Socio-technical challenges to adoption of remote healthcare technologies

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Abstract

Remote healthcare technologies allow for instant communication and data sharing in large volumes, assisting in decision-making challenges that arise due to insufficient data. With real-time monitoring capabilities, remote healthcare technologies provide an opportunity to capture a comprehensive view of patient behaviors and activities. These systems are especially advantageous in care management for chronic illnesses. For example, a diabetes patient typically sees their care provider 2 to 4 times per year. Thus, care providers must make medical decisions based on a patient’s metrics at a given point in time without taking into account normal daily fluctuations in blood sugar levels. Despite recent research demonstrating the benefits of remote technologies, the healthcare sector has been slow to adopt these systems. Many enablers and barriers to the adoption of remote healthcare technologies exist. The unpredictable behaviors of human and technology interactions highlight some of the complexity within the healthcare system. Without a systems understanding of the complex interactions among the many enablers and barriers, there is little guarantee that the time, money, and effort used in the design of the system will result in an accepted and implementable solution. This paper discusses the need for a systems analysis of enablers and barriers of remote technology adoption in chronic illness management. Specifically, the paper will present an evaluation of healthcare as a socio-technical system and potential to lead to designs for remote health technologies that better address the complex behaviors characteristic of the health services system.

Keywords: Remote technology; healthcare; enablers; barriers; system dynamics; socio-technical system

1. Introduction

Remote technologies for the management of chronic illness have been available for over a decade.\textsuperscript{1} During this time, the potential benefits of these technologies have been extensively reviewed. Through a systematic review of mobile devices in a healthcare setting, Prgomet et al. assessed the impact of mobile technologies in a hospital...
environment. They found that significant benefits included improved access to information, increased communication, decreased errors, and improvements in medication safety.\textsuperscript{2} Other studies have reviewed potential benefits in detection of disease symptoms and subsequent proactive management.\textsuperscript{3,4} Over time, there have been significant improvements to remote healthcare technologies, such as faster speed or real-time monitoring, which have been shown to facilitate communication between patients and healthcare providers.\textsuperscript{5,6}

The decision-making algorithms in technological systems are designed and built with detailed steps to produce repeatable outputs after every performance. Humans, on the other hand, have intuition, previous experience, and subjectivity at their disposal to complete a task however they see fit to achieve the given goal. The human interactions with technology are helpful in balancing the subjectivity and variance among human performance, however, it could also create over-reliance of the technology or expectations of the technology that are better suited for human expertise, like diagnosing a disease. As a socio-technical system, today’s current healthcare is embedded with numerous human-technology interactions. The components of the system include people (e.g., patients, providers), organizations (e.g., hospitals, insurers), and technologies (e.g., electronic medical records, medical devices). The people, organizations, and technologies must work together to improve each individual’s health. When it comes to chronic illnesses, the number of parts may increase or require well integrated interactions to complete one of many functions necessary in working towards the system’s goal. For example, in a clinic setting, a physician and a nurse use medical devices to provide a treatment regimen. Additionally, patient self-care at home may include family members and exercise equipment to maintain good health status. The functions of both the clinic and the patient’s home must be used together to improve the patient’s health.

In spite of the benefits of remote technology in healthcare, there are still multiple challenges with the stakeholders involved in the adoption of remote technology in chronic disease management. Designing a healthcare system that integrates remote technology requires more than the typical “engineer” perspective. As Plsek describes, the typical engineer’s tendency is to design mechanical systems in which each component has predictable behaviors and functions.\textsuperscript{1} Without predictable parts, the designed system may be unreliable in outputs and performance. For industries like petroleum and automotive, unreliable performance is very costly and thus highly controlled to prevent these variations. The trouble in designing healthcare as a mechanical system lies in its socio-technical complexity where behaviors, interactions, and properties can be difficult to predict. The complexity of these systems can make it challenging to learn in and understand its behaviors and interactions.\textsuperscript{8} An industry of health services and human interactions can result in a variety of emergent behaviors, making it necessary to consider the factors to remote technology adoption as complex rather than linear.

