Health Capability Maturity Model: Person-centered Approach in Personal Health Record System

Full Paper

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Abstract

Personal health record (PHR) system is considered an important component in implementing continuity of care and evidence based treatment in modern healthcare. However, the adoption rates for PHR system by general public still remained low due to lack of interest and low health literacy level. In this paper, we propose a health capability maturity model (HCMM) and corresponding improvement paths to improve an individual’s capability to manage one’s health systematically by using PHRs. The HCMM allows an individual to collect, monitor, and control one’s health information. To this end, we attempt to integrate some of the key processes and concepts from Capability Maturity Model Integration (CMMI) and Trans-theoretical Model (TTM) into HCMM that assesses an individual’s capability and awareness on managing health and well-being and suggests customized improvement goals.

Keywords

Personal Health Care, Personal Health Record, PHR system, Health Management

Introduction

Since American Recovery and Reinvestment Act (2009) enacted, personal health record system (PHRs) has drawn much attention because it can be considered an essential part in assuring continuity of care, evidence-based treatment and preventing medical errors, the third leading cause of death in the United States(James 2013). It also promotes self-management and wellness (Archer et al. 2011; Kaelber and Pan 2008; Tang et al. 2006). Besides the advanced health/medical technologies (e.g. mobile apps, wearable devices with sensors and actuators) and the growing adoption of electronic medical record systems (EMRs) have accelerated the interest and investment in PHRs.

Despite significant efforts in implementation of PHRs and its growing availability, its adoption rate remains relatively low overall. According to a national consumer survey conducted by the Markle Foundation in 2011(Markle 2011), only 10% of the public currently use PHR and 9% of doctors offer PHR. The adoption and use of PHRs have many perceived and real barriers from understanding an individual’s health behavior to providing the meaningful intervention(Tang et al. 2006).

One of the barriers is an individual’s lack of maturity and capacity to manage one’s health and wellness(Tang et al. 2006). For successful adoption and use of PHRs, an individual should have motivation, attitude, and capability toward the health improvement. Along with that, PHR should be able to assist the individual’s self-care management efficiently and effectively. Thus, the paper proposes the health capability maturity model (HCMM), which is designed to measure an individual’s level of capability in understanding and managing health related key areas, to assess an individual’s health condition and to provide customized improvement path. An individual will be able to monitor and control
his/her health, achieving required goals in key process areas in the improvement path. During these processes, the individual can build his/her maturity in support of PHRs. The individual can manage his/her health quantitatively as well as share his/her medical information with clinicians in a secure way. PHRs not only allows individuals to access their own health information, but also provides personalized goals and meaningful interventions without interrupting their lifestyle.

The paper is organized as follows. In section 2, we review the related works and theoretical models for health behavior change management. Subsequently we propose a framework of measuring healthcare capability maturity level of an individual on health and wellness management. Finally we conclude the paper in section 4.

**Related Works**

This section provides the theoretical foundations for developing health capability maturity level. To achieve this, the section reviews an overview of PHRs and its role in health behavior change management, the social and behavioral change models and Capability Maturity Model Integration (CMMI).

**Personal Health Record System (PHRs)**

PHRs is an electronic application that allows individuals to access, manage, and share their health information in private, secure and confidential environment(Tang et al. 2006). For instance, PHRs assists an individual to access to one's personal health/medical information (e.g. laboratory results, diagnostic images, etc.), generate health records, and manage information about one’s current health status(Mitchell and Begoray 2010). Furthermore, with the convergence of smart biosensors, smartphone, and cloud computing services, it enables to monitor an individual’s changes in one’s vital signs, provide feedback to manage current health status, and help maintain an optimal health status(Jia et al. 2015; Milosevic et al. 2013).

When integrated with healthcare providers’ information systems and EMR, PHRs provides the ability to track one’s disease conditions, an ongoing connection between individual patients and providers, and eventually promote earlier intervention when problems are encountered and potentially avoiding hospitalization (Tang et al. 2006).

