ICT Interventions Impacting Big Societal Challenges: An Electronic Healthcare Approach to Homelessness

Abstract

This paper investigates how electronic healthcare technology can address a pervasive societal problem: homelessness. Mental illness, a leading cause of homelessness, can be treated successfully with proper medication. Few psychiatric patients, however, adhere to the medication regimen prescribed by their doctors. We employ a systems thinking approach to model the multi-dimensional decision system by which patients choose whether or not to take medication. We identify that interventions raising patients' self-efficacy will significantly improve medication adherence among mentally ill patients and that it can translate into a reduction of homelessness. This paper makes two key research contributions: it call attention to the study of medication adherence within electronic healthcare research and it proposes a systems dynamics model that highlights how, when addressing complex societal challenges, affordances during one time period can become constraints in another.

Keywords: Medication adherence, IT intervention, simulation, societal challenges, homelessness, mental illness, smartphone, self-efficacy, system dynamics, systems thinking

Introduction

This paper emphasizes the abilities of information systems and health IT to address major societal challenges. Homelessness is one such problem that afflicts many countries. Approximately 3.5 million people in America and millions more around the world are homeless (Thompson Jr et al., 2013). In addition to the moral and societal costs, the financial costs are staggering (Culhane, 2008, Moulton, 2013). The problem exists within a complex social system and many studies have reported that the causes can be classified as structural and individualized (Eyrich-Garg et al., 2008, Flåto and Johannessen, 2010, Shinn, 2010). Mental illness is a leading individualized factor (North et al., 2004, Folsom et al., 2005, Johnson and Chamberlain, 2011). While medication can control severe mental illnesses (Kahn et al., 2008, Yildiz et al., 2011), research finds that most mentally ill patients do not adhere to the guidelines set by their doctors (Gilmer et al., 2004, McDonald et al., 2002, Mitchell and Selmes, 2007, Osterberg and Blaschke, 2005). Insufficient levels of medication adherence, which is defined as taking medication in accordance with a doctor's instructions, result in increased homelessness in the developed world (Mitchell and Selmes, 2007). Therefore, a substantial cause of homelessness can be viewed as a healthcare issue that can be mitigated – at least partially – by increasing the rate of medication adherence. This paper addresses the grand societal challenge of homelessness by showing how electronic healthcare can reduce homelessness by helping psychiatric patients stay on their medication.

Medication adherence is a robust research stream in nursing, psychiatry, and other medical disciplines. As such, it is a natural fit with the health IT research that has been used to increased healthcare quality (Kamis et al., 2014, Khoumbati et al., 2006). Despite the fact that information and communication technology (ICT) has the potential to reduce health care costs, decrease patient deaths, and provide other significant improvements in medical care (Gianchandani, 2011), the topic of medication adherence – and how ICT-based interventions can increase it – has received little attention within the information systems and e-health literature. Notable exceptions are Beni's (2011) call for increased health IT research into medication adherence and research into wireless medication reminder systems by Dunbar et al. (2003) and Vervloet et al. (2012).

Although intervention technology affords action potential – what can be done (Gibson James, 1977, Hutchby, 2001) – technology is not always used as intended, so its affordances may not be realized. In other cases, it may be used in unanticipated ways that increase its effectiveness or the in-situ use of an artifact may present constraints that interfere with accomplishing the intended goal (Majchrzak and Markus, 2013). Many factors exogenous to ICT interventions such as peer pressure and individuals' attitudes play a part in determining outcomes (Ajzen, 1985, Triandis, 1980). In decision-making systems like that of patients with mental illness, a variety of factors influence the decision to take medication. Medication adherence is an ongoing process in which the determinants of use such as symptoms and side effects change over time (Boter et al., 2008, Osterberg and Blaschke, 2005, Tsang et al., 2006).

Because the medication adherence decision process is recursive, rather than a linear decision path, we apply a systems thinking perspective (Forrester, 1971, Sterman et al., 1997) and model medication adherence as a system through which patients decide to adhere (or not) to their prescription regimen. We examine the effects adherence in one time period have on the decision to adhere during future periods by including reinforcing and balancing feedback loops, with a focus on the moderators that can prevent intention from become action. Systems thinking offers an effective approach for gaining insight into multidimensional health issues and transforming that knowledge into effective interventions (Trochim et al., 2006, Mabry et al., 2008). The systems approach also allows us to focus our intervention efforts where they will have the greatest impact (Sterman, 2006). Drawing upon social cognitive theory (Bandura, 2001), the health promotion model (Pender et al., 2006) and protection motivation theory (Rogers and Prentice-Dunn, 1997), we postulate that increased patients' perceived self-efficacy can significantly increase medication adherence among those with severe mental illness. We run systems dynamics simulations over a three-year time period and find that ICT based interventions to improve patient efficacy can substantially increase the rate of medication adherence, thereby reducing the number of psychiatric patients who become homeless. Because an ICT-based intervention may require resources that could otherwise be allocated to other types of interventions, we provide multiple simulations of alternative interventions focusing on another key determinant of medication adherence. We also simulate unintended consequences of the proposed intervention, in which the use of ICT may increase or decrease the amount of family support. We find that the ICT based reminder system will increase the number of adherent patients by 21%. We discuss the implications and call for further research into how health IT can be used not just to improve healthcare, but to improve pervasive social issues.

This rest of the paper proceeds as follows. The next section provides background information about homelessness, health IT research and medication adherence. The following section models the decision system by which psychiatric patients decide whether or not to take prescribed medications. The next section runs multiple simulations and demonstrates how using ICT to increase patients' self-efficacy can have dramatic benefits. The results and implications are discussed next. The final section provides concluding remarks and suggests areas for further research.

Literature Review

In recent years, the calls to expand IS scholarship into societal challenges (Cordoba and Midgley, 2008, Venable et al., 2011) are being answered. ICT-based interventions can provide benefits by helping individuals and produce societal gains by increasing social welfare, decreasing social costs, etc. (Castells and Development, 1999). Homelessness is a pervasive and persistent societal challenge that exists within a complex social system. While ICT-based interventions cannot resolve the entire problem, it can make a material difference if applied mindfully to address specific causes of homelessness. Therefore, it becomes important to identify intervention points where ICT can have a material, positive impact on the homelessness challenge. Social sciences literature finds a strong connection between mental illness and homelessness and attributes a material amount of homelessness to low levels of patient adherence to psychiatric medication. This section argues that homelessness can be viewed as a health issue, that studies of medication adherence within medical disciplines provide robust theoretical understanding for designing interventions, and health IT research has made substantial contributions to healthcare, but has paid little attention to the study of medication adherence.