This paper discusses the benefits that remote technologies can provide in healthcare. Preliminary enablers and barriers to remote technology adoption in healthcare (e.g., factors that support or challenge the adoption of remote health technologies) are discussed. These enablers and barriers are presented with a preliminary causal loop model (CLM), an illustration that demonstrates nonlinear behavior and interactions among elements of a system. With a preliminary analysis, this paper highlights some the complex interactions between the enablers and barriers to remote technology adoption and their resulting influence on the system and other components. With the CLM, it is argued that much is still unknown regarding the interactions of the different components found in the healthcare system and its adoption of remote technologies.

\textbf{2. What are remote healthcare technologies?}

Although the implications of this research extend to all remote healthcare technologies, the scope of the present paper is limited to three types of chronic illnesses: diabetes, hypertension, and cardiovascular disease. In many cases, these diseases co-exist. It follows, then, that application of remote technologies with one of these illnesses can be translated with ease to one of the other illnesses for care management. For example, remote technology used in

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\textbf{Nomenclature} & \textbf{Definition} \\
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CLM & Casual loop model \\
FDA & Food and Drug Administration \\
EMR & Electronic Medical Records \\
IOM & Institute of Medicine \\
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the daily monitoring of cholesterol provides data for the physician caring for a patient’s diabetes and the cardiologist treating the same patient for a cardiovascular disease. The need for constant monitoring of diabetes, hypertension, and cardiovascular disease is vital, and it is unrealistic for this task to be left solely to time-constrained healthcare professionals. Each physician visit costs a patient both time and money, therefore placing sole responsibility for a patient’s monitoring may be a poor and expensive use of the physician’s expertise and time.

Chronic illnesses can result in life threatening complications if not managed properly and regularly. Therefore, chronic care requires a patient to monitor their health daily in addition to regular physician visits. Management of chronic illnesses typically involves physicians, nurses, primary care givers, and patients. A physician typically performs the initial assessment of the condition and recommends a plan of action. The plan of action may include some pharmacological intervention and continuous monitoring of the disease measures. Continuous monitoring therefore enables optimal control of the disease, a delay or decrease in the development and exacerbation of symptoms, reduction in hospital visits, and the prevention of life-threatening complications.

Technological advances have made communication faster, more reliable, and even more expansive. These technologies can use simple means of communication (e.g., mobile phones) or more integrated means (e.g., 4G network transfer to cloud storage). Taking advantage of these communication methods, remote health technologies allow a medical professional to access information from a device used by a patient located on his/her body. Common remote health technologies include mobile phones, but remote capabilities have become quite popular. Other mobile devices, such as a blood sugar monitor are now designed to either transmit or receive data to and from cloud storage.

The current model of healthcare has been structured to retroactively care for patients when the need arises. This is especially the case in ambulatory care, treating patients only after the onset of illness or severe events. This system of care centers on patient requests for visits in which he/she must identify a specific health concern to be diagnosed or treated. This care model may be sufficient for simple or short-term illnesses, but complex or long-term care may need a preventive care-driven system in which patients are seen prior to a severe incident as a preventive/cautionary intervention. Remote technology with monitoring capabilities has the potential to shift the current model to a data-driven system using real-time data to prevent the onset of severe events. By providing multiple, if not continuous, assessments of health metrics, these systems of remote technologies enhance the scope and comprehension of a patient’s prognosis. With real-time data monitoring, a care provider can actively monitor and respond to a patient’s data in a timely manner. This active engagement from a care provider bridges the gap in care, addressing a moment in time when a provider is needed but cannot be physically present. Real-time interventions as simple as a reminder to take a medication or advice based on data obtained moments prior have resulted in significant improvements in health outcomes.

