific practice settings is rarely achieved. To ease the evolution towards a proactive and patient-centered healthcare system, it is therefore necessary to provide medical practitioners with tools that can be easily customized and extended to meet the needs of their patients.

In this paper, we propose ManageMyCondition, a standard framework for rapid development and deployment of medical condition management applications. The framework is modular, highly customizable, and extensible to meet the evolving requirements of managing a medical condition for both the patient and the healthcare team. ManageMyCondition is the result of our experience in the development of three mobile applications, which aim at helping parents manage their child's asthma (ManageMyAsthma) and improving the compliance to prescribed medications in oncology patients (ManageMyMedications and ManageMyPatients).

The rest of the paper is organized as follow. Section II

presents the motivation behind the development of a common framework for the development of medical condition management applications, and describes the related work. Section III describes the ManageMyCondition framework, while Section IV presents some example applications that developed using the framework. Section V summarizes the current status of the framework and provides some future research directions. Section VI concludes the paper.

II. Motivation and Related Work

Thousands of mobile applications that target different medical conditions are currently available for download for both Android and iOS devices [4], [5]. A recent classification of these applications found that medical applications are growing in number and are commonly used in healthcare [6]. These applications are equally distributed to target both the public and the healthcare providers (i.e., physicians, nurses, medical students and pharmacists) [6]. However, users are currently being overwhelmed by these apps rather than actually benefiting from them. This is because it is difficult to find the right app that addresses the specific needs of the user, while useful information and features are fragmented over different applications [7]. As a result, the authors in [7] advocate the development of an open source framework that can help standardize the medical information format and the application functionalities, and that can enable both the developers and the final users to personalize the application content to the their needs and context.

The first substantial contribution to overcome these limitations is represented by the open source framework ResearchKit [8], introduced by Apple in March 2015. Using the ResearchKit framework, researchers and developers are able to create powerful apps for medical research. ResearchKit provides three modules that address some of the most common elements of research: surveys, consent, and active tasks to collect data from the iPhone sensors. Researchers can use these modules as they are, customize them, or create completely new modules. The ResearchKit framework does not include a data management solution and methods for connecting to the cloud. Thus, it does not implement any secure communication mechanisms between the app and the server, which need to be defined and implemented independently by each developer. Moreover, ResearchKit is mainly centered on providing an easy way for developing applications to educate patients and gather data for research purposes through surveys and small tasks. Using ResearchKit, eight applications have been currently developed. These include, among others, one application to aid in the early diagnosis and treatment of autism [9], and one application to measure data such as dexterity, balance, memory, and gait to help researchers better understand how various symptoms are connected to Parkinson's disease [10]. The full list of applications can be found in [8].

A similar framework for building research study apps on Android called ResearchStack has been released in April 2016 [11]. The goal of ResearchStack is to help developers and researchers easily adapt existing ResearchKit-based iOS apps for Android devices. Moreover, the idea behind ResearchStack is to offer shared functionality and a common framework and naming scheme to greatly speed up adaptation of ResearchKit apps to Android (and ResearchStack apps to iOS).

The benefits and challenges of moving healthcare information to the cloud have recently been analyzed in [12]–[14]. In particular, the authors in [12] showed that the cloud can make healthcare more efficient and effective by allowing, for example, to easily share data across different information systems. However, trust, privacy and data integrity in healthcare systems are still considered open issues [13], [14].

While some initial work has been done in this area, to the best of our knowledge there is still no general framework for developing medical applications. Moreover, both ResearchKit and ResearchStack are missing some important modules that are part of most of the medical condition management applications. Thus, our focus is to provide developers and medical practitioners with a comprehensive and standardized set of tools to easily develop this type of application. In addition, the framework defines a common format for data acquisition and presentation, thereby simplifying data management and processing, which is critical in today's Big Data era.

III. ManageMyCondition

The goal of ManageMyCondition is to provide medical application developers with a standard framework that can be easily used and customized to the needs of different medical conditions from the perspective of both the patient and the healthcare team or researcher. Thus, it is necessary to determine: 1) what general functionalities are needed to create a comprehensive set of medical condition management applications, and 2) how to create a framework that enables the developers to create and customize applications using these general functionalities. As described in Section II, ResearchKit [8] and ResearchStack [11] already define some common modules. However, these frameworks focus on simplifying the common elements of conducting human research studies, rather than providing ways for creating custom medical applications. In this section, we present the ManageMyCondition framework and its functionalities, starting from the description of the system architecture behind the development of the framework, followed by a description of the application modules and cloud integration as well as security and confidentiality within the framework.

