A Taxonomy for Mobile Health Implementation and Evaluation

Full Paper

Alan Yang
Georgia State University
ayang5@gsu.edu

Upkar Varshney
Georgia State University
uvarshney@gsu.edu

Abstract
We develop a taxonomy of research papers on the topic of mobile health project implementation and evaluation. The paper begins with a literature review on the topics of taxonomy, mobile health, and project evaluation. Following this review is an analysis of the research opportunities in the information systems field and an argument for the application of a categorization system guided by empirical evidence, specifically a taxonomy. We then create a taxonomy of the mobile health project literature guided by design science principles and existing guidelines on taxonomic development. From this development, we present multiple observations on the state of the literature in the field and present two theoretical links for future research.

Introduction
The field of mobile health (mHealth) has grown significantly in the last ten years to become a multi-billion dollar industry. Recent market reports have appraised the global mHealth market at over 10 billion dollars (Ben-Zeev et al. 2013). Despite the growth of industry, effective evaluation of mHealth projects has remained an area of limited focus in the research literature.

Existing studies focusing on the topic of evaluation in mHealth either cover the topic on a case-specific basis or address the issue within a very specific medical context (Whittaker 2012). Evaluation as a concept is not foreign in the HIT fields (Brown et al. 2013; Ybarra et al. 2014) but there are no studies which include both empirical findings from literature and incorporate theoretical frameworks in order to create guidelines for effective mHealth project evaluation.

What we intend to accomplish with this research is to apply a process for categorizing information in this field of literature. To achieve this task, we rely upon the established guidelines of taxonomy development and present our contribution as a design science artifact. Creation and analysis of the taxonomy formulate the key points of discussion for this research project. Possible theoretical links and future directions in this field of mHealth are also addressed.

The primary research question is as follows: “What are the most widely used techniques for evaluation of mHealth projects?” The main research contributions of this study are the organization of mHealth project evaluation techniques into a taxonomy and the subsequent analyses of the resultant dimensions and characteristics.

Literature Review
The review covers three areas of research: mHealth, taxonomy in information systems, and project evaluation in health policy. From a survey of these three fields, certain research opportunities were identified and are the basis for the problem definition and structure of the research project.

Taxonomy
Taxonomy development originated from the field of biology as a means to classify organisms based on a predefined structure of characteristics. There exist two forms of analysis related to taxonomy building, phenetics and cladistics. Phenetics is practiced by clustering together organisms which are deemed to be
similar though similarities in their characteristics determined through statistical analysis. Cladistics looks at the evolution of organisms and creates groups based on a shared heritage (Sneath 1995).

Taxonomies have also been utilized and studied in the social sciences. A major guideline for the application of taxonomies is that they must be distinguished from typologies (Bailey 1994). The key difference between the two tools is that taxonomies are created based on analysis of empirical data while typologies are formed through a conceptual foundation. The two classification strategies run the risk of being confused whenever theory application is involved in research (Follette and Houts 1996).

The field of health information systems contains a number of research studies utilizing taxonomy as the guiding structure for analysis of information. However, most of the developments of these taxonomies are constructed using either ad-hoc or intuitive reasoning and lack some form of conceptual, theoretical, or empirical foundation (Nickerson et al. 2013). Although in recent years, some studies in the field have taken an empirical, evidence-based approach to taxonomy construction in topics such as mobile security (Abdullah et al. 2015). In the fields of mHealth and HIT, application of taxonomy have been used as a means of organizing literature or grouping together medical interventions into like categories (Waterlander et al. 2014). However much of the usage of taxonomy in the mHealth and HIT literature is ad-hoc and follows no set pattern of analysis grounded in taxonomic history (Nickerson et al. 2013).

Mobile Health

mHealth is defined as any system enabled through a wireless infrastructure that provides healthcare to individuals in a manner that decreases spatial and temporal constraints (Varshney 2014; Varshney 2007). Other names for this phenomenon include E-health, wireless-health, and pervasive healthcare (Eysenbach and Group 2011).