In 2012, the Brookings Institution estimated a savings of $197 billion over the next 25 years through the use of remote technologies. In addition to the cost savings, remote healthcare technologies provide medical professionals the ability to actively engage in their patients’ care management through real-time interventions such as notifications or consultation based on real-time health monitoring data. Preliminary reviews suggest significant health outcomes with the integration of remote technologies in the care of patients with chronic illnesses. Specific outcomes include reduced blood glucose levels for patients with diabetes, increased adherence in medication taking, better maintenance of healthy blood pressure levels, and overall positive improvements in self-management. It is important to note, however, that significant health outcomes are limited by several factors, including the system of remote technologies used and its purpose, i.e., continuous monitoring compared to increasing access. Fundamentally, the use of remote healthcare technologies in care management can effectively support professionals in making decisions leading to the care and treatment of their patients.

3. The dynamics of adoption of remote healthcare technologies

In chronic illness management, care may involve more than one medical professional, and with many current models, patients are left to figure out for themselves how to liaise between their care providers. Relaying accurate information between these two parts in the system can be a challenge, especially if the patient does not fully understand what each provider needs to know. While the addition of remote technology can facilitate data sharing between providers, it can also lead to increased demand for medical staff support. Because the physician’s time is valuable, it is typically reserved for patient interactions e.g. treatments and clinical procedures. The physician may need to rely on their medical staff to support not just in learning how to use the technology, but also the
successful monitoring and collection of patient information to be brought to the physician’s attention.\textsuperscript{30}

Consequently, the additional challenge surrounding human-technology interactions can influence how widely remote technology is integrated into clinical practice. Remote technologies that are easier to use have a better chance of acceptance.\textsuperscript{31} The ease of use can also affect the number and severity of errors induced by the technology.\textsuperscript{32} This means that the addition of remote healthcare technologies cannot guarantee improved outcomes. This lack of guarantee makes it more difficult to convince policymakers of the need for adoption.\textsuperscript{33} This also means that insurance providers may have less motivation to cover patient costs or to reimburse providers.\textsuperscript{33,34} These interactions can then lead right back to a physician. If a physician already has medical staff support and motivation to use remote healthcare technology but does not have the financial resources to implement its use, he/she may feel less inclined to provide assistance in design of these systems for broader acceptance.

A definitive number that ensures either adequate medical staff support or the usability of remote healthcare technologies is not known. Furthermore, human-technology interactions are complex, and their effects on design for these systems may be difficult to understand. Multiple evaluations are necessary to understand these dynamics from all stakeholders’ perspectives. As such, an appropriate tool to analyze these interactions lies in system dynamics, a method to develop computer-based models that simulate a system’s structure and resulting dynamics. While it cannot render predictable interactions among the system’s elements, system dynamics can provide critical insight into system behavior through manipulation of key factors and subsequent evaluation of complex interaction effects across different types of influencers.

4. Modeling the dynamics of technology adoption

Health improvements in patients with chronic illness have shown improvements when a holistic and integrative approach to care is provided.\textsuperscript{8,14} This becomes achievable when there is a multidisciplinary integration of resources. However, several factors both enable and deter the adoption of available resources, especially in the area of remote technology. Many efforts have been and are being made to advance the adoption of remote technologies in healthcare, specifically in chronic illness management. These efforts, defined as enablers, act as catalysts for the acceptance and adoption of remote technology by providers and patients. Additionally, existing conditions/factors enable the adoption by providing support, such as infrastructure, that makes the remote healthcare technologies easier to adopt. Alternatively, factors that make this adoption more challenging are defined as barriers. These factors do not exist in isolation but rather are intertwined such that the existence of one ultimately affects others, providing several opportunities for emergent behaviors as they interact with each other. Preliminary analysis of enablers and barriers are described in Table 1 below. Table 1 also highlights the number of interactions each factor encounters in the system, highlighting the different levels of influence and integration of enablers and barriers in the system.

