A Proposal to Measure Success Factors for Location-Based Mobile Cardiac Telemedicine System (LMCTS)

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Abstract

Cardiac telemedicine systems facilitate treatment of patients by sending blood pressure and cardiac performance information to hospitals and medical emergency care units. Location-based services can be used in mobile cardiac telemedicine systems to improve efficiency, robustness and accuracy. This paper proposes a combination of mobile telemedicine systems and location-based services that will enable hospitals and emergency departments to do continuous monitoring of a patient's heart activity; such a system would decrease the probability of critical condition patients in emergency cases and increase the chance of saving lives. In order to evaluate whether this kind of health care system might work, we explore the success factors for such a system by adapting the DeLone & McLean IS success model to the context of location-based mobile system in cardiac healthcare. After reviewing previous works, we identify fourteen factors which can affect the success of a location-based mobile cardiac telemedicine system: Realization of user expectations, Portability, Accessibility, Extent of data processing, Time response, Urgency, Currency, Sufficiency, Understandability, Reliability, Extent of Mobility (spatial, temporal, contextual), System support, Responsiveness, and Assurance. We apply these factors to propose a success model for our location-based mobile cardiac telemedicine system.

Keywords: *Mobile communication, Location-based services, Cardiac Telemedicine System, IS Success, DeLone & McLean IS success model*

1. Introduction

Transferring biomedical signals (blood pressure, cardiac performance, insulin level etc.) over a long distance using wired or wireless communication technologies is called Telemedicine [1]. Adding location based services in mobile telemedicine not only helps patients find nearby doctors or, health centers but also enables medical consultants to see and continuously monitor information about the severity of the patient's health issues [2]. Cardiovascular monitoring systems can be made more efficient by using wireless and mobile phone technology, both of which are improving rapidly in order to reduce the mortality rate of patients suffering from coronary heart disease [3]. Location based services (LBS) are potential enhancement to mobile cardiac telemedicine systems, as a patient's location can be tracked in emergency, in addition to monitoring her health. The purpose of system evaluation is to calculate the potential for success of that system. In the telemedicine area, evaluation criteria are used as measurements, standards, or indicators by which to judge or predict the outcome of the health care system. Patient satisfaction, quality of care, quality of service, accessibility, and cost are examples of evaluation criteria. Although many telemedicine

evaluations concentrate on individual patient care, evaluation of the total population or a specific vulnerable group will be more precise [4]. Measurement of information system (IS) success is critical to understanding the accuracy and value of IS implementation [5]. In order to assess the success of telemedicine systems, the DeLone & McLean Information System (IS) success model can be employed to discover the various success factors. Section 2 of this paper reviews related work on the IS success model. Section 3 describes the theoretical background for measuring information success for different systems. Section 4 presents the effective factors of location-based mobile cardiac telemedicine system (LMCTS) success. Section 5, discusses theoretical scheme for LMCTS; a proposed method in Section 6 along with our conclusions.

2. Location-based Mobile Cardiac Telemedicine System (LMCTS)

Our proposed LMCTS system has five components: location of cardio patient, mobile doctor, telemedicine server, hospital and medical care and network infrastructure as shown in Figure 1. In the location of cardio patient component, a Bluetooth-enabled hemadynamometer sends the statistics of the patient's cardio system heart beat rate and blood pressure, to the mobile device. If the statistics show alarming information, the GPS-enabled mobile device obtains the current location of the patient and sends both cardiac data and location parameters to the designated consultant or physician as well as to the LMCTS server. The LMCTS stores the information in its database as a backup and then communicates with the hospital's management information system (MIS) which then keeps the record permanently. If the patient's designated doctor is busy or out of reach the MIS system searches for another physician that has the appropriate expertise according to the patient's profile. The hospital administration unit is in charge of the secondary physician assignment to the patient. Moreover, the patient's data is analyzed by his designated doctor who will take appropriate steps to insure that the patient gets good treatment. For emergency cases, the physician immediately notifies the appropriate hospital so that EMS can be activated and an ambulance sent to the patient's location.