A. System Architecture

In order to better describe our framework, we first present the system architecture that we consider to be the basis for a generic medical condition management application. Figure 1 shows the three main components of a medical application: a *patient* application, a *cloud* infrastructure, and a *healthcare team* application. According to this architecture, on one side the patient interacts with their personal mobile device to get, for example, information about their current condition or track symptoms over time, while on the other side the healthcare team has real time access to the data recorded by the patient

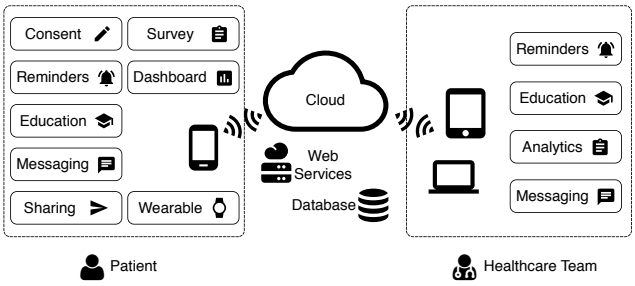

Figure 1. System architecture.

and can provide feedback or adjust the treatment. This real-time sharing of information is provided by a cloud infrastructure, which is used to store and retrieve data and to further extend the functionalities of the application. According to this architecture, the medical condition management application provided to the patient actually become an additional service that the healthcare team provides to its patients. However, the same architecture supports the deployment of self-management applications that target the public and research studies applications, where the healthcare team application has limited functionalities or is not even present. We note that in these cases, the healthcare team component is in fact replaced by other tools that the application provider (e.g., the developer of the application or the researcher that is conducting the study) uses to update the content of the application, as well as to analyze the acquired data.

As summarized in Figure 1, the patient and healthcare team applications are composed of modular components that interact with each other to offer different functionalities to the user. As an example, within the patient application, the reminders and dashboard module work together to record symptoms and track the evolution of the medical condition over time, respectively. Similarly, the analytics module of the healthcare team application display the data recorded by the patient application through seamless interaction with the Cloud.

B. Application Modules

ManageMyCondition has been developed as a highly customizable and extendable framework. As a result, it is composed of different modular components that the developer can directly use or customize. Moreover, existing functionalities or completely new modules can be easily integrated in the final application. In this section, we present an initial set of important modules that address some of the needs of both the patient and the healthcare team in a condition management app.

1) Patient Application: On the patient side, we currently identified the following building blocks:

- **Consent:** A module to obtain the user's consent in case the app is used for a research study. This module explains the details of the study and obtains a signature from the participant.
- **Survey:** A module to deliver surveys that the patient completes in order to customize the application to the user's needs and to collect important background information (e.g., demographics, illness specific information, etc.) for the healthcare team.
- **Reminders:** A system to help the patient record symptoms or take medications.
- **Education:** A module to inform the patient about their condition or medications, and available resources in the community.
- **Dashboard:** A module that allows the patient to track the evolution of their medical condition over time.
- **Messaging:** A module that allows the patient to receive personalized messages from the healthcare team.
- **Sharing:** A module that allows the patient to export the recorded data and share it with others, like e.g., friends or family members.
- **Wearable:** A module to interface the application with commercially available wearable devices.

2) Healthcare Team Application: On the healthcare team side, we currently identified the following building blocks, which closely interact with the modules of the patient application:

- **Reminders:** A module that allows the healthcare team to set reminders for the patient.
- **Education:** A module that allows the healthcare team to provide to the patient information about their condition or medications, and available resources in the community. Additionally, this module allows for easy updating of this information.
- **Analytics:** A module that provides the healthcare team with real time access to the data recorded by the user, as well as an overview of the user habits while interacting with the application (e.g., how many times the user opened the app or what resources and learning modules the user consulted). In addition, this module can be used to present aggregated information from multiple patients.
- **Messaging:** A module that allows the healthcare team to send personalized messages to the patient.