Homelessness

Homelessness is a persistent societal challenge faced by several countries. At any given time, 3.5 million people in America, and millions more around the world, are homeless (Thompson Jr et al., 2013, Wall et al., 2013). Within a 5-year window, approximately 3.1% of the overall American population will experience a period of homeless (Link et al., 1994). The problem exists within a complex social system and many studies have reported that the causes can be classified as structural (state of economy, state support, etc.) and individualized (family dynamics, substance abuse, individual health, mental illness, etc.) (Eyrich-Garg et al., 2008, Flåto and Johannessen, 2010, Shinn, 2010, Wall et al., 2013). Homeless persons use an average of $40,500 in health, corrections, and shelter services (Culhane, 2008) and it costs the government $55,600 to move a single person out of chronic homelessness (Moulton, 2013). While the financial costs are high, the moral and societal cost of millions of people facing homelessness is beyond measure. A leading cause is poverty and homelessness rises during recessions (Shinn, 2010) as unemployment increases (Lehmann et al., 2007). Much of the homelessness is attributable to the lack of affordable housing (Lee et al., 2010, O'Flaherty, 1995) or the absence of sufficient housing subsidies (Early and Olsen, 2002). While dire financial condition is a key cause of homelessness, other factors are responsible for a substantial portion of homelessness. Drugs and alcohol abuse are also significant causes (Thompson Jr et al., 2013), with an estimated 40-45% of the homeless population having a substance abuse problem (Wall et al., 2013, Burt, 1999). Mental illness is another significant cause of homelessness (North et al., 2004). In Australia and the United States, 15% of those with severe mental illness will be become homeless (Folsom et al., 2005, Johnson and Chamberlain, 2011).

Building a society with ample employment opportunities and an abundance of affordable housing requires a society-wide solution. Mitigating the global drug problem has proven beyond the capabilities of the world's most powerful governments. Although pharmaceutical treatments can control mental illnesses such as manic depression and schizophrenia (Kahn et al., 2008, Yildiz et al., 2011), most mentally ill patients do not take their medication (Mitchell and Selmes, 2007). Therefore, a substantial cause of homelessness, at least in the developed world, can be viewed as a healthcare issue.

Health IT

Health IT has the potential to reduce health care costs, patient deaths, malpractice claims, and provide other significant improvements in medical care (Gianchandani, 2011). Health IT research provides insight that can increase the quality of healthcare (Khoumbati et al., 2006, Kamis et al., 2014). Health IT can reduce medication errors and improve patient safety in hospitals (Alsweed et al., 2014) and improves the delivery of health services to people living in remote areas (Angelidis, 2010). This research has provided rigorous, theory-driven insights into the acceptance of specific types of health IT and sheds light into the role that professional cultures and organizational structures play in shaping the use of health information systems (Bhattacherjee and Hikmet, 2008, Wainwright and Waring, 2007). Mainstream IS scholarship teaches that system must align with actual hospital work practices (Cho et al., 2008) and that systems designed to improve the performance of one type of healthcare worker may have unintended, negative consequences on overall care unless the design considers all the workers in the system (Novak et al., 2012). While ICTs have potential to improve public health care, technology is just one part of a complicated system. ICT investments alone will not realize the potential benefits (Raghupathi and Wu, 2011). Research finds that the behavior of those involved with the implementation constrains the success of the implementation and that a reengineering process is also necessary to align the work routines with the technology (Payton et al., 2011). Power dynamics confound what would otherwise be a straight-forward technical issue. Power structures within organizations determine which systems are used (Spinardi et al., 1997) and political forces and the interests of more powerful organizations shape the outcomes by forcing weaker players to conform to their interests (Sahay et al., 2009).

Researchers also make direct contributions to the development of health IT systems. Nicolas-Rocca et al. (2014) design a patient-centered e-health system that helps patients understand their diagnosis and treatment options. Kouris et al. (2010) propose a mobile phone application to help diabetics better self-manage their condition. Escarfullet et al. (2012) design a mobile information system to make it easier for patients to schedule medical appointments and refill prescriptions. Lee and Park (2001) propose a system to classify patients HIV patients by whether they need AIDS treatment. Kartseva et al. (2010) propose method for developing systems of governance and controls for approving medical expenses and Siau et al. (2006) provide insights into making the trade-offs between privacy assurance and cost when designing and implementing health IT systems. Other research measures the impact of ICT on healthcare organizations so that hospitals and health systems can best allocate their resources. Research has found that in most cases, ICTs improve the delivery of public health (Raghupathi and Wu, 2011). To realize the benefits of information systems, however, organizations must also make non-IT investments (Ko and Osei-Bryson, 2004), and often must re-engineer their processes (Payton et al., 2011) which causes time delays that often hide the positive impact of the technology (Devaraj and Kohli, 2000). Studies have shown that ICT can increase the quality of care even when budgets and workforce availability are reduced (Singh et al., 2011) and that health IT investments are having a positive impact not just in hospitals and clinics, but in home-care settings as well (Smith and Bullers, 1999, Singh et al., 2011).

The robust health IT research tradition provides IS scholars with a strong foundation upon which to offer new insights and technology-based interventions that address the healthcare-oriented causes of homelessness. A material percentage of mentally ill persons will experience homelessness despite the availability of pharmaceutical treatments that can control mental illnesses such as manic depression and schizophrenia (Kahn et al., 2008, Yildiz et al., 2011). These drugs require close adherence to a specific medication regimen to be effective, but the vast majority of mentally ill patients do not take their medication as prescribed, keeping them symptomatic and at risk of becoming homeless (Mitchell and Selmes, 2007).

Medication Adherence

The literature on medication adherence is substantial in other disciplines, with 7733 articles indexed in the Web of Science[1]. The literature includes the disease spectrum covering topics ranging from high blood pressure (Kirscht and Rosenstock, 1977) to diabetes (Lee et al., 2006) to HIV (Waldrop-Valverde and Valverde, 2005) to mental illness (Aikens et al., 2008, Rummel-Kluge et al., 2008). Medication adherence, defined as taking medication in accordance with a doctor's instructions, is a complex, multifaceted challenge for healthcare professionals, patients, insurance companies, employers and policy makers. It involves not just taking the proper doses, but also taking medicine at the appropriate time (Claxton et al., 2001). Medication adherence

[1] As of June 25, 2015, 7733 articles have the topic "medication adherence" or "medical adherence"

results in better health outcomes (DiMatteo et al., 2002, Katon et al., 1995, McDonald et al., 2002, D. E. Morisky and Levine, 1986). Even with numerous complex challenges, improving medication adherence is a valuable goal of intervention at the individual as well as the system level (DiMatteo et al., 2002). The satisfactory level of adherence is 80% or higher for most conditions, while for others, such as HIV/AIDS, the required level is 95% (McDonald et al., 2002, Roter et al., 1998). The more severe the condition, the higher the adherence rate will be (Kirscht and Rosenstock, 1977). Medication adherence rates for different illnesses vary with higher rates for acute conditions and lower rates for chronic conditions (Osterberg & Blaschke 2005). Also, individual beliefs about the usefulness of medication will influence the decision to take medication (Zaghloul et al., 2005). Additionally, the positive and negative outcomes of taking medication has been shown to cause feedback loops that can influence future adherence, particularly during a long course of treatment (DiMatteo et al., 2002). Studies have found that socio-demographic factors such as age, gender, intelligence, and formal education level have little relation to a patient's level of medication adherence (McDonald et al., 2002). At the same time, studies have found patients with psychiatric conditions are less likely than many others to comply with their prescription regimens (McDonald et al., 2002). Moreover, psychiatric patients with poor medication adherence are four times more likely to be hospitalized and five times more likely to experience psychotic episodes than those who properly take their medication (Verdoux et al., 2000).