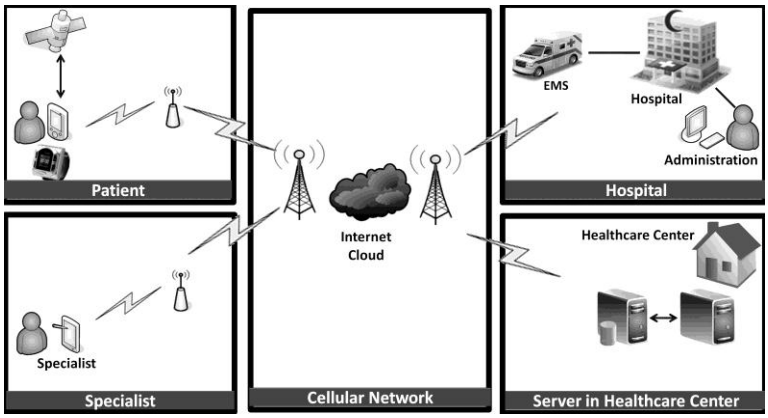

Figure 1. Proposed System Architecture (IS System Components)

3. Theoretical Background

In this section, we examine Information System (IS) success model and different studies in which success of their proposed model is measured using the DeLone and McLean (D& M) IS success model. IS success can be divided into six categories: system quality, information

quality, use, user satisfaction, individual impact, and organizational impact [6]. Information system can be divided into stages from production to consumption level, each of which can influence individual as well as organizational performance. In order to measure the success of an information system, the success of each level of the system must be determined [7]. Measurement of IS success is a critical issue in assigning the accuracy and value of IS integration W. H. DeLone and E. R. McLean, (2003) proposed a new model for measuring information system success based on previous empirical and theoretical IS studies. The D & M model shows how the six elements of success (system quality, information quality, use, user satisfaction, individual impact and organizational impact) are interrelated and not independent [5]. First, the IS is created along with different features to demonstrate the degree of information and system quality. Then, user satisfaction or dissatisfaction are evaluated. Using the system as well as its information will influence individual users and these individual impacts will affect organizational reactions [5]. Because of changes in the management and role of information systems, W. H. DeLone and E. R. McLean, (2003) updated their IS success model. In the new design, quality has three components: including information quality, service quality and system quality. These elements must be controlled separately as they each impact use and user satisfaction elements. DeLone & McLean view intention to use as an attitude whereas use is viewed as a behavior. The use and user satisfaction dimensions are interrelated. But greater user satisfaction will be correlated with a positive experience of use dimension; likewise, user satisfaction has the same impact on use and intention to use [5]. Finally, these kinds of use and user satisfaction elements increase the probability of a net profit.

After updating their success model, DeLone and McLean (2004) applied this updated model to the area of e-commerce. [8]. Municipal Wan Fang (W.F) Hospital located in Taipei, Taiwan, recently proposed a new Health Risk Reminders and Surveillance (HRRS) mobile system. The purpose of the HRRS system is to deliver abnormal patient test results from the Laboratory, Radiology and Pathology Departments [9]. In a study by W.-Y. Jen and C.-C. Chao (2008), an improved version of DeLone and McLean was used to evaluate the HRRS system. S. Chatterjee et al (2009) evaluated mobile work in the healthcare area using the DeLone and McLean IS success model [10].

4. Definition of Key Factors in LMCTS

After studying different IS success assessment models, we used all of the necessary indicators to achieve information success in this study. Our main IS success dimensions are illustrated in Table 1, followed by our hypothesis in the next section.