C. Cloud Integration

Using the building blocks described in the previous section, developers can design many useful medical condition management apps. In addition, ManageMyCondition allows to easily customize the different components of each developed application seamlessly without, in most cases, requiring any user interactions with the mobile device (e.g., without having to explicitly download an application update). This automatic update can be performed through integration with the Cloud infrastructure that is used to store and retrieve data, manage the notification and messaging system, and transparently keep the data synchronized on all the devices.

In the current version of the framework, we leverage the functionalities offered by Google Cloud Platform [15][1].

[1]We note that similar functionalities can be achieved using Amazon Web Services (AWS) [16] or Twitter Fabric [17].

Using Google Cloud Platform, it is possible to easily store data securely and efficiently in the Cloud, as well as to write custom server-side logic and execute background jobs to further extend the application functionalities. In addition, Google Cloud Platform allows the developers to protect the mobile applications against network failures and connectivity issues, enabling a device local datastore. This local datastore is transparently synchronized with the Cloud database so that all the querying and security features of Google Cloud Platform are always available regardless of network connectivity. Finally, we note that while ManageMyCondition enables data to be transparently shared across different mobile applications using Google Cloud Platform, the costs for setting up and maintaining the Cloud infrastructure are the responsibility of the final developers.

D. Security

When dealing with personal sensitive data, security refers to techniques and tools used to protect against the unauthorized access or disclosure of this information. Security and privacy issues are particularly important in the case of health information, so that these issues are considered one of the main concerns for researchers conducting studies using mobile devices [18]. However, thanks to continuous advancements in the areas of cybersecurity and Internet security, developers can now use tools that it make difficult, if not impossible, for malicious users to access secured data. From a security point of view, a general medical condition management application that follows the system architecture presented in Figure 1 presents three main point of vulnerability: 1) the data stored on the patient and healthcare team devices, 2) the communication with the Cloud, and 3) the data stored in the Cloud.

In order to help the developers protect the users of their application, ManageMyCondition embeds different security functionalities in order to address all the sources of vulnerability. In particular, in order to 1) protect the data stored within the mobile devices (i.e., the data stored within the patient and healthcare team applications), ManageMyCondition encrypts all the information before saving it to the device[2]. Similarly, in order to address 3) above, all the data stored in the Cloud uses two security mechanisms (authentication and encryption) that allow the user to add and modify their own data but prevent them from viewing and modifying other users' data. Finally, in order to protect the communication with the Cloud (point 2) above), all the connections between the application and the Cloud are done with HTTPS and SSL, which guarantees the authentication of the Cloud and protects the privacy and integrity of the exchanged data through the Internet.

E. Confidentiality

In addition to the security functionalities described in the previous section, ManageMyCondition allows for the protection of the confidentiality of the data stored in both the mobile devices and the Cloud. In particular, as is common practice in human research studies that involve the collection of sensitive information, the collected data is stored using a random code instead of the user's real name. This unique code does not allow to directly identify a particular patient, since any data that identify the user is either not required to use the application or, in the case of research studies that use the consent module, can be stored separately from the information recorded by the user. Finally, we note that even if ManageMyCondition helps the developer ensuring security and confidentiality of the recorded data, these functionalities need to be carefully designed and tailored to the specific use case, in order to ensure that the application meets state and federal regulations and Institutional Review Boards (IRB) directives.

[2]We note that encryption of the entire content of the mobile device can nowadays be enabled in both Android and iOS. This is highly suggested, especially for the devices used by the healthcare team.

F. Implementation

ManageMyCondition has been designed and implemented using Android OS. The framework includes a set of Java classes and open source libraries that allow the developer to easily create the different modules described in Section III-B. In particular, each module includes a customizable user interface (i.e., Activities or Fragments), easy access to data storage and synchronization. In addition, all the security functionalities are automatically handled by the framework. A porting of ManageMyCondition to iOS is considered as future work.

IV. Example Applications Using the Framework

In this section, we describe three mobile applications that we developed using the ManageMyCondition framework. The first application, ManageMyAsthma, is a mobile application to help parents manage their child's asthma. The second application, which consists of ManageMyMedications and ManageMyPatients, is used to support patient compliance with oral chemotherapy medicine regimes. In what follows, we provide a brief description of the motivation behind each of these applications, as well as the requirements of the different applications, and then we show how the requirements of the applications can be addressed using ManageMyCondition.