**PHRs as a Tool of Health Behavior Change Management**

PHRs has been used as a patient-centered care system, which eventually leads to an individual’s self-care management. Recent studies have proved that the health status and behavior of patients with chronic diseases can be significantly improved by the self-care management program or training(Archer et al. 2011). Basically self-care/self-management support program is to change patients’ behavior by increasing their self-efficacy and educating knowledge, which results in better disease control (Pearson et al. 2007; Sarkar et al. 2006). Accordingly, in terms of self-management, PHRs supports individuals to record, track, and edit information about their own health/health care, notifies with appropriate actions when symptom levels indicate a problem, and provides relevant patient oriented interventions and decision support (Bensley et al. 2004; Goetzel et al. 2008).

Three major social and behavioral change models– 1) Social Cognitive Theory (Bandura 2008), 2) Theory of the Planned Behavior (Ajzen 1991), and 3) Transtheoretical Model (TTM) (Prochaska and Velicer 1997) have been widely applied to health behavioral change management. Social cognitive theory proposes that individuals are not driven by inner forces, but by external factors- personal and environmental factors. As a triadic interaction of behavior with two external factors, behavior will be changed or performed, which is known as reciprocal determinism. Environmental factors represent situational influences and environment where behavior is performed, while personal factors are instincts, traits, and other individual’s motivational forces. Self-efficacy, outcome expectations, self-control and reinforcements are the key variables that intervene in the process of behavior change. Transtheoretical model views change as a process that requires multiple stages over time, rather than an action that is caused by an immediate and direct result of intervention. By proving specific plan and strategies, a process can be evolving and moving forward to the next stage. However, there are possibility of slips and relapses along the way. The theory of planned behavior is based on the premise that individuals with defined intentions are more
likely to engage in change. Such intention is determined by an individual’s attitude based on behavioral beliefs and evaluation of behavioral outcomes and the subjective norms based on normative beliefs and motivations to comply (Ajzen 1991). Also behavior is determined by an individual’s perceived behavior control such as one’s perceptions of their ability or feeling of self-efficacy or confidence to perform behavior.

**Capability Maturity Model Integration (CMMI) as Health Behavior Management**

Originally the Software Engineering Institute (SEI) developed CMMI for software organization (Paulk et al. 1993). As a process maturity framework, CMMI presents sets of recommended practices in a number of key processes areas that have been proved to improve software process capability. The main components of CMMI is the maturity or capability level, process areas, generic and specific goals, and their corresponding generic and specific practices. The underlying principle of CMMI is to guide software organizations in selecting process improvement strategies by assessing current process maturity and identifying few issues most critical to quality and process improvement. As aforementioned in previous section, an individual’s health management process also requires a systematic staged and continuous framework to achieve sets of goals and activities and maintain capability. In this aspect, we attempt to apply the structure of CMMI to our health capability maturity model.

**Domains that influence Personal Health and Wellness**

**Health Literacy**

Health literacy refers to an individual’s ability to seek, understand, and use health information to make appropriate decision regarding one’s health (US Department of Health and Human Services 2000). Many studies have found that health literacy has profound impacts on the effectiveness and quality of medical treatment decision in health care and health promotion (Jordan et al. 2013; Nutbeam 2000).

PHR system must present data and accompanying tools in ways that enable the individual to understand and to act on the information contained in the personal health record. Accordingly, it is very important to capture patients’ levels of general literacy and of health literacy in PHR systems. Generally health literacy may be more amenable to improvement than general literacy (McCray 2005).

According to Nutbeam’s Health Literacy Model (Nutbeam 2000), there are three different levels: Functional Health Literacy (Communication of Information), Interactive Health Literacy (development of personal skills), and Critical Health Literacy (personal and community empowerment). Health literacy can be measured by questionnaires (e.g. The short test of functional health literacy in adults (STOHFLA) (Chew et al. 2004), Survey of HL measurements (Ishikawa and Yano 2008), etc.).