Ideal mHealth environments fulfill certain characteristics. The well-being of the users within the system, particularly the patients, is generally agreed upon to be the top priority (Barton et al. 2012; Demiris et al. 2008). The next major issue is that of data security and privacy protection (Kotz et al. 2009; Doukas et al. 2010). The third qualification of an ideal mHealth environment is that the various components of the system, particularly the hardware devices operated by the users, are functional, reliable, and usable (Asangansi et al. 2010). Finally, the wireless infrastructure that the system is built upon needs to fulfill the same requirements of reliability and functionality to provide a consistent quality of service to users (Varshney 2014).

Definitions for the ideal mHealth environment begin to diverge outside of the four characteristics mentioned above. Some studies have argued for closer examination of the development cycle of mHealth systems, and that different attributes of the design team, such as transparency, can provide strong hints towards eventual outcomes (Mandl et al. 2009). Other studies have looked at the application-level and argue that characteristics of software such as context-awareness and data visualization are the means to interpret the success of a mHealth system (Chang et al. 2011). Other researchers have taken an outcome-based stance and argue that modification of patient behaviors are the best representation of system quality (Blaya et al. 2010). Finally, a notable study utilizes the method of ontology to categorize the phenomenon of mHealth (Cameron et al. 2015).

Project Evaluation

Project evaluation as a field of study in the behavioral sciences has existed for over fifty years. This portion of the literature survey will focus on evaluation methods from the past twenty years in the healthcare and information systems fields.

The goal of evaluation is to provide a means of establishing and reporting goals and objectives to a variety of stakeholders (Frechtling 2002). Key benefits of evaluation are as follows:

- Reduction of needless waste through establishment of consistent standards
- Generation of insights into the motivations of individuals and groups involved in a project
- Determining whether or not the implementation and outcomes of a project are consistent with the vision of the designers
Recent writings on evaluation have focused on the connection between the evaluation and implementation processes. A commonly cited project development and evaluation cycle is shown in Figure 1, illustrating the connection between the different cycles of a project’s life. Fields such as developmental evaluation have come from the idea that the cycles of implementation, planning, and evaluation are inherently linked (Patton 1994).

![Figure 1. The Project Development/Evaluation Cycle (Adapted from Frechtling 2002)](image)

Another crucial role evaluation plays is communicating information to a variety of stakeholders. Projects typically need to provide some form of data on their impact in order to measure success. Information on whether or not the project is successful then feeds back to the planning loop in order to provide more information for future projects. The information being passed through the cycle needs to be standardized and made understandable to the relevant stakeholders involved in order for it to be meaningfully applied.

In the HIT context, evaluation has been identified as a major obstacle because of three problem areas: complexity of the evaluation object, complexity of evaluation projects, and lack of motivation for proper evaluation (Ammenwerth et al. 2003). Research in the field of mHealth has identified the need for stronger evaluation methods of assessments and interventions (Kumar et al. 2013).

**Research Opportunities**

Within the three fields outlined in this literature review, certain patterns can be identified:

- mHealth is a relevant and rapidly changing field but lacks a coherent standard for project evaluation (Tachakra et al. 2003; Kumar et al; Istepanian et al. 2003).
- Few formal evaluation methods exist and are in practice for mHealth programs (Kallander et al. 2013).
- Taxonomy development grounded in empirical and theoretical data has been underutilized as a method for solving complex problems in the IS field (Nickerson et al. 2013; Varshney 2014)
- Evaluation of the field of mHealth has been difficult due to a number of factors involving the complexity of projects and systems (Kumar et al; Ammenwerth et al. 2003)
- Developmental evaluation in the HIT literature has not placed enough emphasis on stakeholder perspectives (Istepanian et al. 2004)

These patterns indicate two phenomena. First, that there is a need for more structured application of taxonomy development in the IS field. Second, there is a need for a more formalized method for evaluating mHealth projects.