Much of the research explores how interventions can increase medication adherence. Studies have found that decisions whether to take medication – and acting on those decisions – is part of a complex system. Interventions incorporating cognitive, behavioral, and affective components are more effective than single-focus interventions (Roter et al., 1998). A systematic review of randomized clinical trials shows that the interventions that were the most effective for long-term care were complex combinations of convenient care, information, counselling, reminders, and reinforcement techniques such as rewards (McDonald et al., 2002, Osterberg and Blaschke, 2005). Complex interventions that require trained personnel and repeat sessions are impractical, as few healthcare systems have the resources to sustain such interventions. A reduction in any of the resources causes a reduction in adherence (Osterberg and Blaschke, 2005).

Several theories have been used to study medication adherence. These include health promotion model (Pender et al. 2006), which focuses on individual characteristics and experiences, behavior-specific cognitions and affect, and behavioral outcomes. Health promoting behavior is the desired outcome, but it is influenced by competing demands and preferences, which negatively influence health promoting actions such as medication adherence. The cognitive load theory (Sweller 1998) relates to the number of units of information that can be retained in short term memory before information loss occurs. The resulting cognitive load has been applied to many complex problems including learning and problem solving, and can be used to study medication adherence for patients with difficult and high stress life-style and/or cognitive challenges. The process of medication adherence is a multi-step process involving learning about medications and doses, planning and consuming the required doses within a window of time. If special efforts are taken in designing, building, and utilizing ICT-based interventions, the cognitive load for the patients could be reduced to match their cognitive capabilities. Social cognitive theory (Bandura 2001) focuses on observational learning, outcome expectations, self-efficacy, goal setting, and self-regulation. The outcome expectations, self-efficacy, and goal setting are related to medication adherence. For example, positive results are a reinforcing feedback loop that creates positive outcome expectations, which will increase the likelihood of engaging in the behavior that reinforces the expectations (Bandura 2001; Pender et al. 2006). This has direct connection with medication adherence for patients with mental illness. Theory of planned behavior (Ajzen 1991) is a predictive model for explaining human behavior. This has been used to explain behavior towards medications and the resulting medication adherence. The protection motivation theory (Rogers and Prentice-Dunn, 1997) suggests that motivation to protect ourselves is based on the perceived severity of a threatening event, the perceived probability of the occurrence, or vulnerability, the efficacy of the recommended preventive behavior, and the perceived self-efficacy. These theories have led to development of other models for medication adherence, such as self-efficacy model for medication adherence in mental illness (McCann, Clark and Lu 2008).

A Systems Model of Medication Adherence

This section describes the systems thinking approach used to model the medication adherence process among mentally ill patients. In contrast with traditional approaches, this approach allows modeling of unstructured problems and combines the power of simulation to provide would-be solutions to multiple what-if scenarios (Randers, 1980b). The approach offers an effective approach for gaining insight into multidimensional health issues and transforming that knowledge into effective interventions (Trochim et al., 2006, Mabry et al., 2008). Modeling and simulation of complex problems help in vividly assessing the impact of altering various control points and preparing the organizations/entities for alternative futures (Sterman, 2000). A great advantage of the systems thinking approach is the simplicity and parsimony with which very complex problems can be modeled (Randers, 1980a, Sterman, 2000, Tank-Nielsen, 1980). Thus, a systems thinking approach to modeling is an effective way to show how a complex system works by using the building blocks of stock accumulation and the feedback loops that exists when actors will later be influenced by the consequences of their actions (Roberts, 1978, Sterman, 2000). The use of feedback loops helps identify unintended consequences that might mitigate some of the benefits intended by an intervention (Sterman, 2000). This approach allows the problem to be viewed at different levels of abstraction. A component of sub-system of a system can be itself modeled as a full system, making it possible to deal with complexity and detail by fragmentation whenever necessary (Sterman, 2000). Systems thinking helps create understanding that can be used to implement more effective policies (Sterman, 2001).

Our model is based on two interconnected stocks and flows. The first flow models the process of the newly diagnosed patients who, after being prescribed medicine, move into the state of "willing patients." Because of intention moderators, only a subset of willing patients will become "adherent patients." The state of adherence creates several conditions, both positive and negative, that influence the patients within the system to remain "willing." There can be time delays between cause and the effect. For example, the side-effects may show up only after one has been in adherence state for a certain time. Consideration of several factors together, all of which may exhibit different relationships, makes the modeling of this system very complex.

The second flow shows the flow of medical data as relates to the availability of quality information. Clinical studies about the safety and effectiveness of medications occurs via corporate-sponsored research studies and a regulatory approval process. Once the drug is approved, information about pharmaceuticals becomes available to prospective patients. Data about individual patients is collected from in-situ drug use is recorded in electronic health records. Participating medical institutions standardize the data, anonymize it by stripping away information that can reveal the identity of specific patients, then aggregate and share it with clinical researchers. These researchers mine the data for new insights about its efficacy, side effects, risks, and measure the most effective dosing policies. These insights go through a rigorous peer review process, after which the information is published as epidemiology reports in various media. These reports increase the availability and accuracy of information about the pharmaceuticals. This in turn influences beliefs about the drug's efficacy that is held by patients initially prescribed the drug.

Notwithstanding this complexity, the purpose of this paper is to show how ICT can be applied to mitigate a very significant social challenge. All models are simplified representations of reality; therefore, making simplifying assumption in modeling the phenomena should not undermine the integrity of the findings (Randers, 1980a, Sterman, 2000). Even well-intentioned patients have low levels of adherence**.** It is these patients that are modeled in this paper. Psychiatric patients who prefer to live in an un-medicated state and patients who deliberately abuse addictive medications are outside the scope of this paper. Figure 1 details the system or interrelated factors that influence the decision to take medication. Because system-wide implementations face many obstacles to implementation (Cho et al., 2008, Payton et al., 2011); the remainder of this section details the flow of patients as they remain adherent or become non-adherent and holds the information stocks and flow constant.

Unlike traditional IS studies of individual ICT use (i.e. TAM (Davis, 1989) and UTAUT (Venkatesh et al., 2003)), our dependent variable is outcome rather than usage. According to the model, patients in the adherent state are a subset of patients in the willingness state. That is, at any point in time, the aggregate total of the willing patients is the sum of adherent and non-adherent patients. Equation 1 represents this relationship.

$$\sum wp = \sum N_{ap} + \sum N_{np} \qquad (1)$$

The willingness to take the medication, however, does not translate into perfect action. Medical research shows that many factors moderate the power of willingness. Competing preferences (CP), peer pressure (PP), and patient self-efficacy (EF) all oppose the willingness –actual behavior (adherence) relationship. Conversely, family support (FS) positively influences the likelihood that a patient will adhere to his or her medication regimen.