**Health Status, Health Behavior & Self Efficacy**

Health Risk Assessment (HRA) or/and Personal Health Assessment (PHA) (Brener et al. 2003; Goetzel et al. 2008) are commonly used to assess health status, health behavior, and self-efficacy in public, private, and government sectors for the following purposes (Goetzel et al. 2008):

1. Provide guidance to providers offering clinical preventative care, health promotion, and disease management services.
2. Reduce health disparities through the use of HRAs and follow-up interventions
3. Improve health outcomes by identifying patients’ modifiable health risks and providing follow-up behavior change interventions over time.

U.S. Department of Health and Human Services (US Department of Health and Human Services 2000) identifies six factors that determine an individual’s health from public health’s perspective: 1) Biology, 2) Behavior, 3) Social environment, 4) Physical environment, 5) Policies and Interventions, and 6) Access to the quality health care. At National Institutes of Health (NIH) 2011 workshop (Oremus et al. 2011) on identifying core behavioral and psychosocial data elements for the electronic health records, a group of NIH Representatives and the Society of Behavioral Medicine (SBM) Health Policy Committee assess the majority of domains and narrow down to 13 core domains: 1) anxiety and depression, 2) eating patterns, 3) physical activity, 4) quality of life, 5) risky drinking, 6) sleep quality, 7) stress, 8) substance use, 9)
tobacco use, 10) patient goals, 11) medication-taking behavior, 12) health literacy, and 13) demographic. 1-9 domains are recommended to collect annually. In terms of measuring health, the Healthy Cities Office of the World Health Organization (Garcia and McCarthy 2000) provides a survey report, which describes survey instruments and boarder health measures. For instance, short-term psychological state can be measured by the Bradburn’s scale that covers positive and negative emotional reactions of people in their daily lives (Garcia and McCarthy 2000). After reviewing related works, key domains are identified as shown in Table 1.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Data For PHRs</th>
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</thead>
<tbody>
<tr>
<td>Biology (Garcia and McCarthy 2000; Oremus et al. 2011)</td>
<td>Physiological data (BMI, etc.)</td>
</tr>
<tr>
<td></td>
<td>Home monitored data</td>
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<tr>
<td></td>
<td>Personal/Family history</td>
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<tr>
<td></td>
<td>Medical condition, Major illness</td>
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<td></td>
<td>Disability</td>
</tr>
<tr>
<td>Life Style/Behavior (Garcia and McCarthy 2000; Oremus et al. 2011)</td>
<td>Social relationship</td>
</tr>
<tr>
<td></td>
<td>Habits (tobacco, alcohol, etc.)</td>
</tr>
<tr>
<td></td>
<td>Physical activity (types, frequency, etc.)</td>
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<tr>
<td></td>
<td>Healthy eating (nutrition intake, etc.)</td>
</tr>
<tr>
<td></td>
<td>Stress</td>
</tr>
<tr>
<td>Access to Health Care (McCray 2005)</td>
<td>Screenings</td>
</tr>
<tr>
<td></td>
<td>Immunizations</td>
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<td></td>
<td>Use of preventative services</td>
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<tr>
<td>Readiness to change behaviors (Goetzel et al. 2008)</td>
<td>Self-efficacy (overcome strategies, etc.)</td>
</tr>
<tr>
<td></td>
<td>Motivation</td>
</tr>
<tr>
<td></td>
<td>Attitude</td>
</tr>
<tr>
<td>Health Literacy (Squiers et al. 2012)</td>
<td>Medical terms/forms competency</td>
</tr>
<tr>
<td></td>
<td>Technology competency</td>
</tr>
<tr>
<td></td>
<td>Study Skills</td>
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Table 1. The Key Assessment Domains

A Proposed Framework

The application of CMMI to Health Behavior Change Management provides a sequence of improvements and permit comparisons across all the facts by the use of maturity levels. The framework generates a customized roadmap for personal health improvements based on the grouping and ordering of interventions. The proposed framework is driven by two models: CMMI and TTM as mentioned in previous section. The framework includes levels of capability maturity on health behavior management.

