A Conceptual Framework for Designing mHealth Solutions for Developing Countries

Stephen Mburu  
University of Nairobi  
School of Computing & Informatics  
P.O. Box, 30197, Nairobi  
smburu@uonbi.ac.ke

Elke Franz  
Technische Universität Dresden  
Faculty of Computer Science  
01062 Dresden, Germany  
elke.franz@tu-dresden.de

Thomas Springer  
Technische Universität Dresden  
Faculty of Computer Science  
01062 Dresden, Germany  
thomas.springer@tu-dresden.de

ABSTRACT

Though mHealth is still at its formative stages, it is undeniably the next big thing in addressing healthcare challenges being experienced in developing countries. However, the complexity of implementing mHealth to address numerous health challenges is evident in many failed attempts to integrate it within healthcare system. We argue that this is due to complexity of migrating to virtual environment most healthcare processes; such as diagnosis and treatment that require more of physical interactions between patients and caregivers. To provide a concrete model to scale-up deployment of mHealth, this paper presents a conceptual framework combining constructs from Process Virtualization Theory, Theory of Planned Behaviour and Task-Technology Fit. The framework is a flexible schema for deriving concrete models that would be used as a blueprint for effective deployment and evaluation of mHealth applications suitability to the intended use. To demonstrate the adaptability of the framework, we discuss its use regarding an mHealth application for maternal and child care in underserved rural and urban areas in Kenya.

Categories and Subject Descriptors
J.3 [Computer Applications]: Life and medical Sciences—Health, Medical Information systems

General Terms

Keywords
Deployment, mHealth, Process Virtualization, Fit, Healthcare, Outcomes, Innovation, Prototypes, Mamacare

1. INTRODUCTION

The United Nations report on progress towards meeting millennium development goals (MDGs) by 2015, particularly those related to health indicates that the progress in most developing countries is below average [11]. Therefore, revitalizing efforts towards dealing with problems especially relating to child mortality, maternal deaths and spread of HIV/AIDS and other diseases is a matter of priority.

Currently, mobile cellular subscription is approaching global figures with a rate of 96% globally; an average of 128% in developed and 89% in developing countries respectively [6]. This progress provides a unique opportunity to accelerate the momentum towards achieving MDGs targets relating to health. This is the motivation behind innovative deployment of healthcare on mobile devices hence the term mHealth.

In developing countries, majority of the people lives below poverty line which leads to poor quality of life and low life expectancy. To raise the living standard of these people, rigorous techniques and innovations are being developed in order to eradicate poverty and improve access to basic healthcare needs. This is the driving force behind several mHealth implementation efforts most of which are in Africa and Southern Asia. Table 1 is a summary of some mHealth solutions deployed in Africa purposely to address MDGs 4, 5 and 6 [13].

Nevertheless, with 2/3 mHealth solutions being pilot projects [13] there is insufficient evidence on how most of these initiatives have influenced the quality of health outcome. This makes it difficult to identify mHealth benefits that would justify its usefulness in enhancing access to healthcare. Therefore, managing mHealth de-
ployment process is fundamental to its acceptance and utilization. However, there are numerous challenges that have been attributed to slow uptake of mHealth [7], [12], [13]. These include but not limited to: poor infrastructure, cultural and ethical barriers, legal and policy issues, limited technical capacity, lack of awareness and uncertainty on mHealth cost-effectiveness. Yu et al. [14] classified these challenges according to the following seven categories: people, process, technology, mobile devices, computing standard, security and privacy, and electromagnetic conformity.

Overcoming these challenges and barriers is a puzzle that requires to be solved by use of a sound mHealth implementation framework. Davis and Venkatesh [3] argue that the usefulness of a system can be predicted prior to its actual implementation through pre-prototyping with the target users. Omachonu and Einspruch [8] introduced a framework to guide innovators of mHealth solutions. Healthcare solutions can only be useful if they are of high quality, cost effective, safe, efficient, and of positive impact to health outcomes. They argue that an in-depth analysis of the needs and requirements of healthcare stakeholders (patients, healthcare practitioners, and providers) is essential to develop such useful mHealth solutions that can belong to the different categories ranging from treatment to outreach.