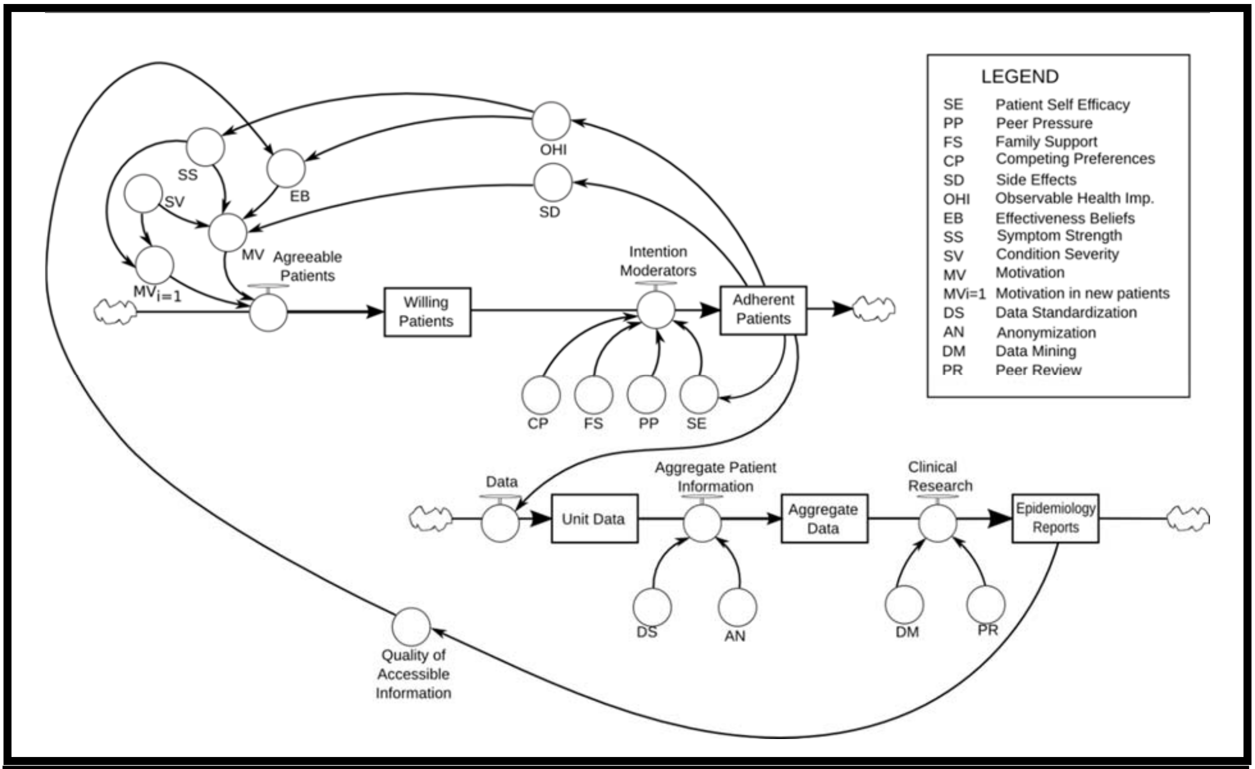

Figure 1. The System Model for Medication Adherence

Peer pressure can have a negative effect on the rate of adherence when important others are neutral or apathetic toward a health behavior (Pender et al., 2006). For psychiatric patients, friends might argue that taking medications to treat a mental illness is a sign of weakness. Friends might also discourage taking medications that may cause personality changes because they want "their 'old friend' back." The self-efficacy (EF) to take medication draws upon social cognitive theory (Bandura 2001). Psychiatric patients are particularly susceptible to low self-efficacy perceptions because they begin to doubt their own mental and cognitive abilities (Vauth et al., 2007). Therefore, those with doubts about their ability to follow doctor's prescriptions or regimen are less likely to be adherent.

Family support has been shown to positively influence the rate of medication adherence (Fenton et al. 1997). As such, the encouragement of a patient's family positively influences the likelihood that willingness (intention) translates into action. According to the health promotion model, competing preferences offer strong disincentives to take medication as prescribed by a doctor (Pender et al. 2006). For example, if a medication cannot be taken with alcohol, a patient might skip a dose in order to have a drink. If the medication causes drowsiness, a patient might skip the medicine in order to work late or go out with friends and remain alert enough to drive home. Family support, self-efficacy to take, peer pressure, and competing preference are intention moderators that affect the patients' medication-taking behavior. We capture this phenomenon in Equation 2.

FS = Family Support
EF = Self-Efficacy
PP = Peer Pressure
CP = Competing Preference

$$IM_t = FS + EF + PP' + CP' \quad (2)$$

There is a feedback relationship between adherence and self-efficacy. Self-efficacy increases when patients successfully manage their conditions (Ilioudi et al., 2010). The adherence to a prescribed regimen of medication positively influences perceived self-efficacy (Pender et al., 2006) and is represented in Equation 3.

$$EF_t = \beta_1 * AP_{t-1} \quad (3)$$

Adherence is the rate at which people successfully take their medication, based on behavior, not intention. The willingness to take medications is the necessary and direct precursor to taking medication. If the patient is unwilling to take medicine, or has a low level of willingness, then it is unlikely that the patient will adhere to doctor's prescription or regimen (Trauer and Sacks, 2000) **.** In other words, the intention moderators (IM) act as a moderator of willingness - adherence relationship. If there are perfect moderating factors (IM=1), all willing patients move to adherence state. Mathematically, the value of IM ranges between 0 and 1. The relationship can be described by equation 4.

$$AP_t = IM_t * WP_{t-1} \quad (4)$$

A high level of adherence creates behavior-reinforcing positive feedback loops. At the same time, a high adherence rate also creates negative feedback loops that can undermine a patient achieving successful long-term adherence to a prescription regimen.

Side effects (SD), experienced after taking the medication, can become a strong disincentive to continuing a medication (Mann 2009). If the side effects are more painful than the actual symptoms, many people will cease taking their medicine (Adams and Scott, 2000, Mann, 2009). Many antipsychotic drugs have visible side effects, such as tremors, which while improving mental health make it more difficult to function in regular society or in the workplace. Such side effects have been shown to discourage patients from continuing their medication (Boter et al., 2008, Fleischhacker et al., 1994**.** Some patients will experience adverse side effects; therefore, there is a counter-balancing feedback loop between adherence and side effects. According to (Boter et al., 2008), side effects cause 12.6% of schizophrenic patients to stop taking their medication. This effect is applicable only in the first cycle of medication adherence because the side effects take hold after the first exposure to the medication but dissipate within the first six months. This behavior is modeled in Equation (5) by using "i" to represent the i^{th} cycle of an individual patient.

$$SD_t = \beta_3 AP_{i=1} + \sum SD_{t-1} \tag{5}$$

Better mental health, which is the objective of taking medication, has both positive and negative impacts on future medication adherence. Positive results create positive outcome expectations, which will increase the likelihood of engaging in the behavior that reinforce the expectations (Bandura 2001). Those who follow the regimen of medication prescribed by the doctor are more likely to feel better and experience observable health improvements (OHI) (Katon et al., 1995). Thus,

$$OHI_t = \beta_2 AP_{t-1} \tag{6}$$

At the same time, the symptom reduction creates a balancing loop. By reaching better mental health, a patient experiences a symptom reduction. Less severe symptoms can decrease the perceived need to take the medicine, because strong symptoms are a key motivator to taking medication (Fenton et al., 1997, Osterberg and Blaschke, 2005). The potential outcomes (e.g. blindness, death, etc.) of an untreated or improperly treated illness – the condition severity (SV) is a key motivator to take medication (Rogers and Prentice-Dunn, 1997). Additionally, the stronger the symptoms,, the more likely the patient is to take medication. As a result, the symptom strength (SS), "the degree to which it is observable by the patients themselves" increases the willingness to take medication (Fenton et al. 1997; Osterberg and Blaschke 2005). In this paper, willingness represents patient's decision to take his or her medication as prescribed by a physician. Both condition severity and symptom strength affect "willingness to take medication" of both newly diagnosed as well as the existing patients.