Table 1. Definition of Variables in the IS Success Model

Variables
System Quality
Communicability: multiplicity of communication channels
Portability: ease with which it can be carried by patients and healthcare workers
Data processing: data processing capability of the mobile device
Time response: reaction time of healthcare system
Information Quality
Urgency: the extent to which the task requires immediate reaction from stakeholders involved
Currency: how new or recent or up-to-date the information is
Accuracy: degree of correctness of data such as blood pressure, heart rate, and patient's location
Service Quality

Reliability: degree to which healthcare system can complete the task without a mistake ***System support:*** software and hardware support for the healthcare system ***Assurance:*** reputation and competence of healthcare system
Mobile Healthcare Anxiety
"a high anxious response towards interaction with the mobile patient safety information system" [9]
Trust
a set of beliefs that other people will fulfill their expected commitments under conditions of vulnerability and interdependence
Outcome Variables
Use of healthcare system User satisfaction IS success

5. Theoretical Scheme for LMCTS

5.1. System Quality

5.1.1. Communicability: There is a positive relationship between the number of communication channels in an information system and user satisfaction [11]. Wireless devices were shown to improve nurses' satisfaction in a Chicago hospital by providing multiple channels of communication [12]. Based on Y. O'Connor et al (2011), network availability and network stability affect system quality [13]. There is evidence that mobile devices are suitable for supporting synchronous and asynchronous communication, especially in a healthcare setting [10, 14]. K. Riemer and F. Frobler (2007) argue that, users prefer to use technologies which offer multiple channels of communication [15]. As a conclusion of above discussion, we propose the following hypothesis:

H1.1.1a. *The communicability of a mobile device will positively affect the use of a location-based mobile cardiac telemedicine system.*

H1.1.1b. *The communicability of a mobile device will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.1.2. Portability: The portability of a technology opens new horizons for the use and effectiveness of that technology [16]. For instance, the extent of mobility of a mobile device affects both its use and its effectiveness [14, 17, 18]. Portability is one of the main reasons for acceptance of PDAs, making them more convenient for users since they can be taken anywhere and used any time [19]. Above all, healthcare experts believed that the portability of a technology, such as PDAs, will increase the use of a healthcare system [20] [21]. Therefore, we propose:

H1.2.1a.*The portability of the mobile device will positively affect the use of location-based mobile cardiac telemedicine system.*

H1.2.1b.*The portability of the mobile device will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.1.3. Data Processing Capability: Data processing capability will affect the use of the system as well as satisfaction among users [10]. The data processing capability of a mobile device has been alleged to affect use of the technology [21, 22]. Additionally, higher data processing capability of a PDA has a positive impact on healthcare as it offers stronger decision making support for experts in this area [23]. Decision support capability of a mobile device will increase user satisfaction [10]. Therefore, we claim:

H1.3.1a. *The data processing capability of a mobile device will positively affect the use of location-based mobile cardiac telemedicine system.*

H1.3.1b.*The data processing capability of a mobile device will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.1.4. Response Time: Response time, which is typical networking statistic [18] will influence system quality [24, 25]. R. B. Miller (1968) argued that response time delays will change user behavior and decrease user satisfaction [26-28]. The faster response time, the better impression it will make on users and thus affect the user's behavior, as delay is considered a "psychological factor" in the user's mind [29]. In healthcare systems, especially for patients who need vital care, treatment must be given as early as possible [30]. Thus we argue:

H1.4.1a.*The response time of the system will negatively affect the use of location-based mobile cardiac telemedicine system.*

H1.4.1b.*The response time of the system will negatively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.2. Information Quality

5.2.1. Urgency: "Immediacy of feedback" the ability of the system to support rapid bidirectional communication is a vital parameter for any communication system. [14, 31, 32]. Urgency of the task is crucial especially in the healthcare field wherein workers need to deal with emergency contingencies and work under time pressure [10, 33]. Some researchers claim that mobile devices are highly suitable for performance of tasks which require immediate access to information [34, 35]. Furthermore, mobile device have the ability to support task performance anytime and anywhere [36]. Therefore:

H2.1.2a.*The level of urgency of the healthcare task will positively affect the use of location-based mobile cardiac telemedicine system.*