We too argue that addressing usefulness (Fit) of a particular mHealth application during deployment requires a concrete model that would be used as a reference for technical and social requirements. The contributions of the paper are twofold: Firstly, we motivate and present a conceptual framework to assess the potential usefulness of mHealth applications. Combining aspects from Theory of Planned Behaviour, Process Virtualization Theory, and Task-Technology Fit, the conceptual framework supports a more comprehensive assessment of usefulness than existing approaches which either focus more on technical issues or lack scientific or theoretical foundation. Secondly, we demonstrate the adoption of the conceptual framework to design mHealth application considering the specific conditions in underserved rural and urban areas in Kenya.

The remainder of this paper is organized as follows: Section 2 gives an overview on the theoretical perspective relating to this study. In Section 3, we describe our conceptual framework and explain its constructs. Section 4 demonstrates the adoption of the framework. Finally, the paper concludes with Section 5.

2. THEORETICAL PERSPECTIVE

Technology adoption is one of the dominant research areas in the field of information systems. However, given that adoption is a post-implementation behaviour, poor system implementation strategies consequently lead to poor adoption [3]. According to Davis and Venkatesh, failure to consider critical factors prior to implementation of a system leads to failure of the system [3].

Current experiences on mHealth adoption should be a learning point for subsequent mHealth projects to put into place effective deployment approaches. One possible way of addressing fundamental mHealth deployment challenges is a multidimensional approach that integrates principles of socio-cognitive theories into design science. This is because justified theory and utility of an artefact are two sides of the same coin that should be evaluated in light of practical implications [5].

Therefore, we argue that most of the challenges that hinder effective deployment of mHealth can best be addressed using a socio-technical approach. We analyzed socio-cognitive theories that are relevant to predicting successful implementation and adoption of mHealth applications. Furthermore, Davis and Venkatesh argue that through pre-prototyping, the usefulness of a solution can be predicted even before its implementation [3]. Therefore, in order to accelerate acceptance and utilization of mHealth innovations, there is need for a well grounded model that would be used for evaluating their Fit prior to deployment.

Our contribution in this paper is to provide a framework that forms the basis for deriving such a model. The framework is a flexible schema containing multiple behavioural and process requirements that can be adapted to specific deployment models.

3. CONCEPTUAL FRAMEWORK

3.1 Background and Structure

The framework presented in this paper is a triangulated product of constructs adapted from three theoretical models namely Theory of Planned Behaviour (TPB) [1], Process Virtualization Theory (PVT) [9], and Task-Technology Fit (TTF) [4]. The purpose of the proposed framework is to model the potential usefulness of an mHealth application.

The technical constructs are mainly adopted from Process Virtualization Theory (PVT) introduced in [9]. Overby suggested a model that considers process requirements that may have a negative effect on the virtualizability of a physical process. These process requirements are both important and inherently fulfilled by the physical process. Virtualization of the physical process, however, does not inherently fulfill such requirements which imply problems of usefulness of the virtualization. However, Overby posited that using moderating IT constructs of representation, reach and monitoring can help to meet these requirements.

Task-technology Fit (TTF) [4] highlights the importance of fit between technology and users task in enhancing individual performance. Goodhue posits that three factors – individual abilities, technology charac-
teristics, and task requirements – influence performance, hence the significance of fit among three factors. In fact, TTF has been extensively explored by researchers by extending these tripartite antecedents of fit in various contexts, including healthcare. This is the conceptual approach that informed our framework that goes further to examine task as a set of processes in healthcare.

To empirically test the viability of the model, Overby and Konsynski developed an integrated model that combined PVT and TTF. Testing the viability requires to consider a specific domain; hence, Overby and Konsynski discussed the viability for an online process of purchasing used vehicles [10].

In this regard, we amended Overby’s basic model by adapting behavioural constructs from Theory of Planned Behaviour [1]. The framework presented in this paper is not only an integration of these theories but also a product of rigorous logical validation by healthcare professionals, scholars and professors.

The need to align people, processes, and technology to develop useful mHealth solutions is the guiding principle in system implementation that forms the three pillars of our framework shown in Figure 1. Individual requirement constructs are adapted from TPB [2] while process requirements are adapted from PVT [9]. The intervening variable Fit is adapted from TTF [4].

According to Goodhue and Thompson, fit refers to the capability of technology to meet demands of a task measured in terms of task characteristics and technology characteristics.