$$SV_t = \beta_4 Imh_{t-1} \quad (7)$$

$$SS_t = \beta_5 Imh_{t-1} \quad (8)$$

According to the theory of planned behavior (Ajzen 1991), positive reinforcement is important to motivate behavior. The motivation factor (Mot) influences previously adherent patients to remain willing patients. This can be represented by equation 9.

$$Mot_t = SV_{t-1} + SS_{t-1} + EF_{t-1} + SD'_{t-1} \quad (9)$$

Where $0 \leq Mot \leq 1.0$

Willing Patients at time t (WP_t) is the sum of product of New Patients at time t (NP_t) with motivation $Mot_{i=1}$ and a certain proportion of adherent patients at time t-1 = AP_{t-1}. This is shown in equation 10.

$$WP_t = NP_t * Mot_{i=1} + AP_{t-1} * Mot_t \quad (10)$$

Where $Mot_{i=1} = SV_{i=1} + SS_{i=1}$

Simulating Interventions Targeting Patient Self-efficacy

ICT-based interventions have been shown to to improve patients' self-efficacy to take their medication. Dunbar et al. (Dunbar et al., 2003) introduced a system of reminders and feedback prompts via two-way pager that improved adherence for 79% of patients. Vervloet et al. (Vervloet et al., 2012) linked an electronic medication dispenser to an information system that sent SMS reminders if patients did not take their medication. The SMS reminders resulted in 46.2% of those who missed their dose taking their medicine within an hour of the proper time.

Patients receiving reminders were almost twice as likely to take the right does of the right medication at the right time as the control group. Similarly, Spaniel et al. (Spaniel et al. 2008) use SMS messages to achieve a 60% reduction in hospitalization rate and 30% improvement in medication adherence among psychotic patients. Because the high cost of home medical equipment inhibits adoption (Wei et al., 2011), ICT-based interventions should use technology that is readily available to everyone (Beni, 2011). Widely used smart phones offer possibilities of designing low cost applications providing a wide range of services. Ubiquitous deployment of high speed data wireless networks provides the necessary infrastructure that offers reliable connectivity for both simple reminder systems and more sophisticated electronic health systems. Given the success of previous experiments using mobile ICT, we run systems dynamics simulations based on interactive, smartphone-based reminder systems.

To measure the effect of changes in self-efficacy on the outcome variable "adherent patients," we conducted simulations of the system model described in Section 3. The systems thinking approach helps us to model the temporal effects of changes in various variables described in Equations 1-10. We examine the impact of the ICT intervention by simulating changes in psychiatric patients' self-efficacy. The stocks and flows of aggregate patient data are not simulated in this paper. We run the simulation for 36 months using 6-month time intervals. We simulate a system in which 100 patients enter per year and compute percentages that can be applied to actual population numbers. The model includes "willingness" and "adherent" patient states and these are modeled as stocks that accumulate or deplete because of several factors broadly categorized as motivation and facilitation factors. What-if simulations manipulate self-efficacy and the variables that are changed through the resultant feedback loops. Other factors are held constant.

The model tracks new patients entering the mental health treatment system and follows them as they remain adherent to their medication. Patients who become non-adherent are dropped from the model. The values assigned to various factors (Table 1) are drawn from previous studies. Prior research shows a patient's effectiveness beliefs and doubts about the drug's potency account for 13% medication adherence variance (Brown et al., 2005); therefore, the "efficacy belief" construct is set to -13%. Side effects cause 12.6% of patients with certain mental illnesses to stop taking their medication (Boter et al., 2008). Literature indicates that adherent patients observe an improvement in their health and a 24% reduction in their symptoms (Katon et al., 1995). Symptom strength is a critical motivation for someone to seek medical treatment and to adhere to a prescription regimen (Fenton et al., 1997, Osterberg and Blaschke, 2005). For this model, we assume that the acute symptoms of mental illness account for 25% of a person's motivation for taking medication.

Research shows that people diagnosed with psychiatric illness self-stigmatize, resulting in negative perception of their self-efficacy. Accordingly, we model the influence of self-efficacy at -20% (Cavelti et al., 2012, Ludman et al., 2003, Tsang et al., 2006, Vauth et al., 2007). Successful adherence in one time period is assumed to improve perceived self-efficacy by 50% in the next period (Equation-3). Peer pressure, competing preferences, and condition severity are held constant during the simulation. Table 1 summarizes the starting values of the dynamic variables.

Table 1. Variable Values used in the Simulation

Factor Symbol	Factor	Value
β_4	Symptom Strength	25%
β_1	Effectiveness Beliefs	-13%
β_2	Observable Health Improvement	24%
β_3	Side effects	-12.6%
SE	Self-efficacy	-20%
FS	Family support	21%
	Benefit of experience on self-efficacy	50%

We run the model, with the baseline of -20% self-efficacy, followed by simulating what-if scenarios that reduce the negative impact of self-efficacy by 25%, 50%, and 75% (using the values of -15%, -10%, and -5% respectively). To test sensitivity, and to represent a best-case scenario in which the artifact raises self-efficacy from a constraint to a positive affordance, we simulate a +5% positive self-efficacy scenario. The results of willing patients are tabulated in Table 2.

TABLE 2. Percentage of Patients Willing to Take Medication												
	6 months		12 months		18 months		24 months		30 months		36 Months	
Simulation	N	%	N	%	N	%	N	%	N	%	N	%
#1 (-20% SE)	24	48.0%	60	60.0%	91	60.7%	118	59.0%	144	57.6%	169	56.3%
#2 (-15% SE)	24	48.0%	61	61.0%	93	62.0%	122	61.0%	150	60.0%	175	58.3%
#3 (-10% SE)	24	48.0%	62	62.0%	97	64.7%	128	64.0%	157	62.8%	184	61.3%
#4 (-5% SE)	24	48.0%	63	63.0%	100	66.7%	134	67.0%	166	66.4%	196	65.3%
#5 (+5% SE)	24	48.0%	65	65.0%	109	72.7%	150	75.0%	191	76.4%	229	76.3%

The results show that the willingness to take medication increases when ICT intervention increases patients' self-efficacy. Given the complexity of the decision system, however, as patients remain in the system, the willingness of some will waiver because of side effects, etc., so the ratio of willing people to those who were diagnosed with mental illness may decrease over time. The second observation is that increased self-efficacy leads to a predictable increase in the percentage of patients that are willing to take their medication. Figure 5 depicts both the number and the percentage of willing patients in each simulation.