A. Asthma Monitoring

1) Motivation and Requirements: Studies have shown that adverse family functioning, including family stress, emotions, and coping, play a role in self-management behaviors and increased asthma symptoms [19]. Fortunately, there is strong evidence supporting a positive relationship between social support and health; individuals with a strong social support system and access to resources are better able to cope with major life stressors compared to those with little or no social support who may be more vulnerable to unwanted life changes. For asthma, current smartphone applications are primarily created to track and manage symptoms and medication use. A 2012 review by Huckvale et al. [20] showed that, among 103 asthma apps for which content was analyzed, approximately half were in line with current recommendations, while only 3 applications met the authors' definition of comprehensive information.

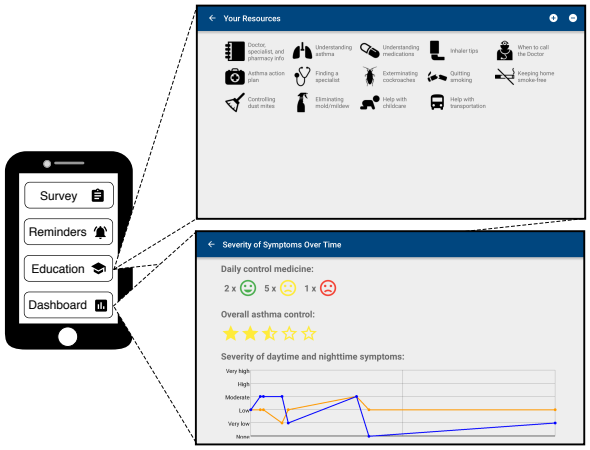

Figure 2. ManageMyAsthma: Modules that compose the application, and screenshot of the dashboard, educational modules and resources available in the local community (Rochester, NY area).

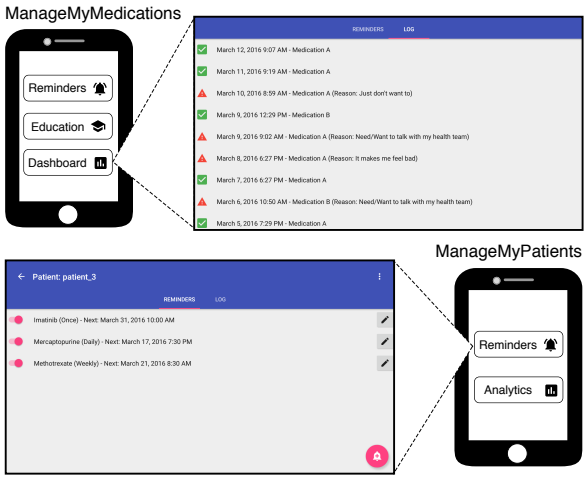

Figure 3. ManageMyMedications and ManageMyPatients: Modules that compose the applications, and screenshots of the module that allows a healthcare provider to add and modify reminders for a particular patient (ManageMyPatients) and of the dashboard module (ManageMyMedications). Other tabs allow real time access to the logged data (ManageMyPatients) and to see the reminders set by the healthcare team (ManageMyMedications).

Additionally, although many applications offered information about asthma, and others provided tools for management, none offered both functionalities. Moreover, no applications provided advice on lay information regarding local resources, and none were comprehensive enough to provide non-asthma resources that may be very important for families of children with asthma.

Given the above, we recognized that there currently is no asthma management application that combines comprehensive information about Asthma, tools for management of the condition, as well as information about local resources that may help families of children with asthma. While we are interested in filling this gap, in order to validate the actual need for this application, we were also interested in conducting a human subject study to get feedback from the users.

2) Implementation: To satisfy the requirements outlined in the previous section, we developed a mobile application to help parents manage their child's asthma. This application combines an educational part, allowing the parents to learn more about their child's condition, easy access to local resources that can help relieve the difficulty of managing their child's condition, and a reminder-based symptoms tracking component that can be used by the child's doctor to control and adjust the child's therapy. Moreover, the application combines an initial survey, which is used to customize the application to the user's needs and to collect important background information (e.g., demographics, condition-specific information, etc.), and a final survey to collect feedback about the benefits, challenges, barriers to use, and overall satisfaction with using this application, as well as features for a future, more comprehensive application.