H2.1.2b.*The level of urgency of the healthcare task will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.2.2. Currency: As stated by J. Bailey and S. Pearson (1983) and W. R. King and B. J. Epstein (1983), currency of information influences the results of information system assessment [37, 38]. Y. Wang and Z. Liu (2007) utilized currency as one of their initial technical quality criteria and measurable indicators by which to evaluate the quality of health information on the Internet. They defined currency for healthcare information as "date of creation" and "date of last update" [39]. To manage an efficient location based service, a real-time GIS platform is needed to deal with the dynamic status of moving objects (i.e., the patient) [40]. Especially in case of emergency, ambulances must reach a patient's location rapidly [41]. Therefore, we propose:

H2.2.2a.*The currency of healthcare information will positively affect the use of location-based mobile cardiac telemedicine system.*

H2.2.2b*.The currency of healthcare information will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.2.3. Accuracy: Accuracy is a significant dimension of information quality [37, 42-44]. According to Y. U. Huh et al. (1990), accuracy, completeness, consistency, and currency are the four dimensions of an information system [45, 46]. Since accuracy is important in a positioning system, R.-H. Jan et al. (2004) proposed a cell-based positioning scheme to improve the accuracy of a positioning system [47] and I. E. Liao and K.-F. Kao (2008) designed a novel method of utilizing mobile user orientation information to improve prediction accuracy [48]. Time and accuracy are two important factors of healthcare, especially in cardiac arrest diagnosis [49, 50]. Consequently, we propose:

H2.3.2a.*The accuracy of healthcare will positively affect the use of location-based mobile cardiac telemedicine system.*

H2.3.2b.*The accuracy of healthcare will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.3. Service Quality

5.3.1. Reliability: User satisfaction has been shown to be positively affected by the reliability of the system and the availability of the particular service to the users [5]. Lack of reliability and efficiency negatively affect the quality of the services [51, 52]. Most traditional healthcare systems focused on service quality, and to assess it they often use the SERVQUAL model which consists of five dimensions: reliability, responsiveness, assurance, empathy and tangibles [53]. S. Akter et al (2010) found four main themes (system reliability, system availability, system efficiency and system privacy) in their qualitative results that can determine a customer's assessment of the quality of healthcare system [54]. One of the important aspects that need to be taken care is the reliable and critical performance and time sensitive nature of the medical information in the healthcare industry while in their deployment phase [55]. Thus, we argue:

H3.1.3a.*The reliability of healthcare service will positively affect the use of location-based mobile cardiac telemedicine system.*

H3.1.3b.*The reliability of healthcare service will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.3.2. System Support: Another component of user satisfaction and use of the system is system support. Poor user support may result in losing customers [5, 6]. Full commercial support of PDA software has been claimed as a key reason for widespread usage in the mobile technology environment [56]. PDAs have become highly functional and useful in healthcare. Y.-C. Lu et al (2005) argued that technical and organizational support of PDAs will improve their usability in enhancing clinical practice [21]. Thus we propose:

H3.2.3a.*System support for a healthcare service will positively affect the use of location-based mobile cardiac telemedicine system.*

H3.2.3b.*System support for a healthcare service will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.3.3. Assurance: Assurance has been defined as the "reputation and competence" of the SST provider [57]. In the past, the service quality assurance dimension has been defined as the "knowledge and courtesy of employees and their ability to inspire trust and confidence". In order to evaluate web based healthcare service quality, G. Büyüközkan and G. Çifçi (2012) utilized the six dimensions of tangibles, responsiveness, reliability, information quality, assurance, and empathy [58]. Hence we argue:

H3.3.3a.*The assurance of the healthcare service will positively affect the use of location-based mobile cardiac telemedicine system.*

H3.3.3b.*The assurance of the healthcare service will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

5.4. Mobile healthcare anxiety

Mobile healthcare anxiety is "the main reason for prevention of computer technology adoption is defined as trepidation, fear, concern and hesitation of damaging the device, being embarrassed." [59]. W.-Y. Jen and C.-C. Chao (2008) defined mobile healthcare anxiety as "a high anxious response towards interaction with the mobile patient safety information system" which has a negative effect on the quality of care that physicians provides for the patient [9]. J. Abelson et al (2009) defined anxiety as the antonym of trust [60]. Thus we argue:

H4.4b. *The level of mobile healthcare anxiety will negatively affect the location-based mobile cardiac telemedicine system user satisfaction.*

H4.4a. *The level of mobile healthcare anxiety will negatively affect the use of location-based mobile cardiac telemedicine system.*

H4.4c.*The level of mobile healthcare anxiety will negatively affect trust in location-based mobile cardiac telemedicine system.*

5.5. Trust

H. Alali and J. Salim (2011) used trust as one of the factors in their "Virtual Communities of Practice" success model, noting that trust influences user satisfaction as well as intention to use [61]. Trust measurement turns out to be an important indicator of support for a healthcare system [60, 62, 63]. Because of the importance of trust in the healthcare area, K. Lord et al (2010) evaluated "the effect of patient physician trust on how British South Asian (BSA) and British White (BW) patients cope when diagnosed with cancer" [64]. E. B. Wright et al (2004) identified trust as the most significant factor in doctor/patient communication [65]. Based on the above, we propose:

H5.5a. *Trust in the healthcare system will positively affect location-based mobile cardiac telemedicine system user satisfaction.*

H5.5b. Trust in the healthcare system will positively affect the use of location-based mobile cardiac telemedicine system.

5.6. Outcome variables

As stated by W. H. DeLone and E. R. McLean (1992) use of the information system can have a positive or negative effect on user satisfaction and vice versa [6]. In addition, A. Rai et al (2002) demonstrated the significant effect of user satisfaction on the use of an information system [66]. The relationship between user satisfaction and the use of an information system for mobile work in healthcare we also confirmed by S. Chatterjee et al. [10]. Therefore, we argue:

H6.6a. *The extent of user satisfaction with the location-based mobile cardiac telemedicine system will positively affect its use within the healthcare environment.*

H7.7b. *Use of the location-based mobile cardiac telemedicine system will positively affect user satisfaction within the healthcare environment.*

W. H. DeLone and E. R. McLean (2003) claimed that the use of an information system and user satisfaction with it will result in a net benefit which shows the success of the information system [5]. The positive effect of use and user satisfaction on net benefit has been proved by S. Chatterjee et al (2009) for mobile work in healthcare [10]. Thus, we propose:

H6.6b.*The extent of user satisfaction with the location-based mobile cardiac telemedicine system will positively affect the success of that system.*

H7.7b. *Use of the location-based mobile cardiac telemedicine system will positively affect the success of that system.*

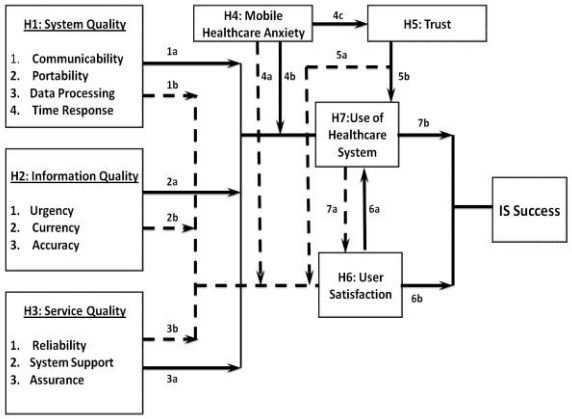

Figure 9. Success Model for Proposed Location-Based Mobile Cardiac Telemedicine System

6. Proposed method

After studying different evaluation methods in the literature review and designing the hypotheses, we have proposed a new success model using the D & M IS success model as depicted in Figure 9, which we believe can assist us in evaluating the success of our healthcare system.

7. Conclusion

This paper proposed a method for assessing the success of a Location Based Mobile Cardiac Telemedicine System (LMCTS) based on the DeLone and McLean IS success model. This method will measure the success factor for this type of mobile healthcare system (LMCTS). Future research should include empirical research on the merits of this assessment method. Proposing questionnaire is the first step that needs to be done, followed by quantitative analysis. The ultimate goal is to identify the factors influencing LMCTS acceptance among cardiac disease patients, which will have important policy and strategy implications for healthcare providers wishing to improve their treatment through the use of such a system.

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