According to PVT [9], moderating IT constructs are posited to positively moderate the potentially negative influence of individual and process requirements to achieve fit. Process requirements in our case refer to characteristics of a physical healthcare process that have to be fulfilled by virtualization, i.e., by an mHealth application. Individual requirements describe factors that influence the acceptance of the mHealth application. We do not discuss individual attitudes regarding the physical process since we assume that the necessity of the physical process is given.

3.2 Description of the Constructs

The framework consists of seven main constructs X1 to X7 hypothesized to potentially negatively influence Fit and three moderating constructs Y1 to Y3 that moderate the potentially negative influence of X1 to X7. Below we describe the purpose of each construct.

3.2.1 Individual requirements

**X1 - Behavioural control:** Behavioural control refers to an individual’s perception on ability to perform a task of interest (Can I do?). Usability and user-friendliness are very important for a positive perception on this ability. Therefore, an artefact should be usable and user-friendly to meet this requirement.

**X2 - Subjective norms:** Subjective norms refer to perceived social pressure to perform or not to perform a task (Must I do?). Though there is social pressure to adopt innovative IT solutions, most healthcare professionals hesitate to adopt such technologies due to fear of violating code of ethics. Another perspective on “Must I do?” concerns benefits of a virtual process in comparison to a physical process, or, in other words, the necessity to use the virtual process such as mHealth. However, regarding the healthcare structure in most developing countries, mHealth can help to overcome problems of physical processes, e.g., improve access to healthcare at reduced cost and travel time.

**X3 - Attitude:** Attitude refers to the degree to which a person has a positive or negative judgment of certain behaviour (Willing to do?). Two factors that may determine an individual’s attitude are motivation and trust. If using the (virtualized) mHealth process promises to be, e.g., faster, simpler, and more cost effective, individuals are motivated to use it. A basic prerequisite for motivating people to use the process is the fulfillment of the process requirements discussed below. Another important factor is trust. Trustworthiness of an application includes security, privacy, and safety; the application has to work as expected even in case of unwanted events such as failures or attacks. Individuals will only use an mHealth application if it is trustworthy.

3.2.2 Process requirements

**X4 - Sensory requirements:** This refers to senses of touch, smell, sight, taste and hearing. These senses are important in healthcare processes particularly those involving diagnosis and treatment. Overby argues that if a process requires use of senses such as smell, taste or touch, then it would benefit more from physical context which make them difficult to virtualize [9].

**X5 - Relationship:** Relationship is the need for participants of healthcare scenario such as a doctor and a patient to interact with one another. While in a face-
to-face interaction cues such as gestures, posture, and inflection are part of communication, in virtual interaction such cues may be lacking. Though some degree of interaction can be achieved through use of multimedia technologies such as videoconferencing, available devices and infrastructure may be a limiting factor.

**X6 - Identification and privacy:** In a physical process the participants involved can easily identify each other but in a virtual environment, it is difficult to certainly confirm the identity of the remote entity. Another aspect is privacy or data protection. In the physical world, we know which information we disclose to whom and in which situation. If we do not meet physically, it becomes harder to control who should know what about us. Both identification and privacy are important factors regarding trust in a virtual process.

**X7 - Synchronism:** Physical processes tend to be highly synchronous because two parties communicate with each other with minimal or no delay. However, in a virtual environment some tasks that require real-time processing such as telesurgery and sensor-based patient monitoring may not be easy to achieve.

### 3.2.3 Moderating IT constructs

**Y1 - Representation:** Representation refers to the capability to use IT to simulate sensory experience and enable interaction between remote participants. The former can be achieved by use of sensors, while the latter by means of multimedia technology such as audio or video. Further, the representation of information as well as functionality strongly influences usability and user experience. Consequently, Y1 is posited to moderate X1, X4, and X5.

**Y2 - Reach:** Using mHealth as a virtualized process clearly provides benefits regarding challenges of accessing healthcare. A useful mHealth solution can potentially reduce the need for physical interaction between doctors and patients. In addition, IT can support reach by ensuring availability of information independent of time. Hence, Y2 moderates X5 and X7. The challenge is how to ensure reach using the available devices and infrastructure.

**Y3 - Security and Privacy Mechanisms:** Security and privacy features have to be integrated into an mHealth solution to ensure that the corresponding process requirements are met. Fulfilling these requirements is essential for the trustworthiness of the application. Another example is the enforcement of integrity of information; doctors will not use an mHealth application if they cannot be sure to get the right information regarding a patient. Thus, IT construct Y3 is posited to moderate X3 and X6.