It is easy to see how the aforementioned functionalities clearly match with some of the modules that characterize ManageMyCondition, and are described in Section III-B. In particular, the ManageMyAsthma application is composed of 4 modules: a) the Survey module, which is used to deliver the initial and final survey to the users, b) the Reminders module, which is used for recording the child's symptoms, c) the Education module that provides information related to asthma management and resources available in the community, and d) a Dashboard module that provides quick access to the recorded symptoms over time. The application modules and two screenshots of this application are shown in Figure 2.

B. Compliance to Medication Regimens

1) Motivation and Requirements: Inconsistent use of prescribed medications by patients is common in medicine. The consequences of medication noncompliance are deadly. In oncology, it has clearly been shown that failure of patients to take less than 90% of prescribed doses of oral chemotherapy leads to increased rates of cancer relapse and death. Improvement in compliance is a high priority for the National Cancer Institute (NCI) and the National Institutes of Health (NIH). It has been estimated that improvements with compliance may have greater impact on health than development of new drugs and procedures. Several studies report that the main reasons for noncompliance include: forgetting to take the medication, lack of understanding of the critical importance of medication compliance, and not having the medication available because of lack of planning or lack of resources. No simple strategy to improve compliance has been consistently successful [21].

Given the above, our view is that a successful strategy for improving patient compliance with cancer treatment medication regimens must address all of these factors. In this regard, we recognized that a mobile application can easily provide all these functionalities.

2) Implementation: To satisfy the requirements outlined in the previous section, we developed two mobile applications to improve the compliance to prescribed medications in oncology patients. These applications are used to test if a novel approach

that simultaneously addresses patient understanding, provides a structured schedule of reminders and real time data logging (ManageMyMedications, patient application), and gives active case management based on real time data (ManageMyPatients, healthcare team application), will significantly improve patient compliance with oral chemotherapy regimens.

It is easy to see how the aforementioned functionalities clearly match with some of the modules that characterize ManageMyCondition (see Section III-B), and can take full advantage of the system architecture presented in Figure 1. In particular, the patient application uses the Reminders and Dashboard module to log the patient medication intake and provide access to the logged information, respectively, and the Education module to provide information about the medications and the importance of complying with the medication regime. The healthcare application, instead, uses the Reminders module to set the remainders for the patient, and the Analytics module to access the data recorded by the user. The two applications interact with the Cloud infrastructure, which enables the real time interaction between the patient and the healthcare team. The modules and screenshots of these applications are shown in Figure 3.

V. Future Research Directions

ManageMyCondition allows developers to design many useful medical condition management apps. However, even if the framework makes the creation of medical applications easier, it still requires the user to be able to develop a mobile application. In order to lower the barrier for medical application development, we are currently working on an extension of ManageMyCondition that will enable medical practitioners without prior programming knowledge to develop their own medical condition management applications. In particular, we are currently developing a novel programming language that embeds the creation of the functionalities required by the application, and a compiler that translates this code into the actual mobile application source code that sits on top of the Google Cloud Platform. Starting from this, our long term goal is to develop a more user friendly drag-and-drop based Graphical User Interface (GUI), which will allow the user to choose between a set of application templates, and then easily add to the application the different modules described above.

VI. Conclusions

In this paper, we presented ManageMyCondition, a framework for the rapid creation and standardization of cloud-based medical condition management applications. The framework defines different modular components that the developer can directly use or customize to meet the needs of different medical conditions, and defines a common format for data acquisition and presentation, thereby simplifying data management and processing. In addition, we described three applications that we developed using ManageMyCondition, and showed how the requirements of these applications can be easily addressed using the framework. Finally, our positive experience in the development of mobile applications using the framework motivates future extensions of ManageMyCondition, which will enable medical practitioners without prior programming knowledge to develop their own medical condition management applications.

Acknowledgments

The authors would like to thank Lauren Kemperman and Jean Chakmakas for their contribution in the initial development of ManageMyAsthma.