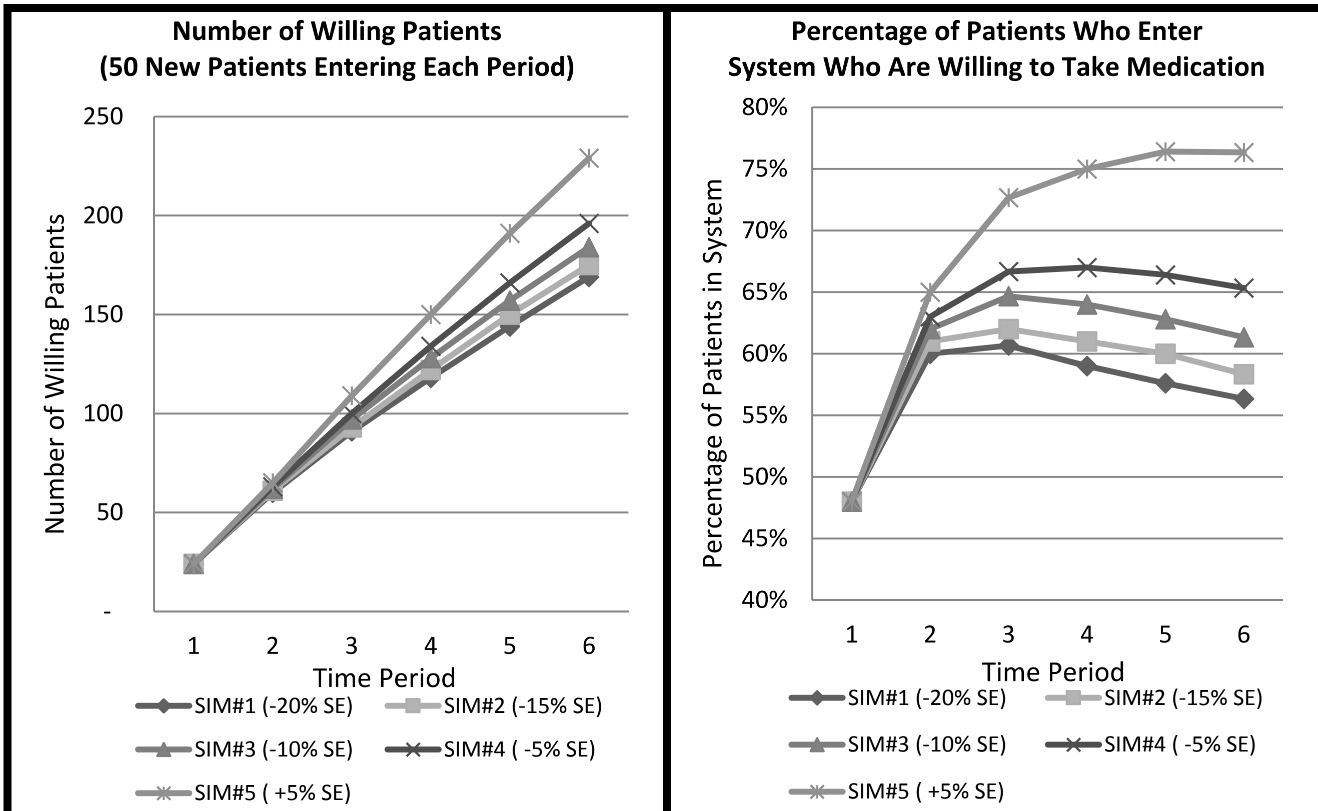

Figure 5. Number and Percentage of Willing Patients

According to our systems model for medication adherence, the behavioral intention to take medication as prescribed by a doctor does not translate directly into action. Accordingly, a subset of the stock of "willing" patients becomes adherent patients (refer to Equation 4). Table 3 shows the number of patients who are adherent during each time period for each simulation.

TABLE 3. Percentage of Patients Who are Adherent to their Medication Regimen

Simulation	6 months		12 months		18 months		24 months		30 months		36 Months	
	N	%	N	%	N	%	N	%	N	%	N	%
#1 (-20% SE)	19	38.0%	28	28.0%	34	22.7%	37	18.5%	39	15.6%	40	13.3%
#2 (-15% SE)	20	40.0%	31	31.0%	38	25.3%	43	21.5%	46	18.4%	48	16.0%
#3 (-10% SE)	21	42.0%	34	34.0%	43	28.7%	54	27.0%	54	21.6%	58	19.3%
#4 (-5% SE)	22	44.0%	37	37.0%	49	32.7%	64	32.0%	64	25.6%	70	23.3%
#5 (+5% SE)	24	48.0%	44	44.0%	61	40.7%	76	38.0%	90	36.0%	103	34.3%

Increase in self-efficacy resulting from ICT interventions increase adherence. Figure 6 shows how ICT interventions can increase the growth in number of adherent patients at each time period compared to the baseline.

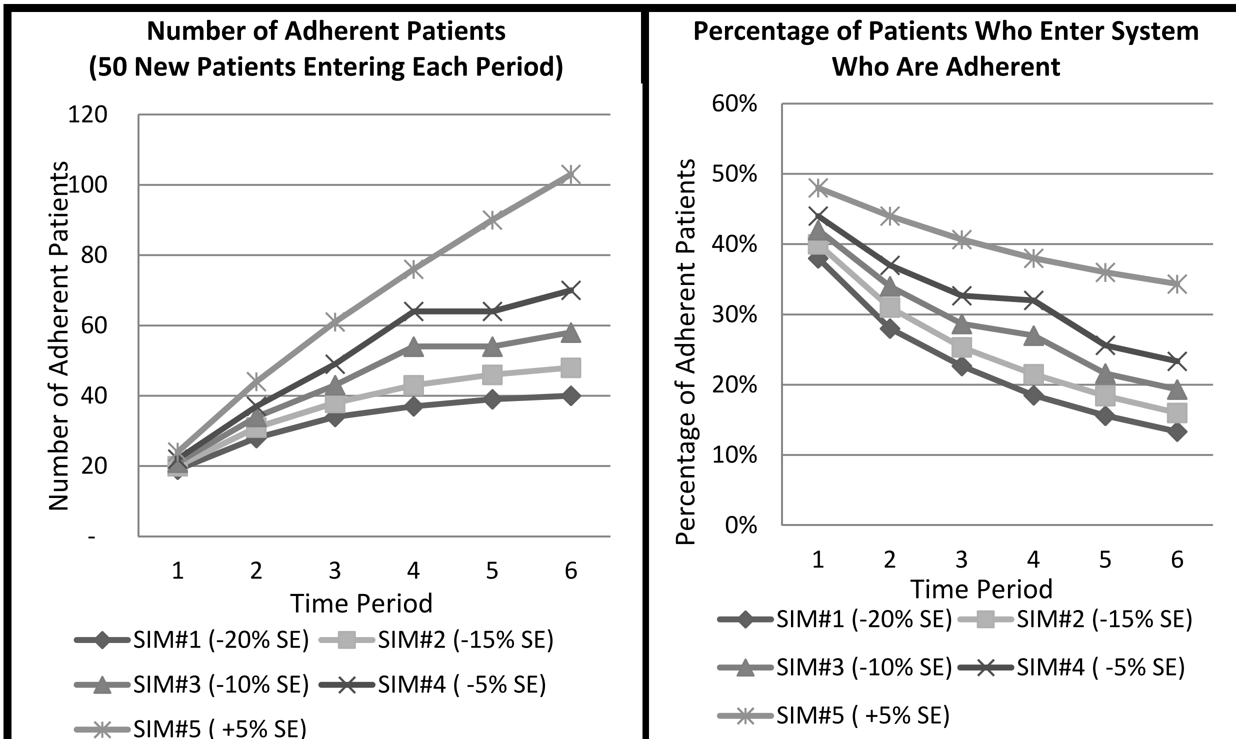

FIGURE 6. Adherent Patients within the System

While various factors may cause patients to become non-adherent over time, the positive effect of the ICT intervention is illustrated in Table 4, which shows the *increase* in adherent patients as a percentage of people in the system.