### 3.2.4 Intervening and dependent constructs

**Fit:** Fit refers to the suitability of an artefact to its intended use. In our framework, it is an intervening variable intended to measure the usefulness of a particular mHealth solution in meeting user needs. We hypothesize that Fit is influenced by potentially negative individual and process requirements. However, these requirements if well addressed using an IT solution; it is possible to significantly improve Fit.

**Quality of healthcare support:** Quality of healthcare care support is a measure of overall quality of support provided by an mHealth solution. Referring to the healthcare innovations framework described in [8], parameters used to evaluate healthcare IT innovations include quality, costs, safety, efficiency and outcomes. However, because quality is more general, we additionally use healthcare quality indicators as proposed by Arah [2] namely effectiveness, safety, and responsiveness.

#### 3.2.5 Practical application of the framework

The framework is a generic schema of multiple requirements that have been hypothesized to influence Fit. Obviously, there are different requirements for different categories of care. This makes the framework flexible to be adapted to a model for deploying mHealth applications for specific healthcare services.

### 4. ADOPTION OF THE FRAMEWORK

#### 4.1 Description of the mHealth Application

In developing countries, haemorrhage and hypertension complications during pregnancy and childbirth are the leading cause of death among women of reproductive age [11]. These complications arise due to lack of vital information required at particular stage of pregnancy. To facilitate regular checkups for early detection of these and other potential complications, patients are expected to make frequent visits to healthcare facilities which in most cases are as far as 30 km away. This is at one hand quite difficult and expensive for woman during the advanced stage of pregnancy and first year after birth. On the other hand, it creates high workload for doctors and increases cost of the healthcare system.

This is the motivation behind deployment of mamacare, an mHealth application aiming to leverage on available low cost technologies to provide better access to maternal and child care at lower cost, particularly in rural parts of Kenya. It is planned as an integrated web and mobile-based diagnosis and treatment application that would provide access to services and information on family planning, prenatal, and early childcare.

During pregnancy and the first three months after birth, mamacare will help in remote monitoring of physiological parameters such as blood pressure, body temperature, proteinuria, fudal height, and body weight in order to adjust the number of visits to healthcare facil-
ities according to the mother and child health state. In cases of low risk, visits can be reduced while high-risk pregnancies can be detected early enough for appropriate plan of action. Other mamacare functionalities include scheduling appointment, medication reminders, and basic prescription.

Though we acknowledge that these services can best be provided by integrating high-end technologies such as smart-phones and biometric sensors, to be realistic, we consider using basic phones and biometric devices to provide information necessary for early detection and management of pregnancy and early childhood problems. In the next section, we analyze the individual and process requirements of mamacare based on our conceptual framework described earlier.

4.2 Concept Mapping to Mamacare

X1 - Behavioural control: Behavioural control requirements can be achieved by making mamacare more user-friendly, making users more interested and motivated to use it. Considering the diversity of users of mamacare in terms of age, geography, and education level, user interfaces should help the user to complete tasks with ease. This can be achieved by providing features that minimize necessary input through a simple user interface with self-explaining navigation, responsiveness and instant feedback about errors and correct data input procedure.

X2 - Subjective norms: In Kenya, mamacare deployment effort is motivated by social pressure to integrate mHealth into healthcare system. This has been necessitated by unprecedented success story of mobile payment systems such as M-Pesa. But for mHealth, there are concerns on medical and social norms regarding consequences of clinical decision making based on remote care processes. To investigate normative values and principles that would determine suitability of mamacare, we used collaborative and agile through joint brainstorming sessions with healthcare experts. The main subject was how mHealth can be used as a tool to aid for effective decision making in remote diagnosis and treatment. Based on findings from these meetings, mamacare is designed to be a support tool to be used for shared decision-making between caregivers and patients within established medical ethics and social norms.