References

[1] D. H. Gustafson, R. Hawkins, E. Boberg, S. Pingree, R. E. Serlin, F. Graziano, and C. L. Chan, "Impact of a patient-centered, computer-based health information/support system," *American Journal of Preventive Medicine*, vol. 16, no. 1, pp. 1–9, 1999.

[2] "Medical informatics for better and safer health care: Research in action, issue 6," Agency for Healthcare Research and Quality, Jun. 2002. [Online]. Available: http://archive.ahrq.gov/research/findings/factsheets/informatic/informatics/informatria.html

[3] "Smart and Connected Health (SCH), Program Solicitation NSF 13-543," National Science Foundation (NSF). [Online]. Available: http://www.nsf.gov/pubs/2013/nsf13543/nsf13543.htm

[4] "Google Play Store - Medical Category," Google. [Online]. Available: https://play.google.com/store/apps/category/MEDICAL?hl=en

[5] "App Store - Medical Category," Apple Inc. [Online]. Available: https://itunes.apple.com/us/genre/ios-medical/id6020?mt=8

[6] H. J. Seabrook, J. N. Stromer, C. Shevkenek, A. Bharwani, J. de Grood, and W. A. Ghali, "Medical applications: a database and characterization of apps in apple ios and android platforms," *BMC Research Notes*, vol. 7, no. 1, pp. 1–8, Aug. 2014.

[7] L. van Velsen, D. J. Beaujean, and J. E. van Gemert-Pijnen, "Why mobile health app overload drives us crazy, and how to restore the sanity," *BMC Medical Informatics and Decision Making*, vol. 13, no. 1, pp. 1–5, Feb. 2013.

[8] "ResearchKit." [Online]. Available: http://www.apple.com/researchkit/

[9] "Autism & Beyond," Duke Health. [Online]. Available: https://itunes.apple.com/us/app/autism-beyond/id1025327516?mt=8

[10] "Parkinson mPower study app," University of Rochester and Sage Bionetworks. [Online]. Available: https://itunes.apple.com/us/app/us-researchkit-itms-mpower/id972191200?mt=8

[11] "ResearchStack," 2016. [Online]. Available: http://researchstack.org

[12] S. P. Ahuja, S. Mani, and J. Zambrano, "A survey of the state of cloud computing in healthcare," *Network and Communication Technologies*, vol. 1, no. 2, p. 12, 2012.

[13] A. Gawanmeh and A. Alomari, "Challenges in formal methods for testing and verification of cloud computing systems," *Scalable Computing: Practice and Experience*, vol. 16, no. 3, pp. 321–332, 2015.

[14] A. Gawanmeh, H. Al-Hamadi, M. Al-Qutayri, S.-K. Chin, and K. Saleem, "Reliability analysis of healthcare information systems: State of the art and future directions," in *Proc. of IEEE HealthCom*, Oct. 2015, pp. 68–74.

[15] "Google Cloud Platform." [Online]. Available: https://cloud.google.com

[16] "Amazon Web Services." [Online]. Available: http://aws.amazon.com

[17] "Fabric - Twitter's Mobile Development Platform." [Online]. Available: https://fabric.io/

[18] S. Arora, J. Yttri, and W. Nilsen, "Privacy and security in mobile health (mHealth) research," *Alcohol Research: Current Reviews*, vol. 36, no. 1, pp. 143–151, 2014.

[19] B. H. Fiese and R. S. Everhart, "Medical adherence and childhood chronic illness: family daily management skills and emotional climate as emerging contributors," *Current opinion in pediatrics*, vol. 18, no. 5, pp. 551–557, 2006.

[20] K. Huckvale, M. Car, C. Morrison, and J. Car, "Apps for asthma self-management: a systematic assessment of content and tools," *BMC Medicine*, vol. 10, no. 1, pp. 1–11, 2012.

[21] J. Demonceau, T. Ruppar, P. Kristanto, D. A. Hughes, E. Fargher, P. Kardas, S. De Geest, F. Dobbels, P. Lewek, J. Urquhart, and B. Vrijens, "Identification and assessment of adherence-enhancing interventions in studies assessing medication adherence through electronically compiled drug dosing histories: A systematic literature review and meta-analysis," *Drugs*, vol. 73, no. 6, pp. 545–562, 2013.