**Methods**

Design science is the chosen means by which this proposal will seek to address these questions uncovered from the field. The focus of design science on the creation and evaluation of an artifact is well suited for the design and testing of a taxonomy and method. According to March and Smith 1995, artifacts can be classified into one of four groups: construct, model, method, and instantiation. While the proposed evaluation method naturally falls under the category of method, the creation of a taxonomy can be described as formation of a model (Nickerson et al. 2013).
Beyond simply providing the definitions for a solution, design science research can help to identify and address difficult problems directly. The main issues with evaluation of mHealth projects meets the description of a wicked problem as defined by Weber 1973. Specifically, this research proposal attempts to address the problem of effective evaluation which involves both human and technological factors within a complex environment with no one solution that is easily applicable at any point in time (Ammenwerth et al.).

The research would follow the three stages proposed in Hevner 2007 of relevance, design, and rigor. Relevance would come from the literature review and the application of theory. The design artifact would be the proposed taxonomy and method for mHealth system evaluation. The rigor would stem from the theoretical links and methods that the study would reference and draw upon in order to create the artifact.

**Taxonomy Design**

The creation of the taxonomy followed the three-level, seven-step indicator model described in Bailey 1984 and adapted in Nickerson et al. 2013 (Figure 2). The justification for use of this model is that it adheres the taxonomy development literature closely and is a practical means of classifying information. The final taxonomy was created through three iterations of the development cycle. The explanation of the process for taxonomy creation will be presented as a series of steps adhering to the development method.

![Figure 2. Taxonomy Development Method (Adapted from Nickerson et al. 2009)](image-url)
Iteration 1, Step 1

The meta-characteristic of the taxonomy was determined to be: “project implementation and evaluation” within the field of mobile health. Establishing this aspect of the taxonomy prior to the analysis of the data serves a two-fold purpose. One, it prevents an ad-hoc search through a broad field of literature with the hope of stumbling upon a pattern. Two, it helps to guide the creation of the taxonomy past its genesis by creating a standard to which dimensions can be evaluated.

Iteration 1, Step 2

Ending conditions for the taxonomy as a whole were established before the papers from the sample were analyzed. The criteria for ending conditions were evaluated based on the guidelines proposed in Nickerson 2013 of both subjective and objective ending conditions. The conditions are listed in Table 1 and were used as a standard to determine whether or not further iterations were created.

<table>
<thead>
<tr>
<th>Objective criteria</th>
<th>Subjective criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) All objects of a representative sample of objects have been examined</td>
<td>1) Taxonomy is concise</td>
</tr>
<tr>
<td>2) No object was merged or split in the last iteration</td>
<td>2) Taxonomy is robust</td>
</tr>
<tr>
<td>3) At least one object is classified under every characteristic of every dimension</td>
<td>3) Taxonomy is comprehensive</td>
</tr>
<tr>
<td>4) No new dimensions or characteristics were added in the last iteration</td>
<td>4) Taxonomy is extendible</td>
</tr>
<tr>
<td>5) No dimensions or characteristics were merged or split in the last iteration</td>
<td>5) Taxonomy is explanatory</td>
</tr>
<tr>
<td>6) Every dimension is unique</td>
<td></td>
</tr>
<tr>
<td>7) Each cell is unique</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Taxonomy Ending Conditions (Adapted from Nickerson et al. 2013)

Iteration 1, Step 3, 4e, 5e, and 6e

Step three involves a decision point indicating what type of approach is to be taking in creating new dimensions and characteristics for the taxonomy. We chose to follow the empirical-to-conceptual track for this first iteration in order to obtain a representative sample and begin to analyze units to obtain initial dimensions.

At stage 4e, empirical data was obtained through a review of the literature. We conducted a search for the terms “Mobile health”, “Implementation”, and “Evaluation” on the academic databases Web of Science and IEEE explore from the year 2000 until November 2015. The search terms were decided based on the meta-characteristic determined in step 1. Combined, various permutations of the search terms yielded over one-thousand results. Papers were then further narrowed through identification of shared characteristics. Specifically, any papers that did not specifically deal with some form of mobile health implementation in a project setting were not considered for the taxonomy. Filtering at this level resulted in a vast decrease in the number of papers for consideration. 64 papers were identified as relevant and were the basis for our sample.