The interactions of enablers and barriers can be illustrated through system dynamics modeling. A preliminary causal loop model of this system is shown in Fig. 1, outlining the interactions between factors. This CLM illustrates an initial analysis of the interactions and relationships among entities that serve as enablers and barriers to remote technology adoption in healthcare. Influenced by current perceptions, limited experience in healthcare, and preliminary research thus far, an initial analysis of the complex system regarding the adoption of remote healthcare technologies is performed. An understanding of the interactions between enablers and barriers to remote healthcare adoption is limited. In a complex system with as many components as healthcare, it can be challenging to ensure all possible interactions and dynamics are accurately reflected in the model. Furthermore, this analysis illustrates the amount of user feedback rather than quality of feedback as the effects of quality remain unknown. Further work is needed to analyze current dynamics as well as expand the CLM to a more comprehensive model. After comprehensive review of literature is completed, the CLM will be built further to provide a foundation for the design of a system dynamics model that will provide critical insight of the complex factors influencing adoption of remote healthcare technologies.
The CLM in Fig.1 is color-coded to direct attention to critical influencing factors of enablers and barriers. The purpose of the color-coding scheme is to illustrate the reach of influence one factor may have on others. In the CLM, red links are defined as enablers or barriers that have direct interactions with the process of receiving clearance from the Food and Drug Administration (FDA). If these barriers are not overcome, a remote device will not have the FDA’s clearance for medical use. Critical influencing factors associated with cost are defined as yellow links, illustrating the widespread effect of cost on the system. Highlighted in purple links are enablers/barriers under policy. While the number of links is limited, its impacts reach several far-reaching enablers/barriers. The other noteworthy enabler/barrier is the medical staff resources. Without sufficient medical staff support, the infrastructure of the system deteriorates as the staff are often needed in routine patient care and aiding the physicians with the daily use. However, increasing the staff support results in increased cost to the physician. Details of these interactions and resulting effects are described further in the following sections.
4.1. Enablers of adoption of remote healthcare technologies

Preliminary reviews have identified categorical enablers such as organization through adequate staff and buy-in by medical professionals.28-35 These enablers make it possible for management to integrate remote technology into the healthcare system with the acceptance and support of their staff. As illustrated in Fig. 1, these enablers make it possible for patients to receive support and motivation from their care providers. If the care providers choose to use the technology in their care, it can turnaround and increase patient acceptance. Consequently, with increased patient acceptance and medical professional buy-in, the demand will increase for manufacturers to produce remote technologies for application in healthcare. However, Fig. 1 also illustrates that both physician acceptance and patient acceptance influence the usability of the device. While some individuals are able to work with cumbersome technological devices and others require simple interfaces, it is not clear how the technology’s usability will sway either physician or patient acceptance.

There are several motivating factors that may drive the motivation behind the medical professionals. Institutional support is one influencing factor on healthcare procedures, including policy and support from medical institutions. For example, in their 2010 report on the quality of care, the Institute of Medicine (IOM) recognized the value in information technologies in improving the quality of healthcare.7 Also, the American Academy of Family Physicians’ identified technology as a key factor in facilitating coordination of care.36 For some medical professionals, institutional support may provide the push to incorporate these technologies into their practice, as this serves as confirmation of their internal motivation to adopt these systems. However, for some, it may require more than a recommendation, perhaps one attached to payer policies, guaranteeing physician payment for this new type of care service provided.37

4.2. Barriers to adoption of remote healthcare technology

Manufacturers and system designers face several challenges in developing these systems. Designers face increased pressure to create small portable devices with powerful software and hardware capabilities without sacrificing safe healthcare delivery. Additionally, these systems must meet strict standards for approval by agencies like FDA. This has resulted in increased production costs and time.38 Inadequate system integration and
interoperability with quality and safety assurances restricts data sharing and utilization, resulting in end-user dissatisfaction. The lack of a standardized metric for automated decision support further creates a challenge in the design of a universal yet customizable telehealth system. 38,39