TABLE 4. Increase in Adherent Patients as Percent of People in the System						
Simulation	6 months	12 months	18 months	24 months	30 months	36 months
#2 (-15% SE)	2.4%	2.8%	3.0%	3.0%	2.8%	2.7%
#3 (-10% SE)	4.7%	5.8%	6.3%	6.4%	6.2%	5.9%
#4 (-5% SE)	7.1%	8.9%	9.9%	10.3%	10.2%	9.9%
#5 (+5% SE)	11.8%	15.4%	18.0%	19.6%	20.6%	21.0%

Although the magnitude of change in the conservative simulations may seem small, the problem is substantial, so any increase will improve the lives of thousands of people. If we apply real estimates of the mentally ill population, we can see a notable impact of even a small percentage change in medication adherence. Various mental illnesses are associated with homelessness. Depression and schizophrenia are the most common. If we analyze the potential impact on schizophrenic patients, we can see the power that simple ICT interventions can make in reducing homelessness. We use recent studies that reported the scale of the problem of mental illness and homelessness in order to demonstrate the impact of the ICT interventions. Each year, 1.5 million people are diagnosed with schizophrenia (Initiative", 2014). Up to 95% of these people can be helped with medication (McCann et al., 2008). Of those diagnosed, only about 45% acknowledge that they have a medical condition, a necessary precondition for them to be a realistic candidate for effective drug therapy (Kessler et al., 2001). Therefore, Table 5 shows the annual number of new patients whose conditions can be managed if they adhere to their medication regimen.

TABLE 5. PATIENTS ENTERING SYSTEM EACH YEAR			
Diagnosed Annually	Acknowledge Condition	Treatable with Medication	Candidates for Successful Drug Treatment
1,500,000	45%	95%	641,250

Each year, 641,250 patients diagnosed with Schizophrenia can manage their symptoms with proper medication. Over a 3 year period, 1,923,750 people are candidates for successful treatment. Fifteen percent (15%) of those who do not successfully manage their conditions with medication will go homeless (Folsom et al., 2005). Table 6 calculates how many people suffering from schizophrenia can avoid becoming homeless through ICT based interventions by increasing patients' self-efficacy.

TABLE 6. Number of Persons Who Do Not Become Homeless Because of ICT Intervention

Simulation	Patients Entering System	% Increase in Adherent Patients	Additional # of Adherent People	% Would Become Homeless	Prevented Cases of Homelessness
#2 (-15% SE)	1,923,750	2.7%	51,090	15%	7,663.45
#3 (-10% SE)	1,923,750	5.9%	113,914	15%	17,087.04
#4 (-5% SE)	1,923,750	9.9%	191,284	15%	28,692.59
#5 (+5% SE)	1,923,750	21.0%	403,723	15%	60,558.45

Given the scale of the homeless challenge, even just the cases caused by one mental illness, any small improvement can affect thousands of lives. The calculation above models only one of the treatable disorders associated with homelessness, yet it shows how simple ICT interventions can help thousands of people. In addition to the substantial impact on the human condition, preventing even a few thousand people from becoming homeless can have a major financial impact. The estimated costs of providing social services to homeless persons vary by country, but are estimated to be as high as $40,500 per person (Culhane, 2008). Reducing homelessness by a few thousand people can save hundreds of millions of dollars, funds that can be reallocated to other interventions.

While the initial simulations show the potential benefits afforded by interventions when used as intended, ICT often has unintended consequences. These interventions can offer additional affordances. For example, it may provide family members an additional opportunity to engage with the patient. They could follow-up with the patient by monitoring adherence, providing reinforcement when the patient is adherent and intervening when the patient risks becoming non-adherent. At the same time, the availability of technology to assist medication compliance may lead family members to over-estimate the impact of the technology and become less involved and play a less supportive role. Another potential constraint arises from a dependence on the artifact. Because mentally ill patients experience low levels of self-efficacy, losing their ICT-based system could lower their confidence in their ability to adhere to the medication regime below the pre-artifact starting point. The effects of these unintended scenarios are detailed in Table 7. Simulation #6 uses the lowest simulated value for the change to self-efficacy (-15%) while increasing family support by 25%. Simulation #7 depicts a 25% drop in family support coinciding with the introduction of the ICT intervention, while using the lower end -15% value for self-efficacy. Simulation #8 depicts the loss of the mobile phone during the first half year, which lowers the patient's self-efficacy by 25%.

TABLE 7. Potential Unintended Changes in Family Support

Simulation	6 months	12 months	18 months	24 months	30 months	36 months	% change at 3 years
SIM#1 (-20% SE)	19	28	34	37	39	40	-
SIM#2 (-15% SE)	20	31	38	43	46	48	20%
SIM#6 (-15% SE + 25% more FS)	21	34	42	49	53	56	40%
SIM#7 (-15% SE - 25% less FS)	19	28	34	38	40	41	2.5%
SIM#8 (Lose phone: -25% SE)	18	26	30	32	33	34	-15%

If the affordance of greater family support increases the involvement of loved ones by 25%, then the benefit of the ICT based intervention raises the success by 40%, making the intervention twice as effective as the intervention's intended effect. Conversely, an inadvertently reduction in family support could mitigate almost all the benefits of the ICT-based intervention. Furthermore, non-availability of assistive technology within the first half year caused patients' perceived self-efficacy to drop by 25%, 15% fewer patients would be adherent, making the situation worse than if no artifact had been introduced.

The ICT interventions can be effective at increasing medication adherence and therefore reducing the number of new people who become homeless. At the same time, however, researchers must acknowledge that there are limited resources to be allocated to address societal challenges. One must evaluate whether dedicating resources to implementing an ICT-based systems would be of greater benefit than focusing those resources elsewhere. Therefore, we have run simulations to compare the impact of allocating resources to increasing family involvement. We compare the impact of an increase of family involvement by 25%, 33%, and 50% versus the baseline and conservative simulations of the ICT based intervention (i.e. simulations 1 and 2) as shown in Table 8.

Table 8. Impact of Alternative Interventions						
Simulation	6 months	12 months	18 months	24 months	30 months	36 months
SIM#1 (-20% SE)	19	28	34	37	39	40
SIM#2 (-15% SE)	20	31	38	43	46	48
SIM#3 (-10% SE)	21	34	43	50	54	58
SIM#9 (Increase FS by 25%)	20	31	38	42	45	46
SIM#10 (Increase FS by 33%)	20	32	39	44	47	49
SIM#11 (Increases FS by 50%)	21	34	42	47	51	54

If the ICT intervention is only increases self-efficacy by 25% (5 basis points), then it may be more appropriate to allocate resources to programs that can substantially increase family involvement. In all other simulations, however, using the ICT intervention will provide material benefits.