<table>
<thead>
<tr>
<th>Focus</th>
<th>Biometric Monitoring</th>
<th>Implementation Obstacles</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physician</td>
<td>Patient</td>
<td>Invasive</td>
<td>Non-Invasive</td>
</tr>
</tbody>
</table>

Table 2. First Iteration of Taxonomy

At stage 5e, the papers were analyzed and themes and patterns of the various mobile health projects within the papers began to emerge. The emergence of these common characteristics lead to stage 6e, where the first dimensions and characteristics of the initial taxonomy (Table 2) were formed. Four dimensions were identified with two attributes each: Focus of study (Physician or patient), type of biometric monitoring
(invasive or non-invasive), implementation obstacles (hardware or people), and duration of study (0 – 6 weeks to 6-18 weeks). An initial grouping of 10 papers were categorized by these dimensions.

**Iteration 1, Step 7**

A review of the initial taxonomy quickly revealed that it did not meet multiple ending conditions. Multiple dimensions had unpopulated characteristics and the dimensions themselves were too broad to reasonably provide any value in subsequent analysis. The cycle then progressed back to stage 3 and lead to the start of iteration 2.

**Iteration 2, Step 3, 4c, 5c, and 6c**

We decided on the conceptual-to-empirical approach for the second iteration. We believed our existing sample was representative but that our dimensions needed modification in order to properly portray the state of current mHealth projects. Step 4c involved multiple changes to the existing dimensions and addition of two new dimensions (Table 3). “Focus” was seen as too broad and changed to “Determinant of success”, with the characteristics modified with the word “outcomes” rather than simply “provider” or “patient”. “Implementation Obstacles” was modified and the characteristics made more specific. The dimension of “Biometric monitoring” was determined to be an inadequate dimension and subsequently deleted from the taxonomy. mHealth applications with a body-invasive hardware component were not represented at all in our sample. “Study type” was a newly added dimension as the initial analysis of the papers revealed that projects fell into one of two categories, “simulation” or “field study”. Simulations focused on the more theoretical application of mHealth while field studies recorded the influence of implementation of a mHealth technology in the world. Finally, a new dimension was added titled “Implementation type” with characteristics of “Developing” and “Improving”. More specifically, the dimension determines whether mHealth projects with particular goals developed a new information system or were expanding upon an existing one. Finally, the dimension of duration was altered from “weeks” to “months”, as nearly all papers describing a timeline of research lasted for over a 6 week period.

<table>
<thead>
<tr>
<th>Determinant of Success</th>
<th>Implementation Type</th>
<th>Primary Obstacle to Implementation</th>
<th>Duration</th>
<th>Study Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provider outcomes</td>
<td>Patient outcomes</td>
<td>Develop</td>
<td>Improve</td>
<td>0-6 Months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tech centric</td>
<td>People centric</td>
<td>6-18 Months</td>
</tr>
</tbody>
</table>

**Table 3. Second Iteration of Taxonomy**

**Iteration 2, Step 7**

The taxonomy did not meet all ending conditions as new dimensions were added and other dimensions modified during the iteration. This lead to another cycle and a return to stage 3.

**Iteration 3, Step 3, 4c, 5c, and 6c**

Similar to the situation in step 3 of iteration 2, the conceptual-to-empirical approach was used again to further clarify the existing dimensions for iteration 3 (Table 4). Stages 4c and 5c saw the addition of two new dimensions, “Theory based” and “Project setting”. The theory dimension tracked whether or not mHealth projects with certain objectives utilized theory in the application of their solutions. Project setting had the characteristics of “Developed country” or “Developing country” and was meant to serve as a guideline for where projects tended to take place depending upon their goals. The final change was a clarification of the “implementation type” dimension into the “Impact on existing healthcare system” dimension. This change serves to better represent the characteristics of mHealth projects through more specific definition of key terms. A minor change in the duration column resulted in “6-18 months” becoming the broader category of “over 6 months”. This change was made as papers with projects lasting over a year and a half were found and included in the analysis. The final change was the removal of the “Primary obstacle to implementation” dimension. Projects were initially classified as either impeded by “hardware” or “people”. However, many projects did not neatly fit into either category, as both issues with technology and people arose and became hindrances to successful project completion.
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Determinant of Success | Theory Based | Impact on Existing Healthcare System | Duration | Study Type | Project Setting
---|---|---|---|---|---
Provider – outcomes | Patient – outcomes | Yes | No | Incremental Improvement | New System | 0-6 months | 6+ Months | Simulation | Field Study | Developed Country | Developing Country