HCMM’s Capability Maturity Level

The proposed framework includes two properties: Capability and Maturity level. Maturity implies a potential for growth in capability and indicates both the efficiency and effectiveness of individual’s self-management process and consistency with which it is applied to another process.

• Capability Level is the degree of an individual’s health literarcy to obtain, process, understand, and communicate about health–related information needed to make informed health decisions (Entwistle and Watt 2013; Squiers et al. 2012).

• Maturity Level is the extent to which a specific process area that an individual should acquire for the goal achievement and health improvement is explicitly defined, managed, measured, controlled, and effective (Cutis et al. 2001; Paulk et al. 1993).

Level Definition and Health Improvement Key Process Areas

Identification of key process areas in terms of health literacy and self-management in capability level should be addressed to achieve a maturity level. The key process area consists of a set of related activities that accomplish a set of goals considered important to enhance the capability. The path to achieve the
goals of each process area may differ across the health domains. However, all the goals should be completed within these key processes areas. The key process can be considered the requirements for acquiring maturity level. Since health behavior change management and health literacy are multifaceted, it is difficult to set an exact boundary for each key process in the respect to the maturity level. HCMIM levels are defined as follows and the key process areas and goals based on the related empirical works in health domain are identified as shown in Table 2.

- **Level 0** is a level in which an individual lacks health self-management practices, its pertaining skills, knowledge, and motivation. Therefore, at this level the individual’s clinical data (if it is necessary) and health status are collected as baselines through personal health assessment.
- **Level 1** is a level in which an individual intends to change, is aware of the pros and cons of change, and is able to repeat routinely the processes to improve the health and wellness.
- **Level 2** is a level in which an individual conducts some significant actions of a plan, adopts a care plan; establish the defined processes according to personalized risk management and decision-making.
- **Level 3** is a level in which an individual makes mortification in lifestyle and use quantitative techniques to manage self-monitoring and controlling performance.
- **Level 4** is a level in which an individual works to prevent relapse and continuously improve the performance as well as respond rapidly to changes and opportunities.

<table>
<thead>
<tr>
<th>Level</th>
<th>Process Area</th>
<th>Recommended Goal</th>
<th>Related Works</th>
</tr>
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</table>
| Level 0 - initial | • Health assessment  
• Baseline data collection | • Acknowledge clinical severity, functional status, and problems | Bensley et al. 2004; Garcia and McCarthy 2000 |
| Level 1 - repeatable | • Requirement Identification  
• Health Literacy Education  
• Self-Measurement Training  
• Resource Management | • Identify target behaviors for improvement  
• Develop and sustain self-measurement capability  
• Acknowledge clinical severity, functional status, problems, and barriers to behavior change and self-management  
• Obtain evidence-based information | Broderick and Haque 2015; Coulter, Entwistle, Eccles, Ryan, Shepperd 2015; Jia et al. 2015; Mitchell and Begoray 2010; Nutbeam 2000, 2009 |
| Level 2 - defined | • Self-Care Management  
• Technology-based Intervention Training  
• Risk Management  
• Decision Analysis and Resolution | • Establish defined processes and goals and identify the priorities for goal achievement  
• Facilitate to assess the milestones via technology-based intervention (e.g. immediate feedback, text reminder)  
• Identify potential health problems and mitigating strategies using technology based intervention  
• Analyze and evaluate possible decisions for the processes | Broderick and Haque 2015; Free et al. 2013; Murray and Frenk 2000; Norman et al. 2007; Oinas-Kukkonen 2013 |
| Level 3 - managed | • Quantitative Self-Monitor and Control | • Establish quantitative objectives based on the needs of the current health status | Jia et al. 2015; Meyer and Boll 2014; Simon and Seldon 2012 |
| Level 4 - optimized | • Health Promotion Management  
• New Innovative Evidence-based Health Intervention Adoption | • Focus on continuous improvement based on quantitatively managed processes  
• Adopt new and innovative technology or support to maintain and/or optimize the current level | Entwistle and Watt 2013; James 2013; Kok et al. 2004; Wandersman et al. 2012; Yardley et al. 2015 |