Discussion

This paper investigates the use of ICT to address a health problem outside of hospitals and clinics (Singh et al., 2011, Smith and Bullers, 1999). Simulations show that a health IT intervention can contribute to ameliorating the societal challenge of homelessness. Drawing upon the health promotion model, social cognitive theory, and protection motivation theory, this paper models the medication adherence decision process as a system in order to identify an intervention point where a simple, low-cost ICT intervention can have a significant impact. The potential human and financial benefits of such an intervention are significant. As demonstrated through the simulations in the previous section, even a simple intervention that makes a small improvement can improve thousands of lives and save millions of dollars.

This study simulates an intervention targeting the stock of patients because such an intervention employs a ubiquitous technology and requires acceptance only by patients. System-wide implementations face many obstacles to implementation (Cho et al., 2008, Payton et al., 2011); therefore, this paper does not simulate the information stocks and flows of the systems model for medication adherence. Future research can simulate the intervention's impact on the entire system. In addition, this study focuses on increasing the perceived self-efficacy of patients and its subsequent feedback loops. It holds constant many other drivers and inhibitors of medication adherence that are not theory-based feedback loops linked to self-efficacy. Prior research has shown that interventions which address multiple factors are more effective than single-focus interventions (Osterberg and Blaschke, 2005, McDonald et al., 2002). Future research can study ICT interventions that directly target other key factors, such as providing social features to increase family support or enabling better education about medications.

In decision-making systems like medical choices faced by patients with mental illness, a variety of factors influence the decision to take medication. Although ICT offers affordances (Gibson James, 1977, Hutchby, 2001), we cannot assume that ICT interventions will be used exactly as expected. Nor can we assume that it is used within a closed system in which introducing ICT has no ripple effects. It may be used in unanticipated ways that increase its effectiveness; conversely, the in-situ use of an artifact may present constraints that interfere with accomplishing the intended goal (Majchrzak and Markus, 2013). Health IT interventions are parts of complicated systems of care (Raghupathi and Wu, 2011) and research has found that introducing ICT to improve medical care may have unintended consequences (Novak et al., 2012).   An ICT-based intervention could give family members a reason to check up on a patient, increasing family involvement. Such an unintentional affordance would increase the effectiveness of the intervention. A simulation showed that such an unintended consequence could almost double the effectiveness of a mobile app. At the same time, using an ICT-based intervention could constrain family support if it were to give family members the impression that the technology would reduce the need for their support and involvement. Under such circumstances, the unintended constraint could mitigate almost all the gains from the technology.

The decision to adhere to a medication regimen is not a one-time choice, but an ongoing process during which decision drivers like side-effects, severity of symptoms, and perceptions of self-efficacy change with time and experience (Boter et al., 2008, Osterberg and Blaschke, 2005, Tsang et al., 2006). Therefore, the model contains positive and negative feedback loops to represent the multifaceted, dynamic system in which people live and make their decisions. To account for changes over time and the effects experience have on future decisions, we simulate a three year time period with a new iteration every six months. Such a model differs from the traditional individual-level technology use literature, which views use either as a onetime decision (i.e. TAM (Davis, 1989) and UTAUT (Venkatesh et al., 2003)) or as an ongoing process in which experience affects subsequent decisions but assumes the same variables drive choices made at every decision point (i.e. (Bhattacherjee, 2001)). The model proposed in this paper also differs from traditional IS research, which assumes a perfect correlation between intention and action. The study employs an alternative perspective by modeling variables that moderate intention from becoming action (Triandis, 1980). Furthermore, this study breaks from traditional individual-level information systems use research by modeling the outcome of use rather than use itself as the dependent variable. While traditional theories and models have proven remarkably robust and provided important insights into our understanding of individuals and technology, incorporating alternative approaches to modeling complex systems and different dependent variables may afford new types of insights.

This paper also has limitations that should be noted. As previously discussed, the decision system is complex and includes medical guidelines and clinical research, all of which influence a patient's beliefs about whether taking medication will be beneficial. The simulations hold available information constant and do not take into account the flow of information from patients and healthcare providers to clinical researchers and epidemiologists. The simulations do not factor in a percentage of patients who will not accept an ICT-based intervention tool. In practice, such a limitation would have a material impact of the intervention's effectiveness. Another important limitation arises from the use of multiple simulations to test effectiveness of the intervention rather than enacting an in-situ experiment with real patients. While the simulations show benefits of scenarios incorporating interventions, a simulation cannot predict all unanticipated affordances and constraints that would appear a real-world trial.

Conclusion

This paper emphasizes the abilities of information systems and ICT to address major societal challenges. Homelessness is one such problem. Severe mental illness, a major cause of homelessness, can be controlled through pharmaceutical treatment. Research shows, however, that most psychiatric patients do not adhere to the guidelines set by their doctors. Insufficient levels of medication adherence result in preventable homelessness. Consequently, this paper views homelessness as a healthcare issue that can be addressed by ICT interventions designed to increase the rate of medication adherence. This paper addresses the grand societal challenge of homelessness by modeling the process by which people form the behavioral intention to adhere to their medication regimen as well the obstacles to turning intention into action. Because the medication adherence decision process is complex, rather than a straight-forward decision path with steady-state moderating influences, we apply a systems thinking perspective to model medication adherence as a system through which patients decide to adhere to their prescription regimen. Employing systems thinking offers an effective approach for gaining insight into multidimensional health issues, including the presence of feedback loops that can lead to unintended consequences.

Drawing upon social cognitive theory, the health promotion model, and protection motivation theory, we show that ICT-based interventions designed to increase patients' perceived self-efficacy could significantly increase medication adherence among those with severe mental illness. We simulate unintended consequences of the proposed ICT-based interventions, in which use of the assistive application may increase or decrease the amount of family support, a key adherence driver. We find that the proposed ICT intervention will increase the number of adherent patients by up to 21%. We discuss the implications, which include better mental health within a society, a reduction in homeless persons, and a decrease in the societal costs of homelessness. We also discuss a key limitation -- the proposed e-health intervention only affects one aspect of a complex societal problem.

This paper examines a specific issue, namely using ICT to increase medication adherence as a way to reduce homelessness. Future research can investigate the stocks and flows of information recorded by ICT interventions and their impacts on medication adherence. Additionally, researchers can examine how other information and communication technologies can be used to ameliorate the homelessness epidemic. Health IT scholars can also expand the IS-based research of medication adherence into other medical conditions. Poor medication adherence leads to an estimated $100-$300 billion in extra healthcare costs (Braithwaite et al., 2013) and thousands of hospitalizations that could be avoided (Sokol et al., 2005), making medication adherence a rich area for future research. Future studies could investigate topics such as: 1) the adoption of ICT-based interventions by medical institutions, providers/practitioners, and patients; 2) the design and implementation of ICT-based interventions; and 3) the adherence-enhancing ICT policy at the regulatory level.

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