X3 - Attitude: Positive attitude could be influenced by high user benefit. For a patient to feel satisfied that her needs are met, an intervention should aim at reducing effort and cost for traveling, by providing instant feedback and support from the doctor. On the other hand, the doctors would be more motivated to use the system if it offers reduced workload, good system integration, simplified processes, and assistance from technical system. Consequently, patients attitude towards using mamacare would be low if she is dissatisfied with unfulfilled expectations, and unresolved medical issues. On the other hand, lack of evidence-based practice of mHealth would make it difficult to convince caregivers of the benefits of mamacare. In fact, participants in our preliminary investigation raised concerns on mamacare compatibility to existing systems, relevance to their tasks, and its impact on medical norms and practice. However, despite these reservations, majority felt that mamacare can be used as a first aid tool for patients screening and preventive care.

X4 - Sensory requirements: During physical routine check-up, vital physiological parameters such as temperature, blood pressure, blood sugar, fundal height, baseline weight, urine sample, and other tests are taken. In a virtual environment, to avoid cases of medical errors, biometric devices need to be calibrated to ensure accuracy reading. In addition, the user must learn how to correctly measure and read the values. In high resource settings, these parameters may be captured and transmitted using wireless sensors with minimal user intervention. However, in low resource setting like in our scenario, the issue of cost limits us to consider options that are cost-effective. This explains why we are considering using low cost locally available devices like thermometer, and scales or blood pressure meter.

X5 - Relationship: Sufficient interaction between patients and caregivers in mamacare is crucial because it often leads to better understanding of each other and mutual trust. For mamacare to be useful, it should ensure patients are “seen and heard” remotely to a good degree of satisfaction. Though videoconferencing would be ideal, but limited bandwidth and data cost may make such implementation not feasible. Therefore, in mamacare face-to-face meetings are combined with remote interactions between patients and caregivers with the final goal to reduce but not to completely remove face-to-face meetings.

Remote interactions set up on a simple communication protocol to ensure low cost. This is because the majority of our target users own only simple and feature phones of which most of them hardly support run Java applications. Therefore, the least common denominator may be limited to text messaging and voice. However, this does not limit mamacare to messaging only; the application will have provision for extended services such as multimedia chatting that can be accessed if the necessary resources are available, i.e., the services will be provided depending on the technical context.

X6 - Identification and privacy: Identification of the communication partners in mamacare is crucial both for patients and caregivers: Patients should feel secure to whom they deliver their measured physiological parameters. Likewise, they will only accept the health advices if they can be sure about the identity of advising healthcare personnel in mamacare. For caregivers,
being sure about the patients identity is crucial to give the correct advices. Other than common SIM-based authentication using personal identification number, mamacare will provide light weight and user-friendly authentication and authorization, as well as encryption mechanisms that fits into healthcare standards. The physiological parameters and health advices necessary in mamacare are sensitive data that have to be protected to ensure patients’ privacy.

**X7 - Synchronism:** Though ordinarily synchronism refers processes occurring simultaneously, in this context we refer to synchronism requirements as interaction between two distant entities with minimal delay. In situations where immediate feedback is required, mamacare is designed to incorporate alerts to a caregiver in order to provide necessary support such as first aid in case of emergency. Synchronism requirements are lower for regularly checkups of the physiological parameters. Of course, the patients may want to get feedback in time, but unlike in a physical setting, virtual process participants are abstracted away from one another which may introduce delays in getting such immediate feedback.

As sketched above, the framework can be used as a pre-deployment analysis tool that supports a comprehensive consideration of individual and process factors providing a better understanding of the specific conditions and problems of the analyzed scenario, and thus, guiding the successful deployment and utility of such an mHealth solution.

5. CONCLUSIONS

The framework presented in this paper is in our view an important analysis tool that describes socio-technical approach to successful implementation of mHealth in developing countries. We innovatively integrated and modified selected constructs from relevant models discussed in the paper in order to investigate factors that affect suitability (fit) of most mHealth solutions in low resource settings.

We therefore proposed a conceptual framework to be used as a predictive tool for assessment of fit of an mHealth solution prior to its deployment. We belief this will help during use case analysis scenarios to provide better understanding of a problem, hence avoid possible post-implementation failure currently being experienced. However, because more detailed investigation is required to further establish the utility of the framework, our next step is to deploy mamacare prototype in a controlled field experiment.

6. ACKNOWLEDGMENTS

We like to thank Alexander Schill, Okelo-Odongo, Robert Oboko and Klemens Muthmann for supporting this work. We also wish to acknowledge Erasmus Mundus (EU Project), University of Nairobi, and participating healthcare professionals in Kenya.

7. REFERENCES