**Table 2. Proposed Health Capability Maturity Level**
Health Interventions and Technology involvements

Interventions are to attempt to influence behavior at the individual, organizational, community, or societal level with regards to health promotion and illness prevention (Westmaas and Gil-rivas 2007). The proposed framework focuses on individual-level (e.g. self-monitoring) or interpersonal level interventions (e.g. social group support), which is characterized by higher levels of interaction between the targets of interventions and technology-involved interventions (e.g. coaching emails, reminding texts, motivational texts, instant feedback, etc.) (Free et al. 2013). Based on the improvement paths as shown in Figure 1, technology-based health interventions are provided through PHRs. In addition, each plan and goal are suggested through a theme of quality health care that is defined by the US agency of Healthcare Research and Quality - “doing the right things, at the right time, in the right way for the right persons – and having the best possible results (Pearson et al. 2007). Improvement path can be done in one of the following two ways:

- Staged: satisfy predefined generic goals and specific goals in each level
- Continuous: improvement can be done by selecting any goals that are corresponding to the weak spots for each individual.

![Personalized Improvement Path Based on HCMM](image)

Figure 1. Personalized Improvement Path Based on HCMM

Health Self-Management in Scenario

Figure 2 illustrates the proposed framework integrating with mobile PHR system. The initial stage of a proposed framework is to assess an individual’s capability on health domains, which quantitatively collects data such as health related personal data, a degree of motivations, a level of health literacy, and so on. Based on the collected data, the level of capability and maturity of the individual on health behavior/lifestyle, health status, and motivation is measured at the second stage. The third stage will generate a personalized health improvement path to aim for a desired level in terms of key process areas, its corresponding goals and practices such as physical activity tasks, dietary interventions, and health literacy skills. Based on the recommended improvement path, the fourth stage is for the individual to monitor and control in support of emerging health care technologies and devices such as fitness band, micro chipped medication, physiological and contextual bio-sensors, mobile blood glucose tracker, and so on (Meyer and Boll 2014; Pantelopoulos and Bourbakis 2010). Finally all the data is stored to be accessible and sharable with family, health care providers as well as the individual for further collaborative meaningful interventions and continuity of care.
Conclusion and Future Work

PHRs is designed to assist an individual to access to one’s personal health record to manage and maintain one’s health and wellness. Recently PHRs that are integrated with new technologies and devices can monitor an individual’s physical activity, physiological data (e.g. blood pressure, pulse rate, electrocardiogram (EGG), weight, blood glucose, etc.), and medication adherence and store them into PHR for more holistic health care management. In this paper, we attempt to apply innovatively the concept of maturity and capability in software engineering development to health domain context in order to assess systematically capability maturity level of an individual for the health improvement in general and specific areas. By implementing HCMM into PHRs, PHRs can provide more personalized goals and a set of activities to achieve the desired maturity level. From assessment to monitoring and managing health behavior and status of an individual, PHRs plays an important role as a facilitator that continuously interacts with an individual to motivate, engage, monitor, remind, reward, and warn the individual to manage and maintain one’s capability and maturity.

One limitation of this study is validity of the HCMM. Although the HCMM is grounded on the theoretical models and related empirical studies, the validity of the HCMM has not been tested statistically and empirically. Therefore, the study can be continued in the following directions:

- Validation of HCMM with meta-analyses on the empirical literature, statistical validity measures, and the focus group study with health care professionals.
- Design and implementation of a framework into mobile PHR application or version of a website that supports for mobile devices
- Integration with biosensors and actuators to seamless monitor and control an individual’s physical activity and lifestyle
- Security and privacy issues on collecting PHR data over the PHR systems
REFERENCES