Preliminary reviews have indicated difficulties in understanding and usability of the technology as a potential barrier to its adoption by patients, especially in the aging population. 40 The structural design and interface of some existing remote healthcare technologies exceeds the capability of some eligible users. 38,40 A certain level of patient competence and technological savvy is required to use the technologies that are currently available, posing a barrier to those without these abilities. 31,41 Customizing remote technologies to be more user friendly may help in the technology’s adoption. Again, because of the subjectivity of humans, customization of remote healthcare technologies can result in complex designs so that many of their users find it friendly and easy to use. However, creation of advanced systems may require expensive equipment or time for a manufacturer. That manufacturer may then push the costs back onto the patient. As illustrated in Fig. 1, cost is another key category of factors that interact with many other potential enablers and barriers. Cost barriers can be mitigated through insurance coverage, policy intervention, or other financial resources that are still unclear, thus requiring further system’s analysis.

Another commonly cited reason for reluctance to embrace the use of remote healthcare technology is the perception that it is often associated with ill health and dependency. A study by Sanders, Caroline et al., 2012, showed that while some participants in the study were concerned about loss of control with the use of remote healthcare technology, others were concerned with the associated stigma of being ‘sick’. 41 Boyer et al. used a wristband sensor device to measure changes in vital signs in illicit drug users. 4 The participants indicated that wearing such a device in public might cause unwanted attention and stigmatization. One possible way to mitigate this would be to develop more relatable devices that have an appearance and functionality consistent with daily use. 3 Patient hesitation shows an unwillingness to deviate from what has long been the norm, which creates another drawback to the adoption of remote healthcare technologies. There is some reluctance to embrace the new innovation because of a perception that it would limit contact with primary care providers. 41 Other reasons why physicians sometimes resist the adoption of innovative technology in healthcare include a perceived increase in workload, unnecessary time spent to familiarize oneself with the technology, device complexity and a general perceived loss of power. 31,33,42

The aim of remote technology in healthcare is to enhance patient care, but significant resistance from patients reduces physicians’ willingness to embrace its adoption. The adoption of remote technology is not centered only on physician and patient preferences. As mentioned above, and illustrated through the CLM, resistance can come from dissatisfaction with the technology perception, usability, and costs. Designing a system to accommodate the needs of both patients and physicians leaves the manufacturers at risk of increasing either production costs or complexity of the technology. This ultimately influences how payers address it in their insurance plans.

5. Conclusion and continued work

Several studies have evaluated the effectiveness of remote healthcare technologies. In research settings, these systems are explored in various contexts, sometimes disregarding the feasibility of “real-world” application, including costs and provider satisfaction. Thus, it is crucial for any system designer to understand the interactions among enablers and barriers to the adoption of remote technologies in the management of chronic illness. Analysis of the dynamics among enablers and barriers can help to highlight the key relationships and behaviors that will result in implementable remote technology solutions for the healthcare environment, specifically chronic illness.

The preliminary review in this paper illustrated interactions between factors critical to successful implementation, but it has also reiterated the additional concerns and interactions that remain unknown in the healthcare systems dynamics in adopting remote technologies. Further work is needed to build on the preliminary systems analysis presented here, which can lead to better comprehension of the complex socio-technical system involved in adopting remote healthcare technology.

The next steps in this work include an extensive review of literature in the use of remote technologies for care management of chronic illnesses. This review will integrate descriptive literature (e.g. survey, peer-reviewed editorials) with research literature to obtain a systems view. Descriptive literature may include editorials from medical professionals evaluating the state of chronic illness and/or the need for technology integration. To maintain objectivity throughout the entire review, more than one researcher will review each piece of literature. A systematic
review will ensure repeatability of literature collection for analysis. For all the literature that moves forward in analysis, a scoring sheet is completed, a form that records characteristics of the system to provide a collection of key features and a high-level view of what was involved in the system and how they may have affected the final outcome of the literature. The resulting scoring sheet serves as the collection of data to develop a system dynamics model to understand socio-technical challenges of remote healthcare technologies adoption. Future work will use the findings from the systematic review to expand the CLM and systems dynamics modeling in this paper to obtain a more comprehensive view.

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