Table 4. Final Iteration of Taxonomy

Iteration 3, Step 7

The taxonomy technically did not meet all ending conditions as dimensions were added and altered. However, upon resolution of iteration 4, no further changes were made to the taxonomy. Thus, iteration 3 was determined to be the final iteration.

Observations

The final tally for observations in the final taxonomy is presented in Table 5. The sample of papers focused on provider outcomes and patient outcomes evenly. Our initial predictions while creating the taxonomy would be that mobile projects would focus more on patient-outcomes as the key measure of success. While patient health may ultimately be the goal of a healthcare system, many papers utilized group-level or hospital-level analysis in evaluating the impact of mHealth implementation. Provider efficiency was a recurring theme throughout many of the surveyed papers.

Table 5. Instances for Each Characteristic in the Taxonomy

Papers in this field rarely applied theory to analyze research questions and results. Some papers proposed some form of framework related to project management in their analyses, but only two specifically included academic theory in their arguments (Kimaro et al. 2005; Maar et al. 2016). The majority of papers focused on incremental improvements on existing healthcare systems rather than complete overhauls or introduction of a new health system (49 to 15 papers). The duration of papers was more varied but still fairly evenly split, with slightly more research projects lasting 0 to 6 months rather than over 6 months (37 to 26). The dimension of study type saw an identical split, with simulations accounting for the majority over field studies (37 to 26). Finally, projects were equally split between developing and developed countries.

Table 6. Observations Between Country Development and Implementation Type

Another interesting observation was the connection between studies conducted in a developed country and those completed in a developing countries (Table 6). All of the studies conducted within developing countries in the sample presented incremental healthcare improvements to existing healthcare delivery systems. Studies held in developing countries were more diverse, with 15 studies focused on improvement and 9 on establishing a new healthcare system with mobile technology as a centerpiece in project implementation.
These patterns show that developed countries tend to have established healthcare systems in which mHealth implementation serves a supportive capacity. Developing countries with no concrete healthcare delivery system may utilize mHealth services in a more revolutionary capacity and either build new healthcare systems or reform existing systems around the technology.

Insights also occurred between the iterations in taxonomy designs. The even split between provider outcomes and client outcomes as the variable of success shows that researchers in this field are still interested in both sides of the healthcare equation. Future versions of the taxonomy may need to further refine this dimension, as some papers exhibited no strong inclination towards either attribute. Those papers instead seemed to focus on the system as a whole and included both provider and patient outcomes in the final analysis. This change parallels the gradual modification and eventual removal of the “obstacles” dimension. At first, we theorized that roadblocks to mHealth implementation can either take the form of technology or people. After the first iteration we began to discover that many of the papers identified both technology and people as obstacles, rather than simply one or the other.

Moving Towards Theory

We offer two potential theoretical applications based on our observations from the taxonomy. The first is the health promotion model, which was meant to serve as a way to influence patients into more healthy behaviors (Rosenstock 1988). Some studies in the field of mHealth have suggested a link between patient health and smartphone utilization (Bert 2014), however no projects within our sample used the model in informing or measuring the results of their projects. The health promotion model draws upon psychology theories of self-efficacy and self-determination, which can be useful in better evaluating patient-centric outcomes of mHealth projects (Maddux 1995; Glanz 2010). Smartphone usage is typically seen as an external factor in influencing patient health. Depending on the implementation of the technology, there is potential for mHealth to exert additional levels of influence over patient behavior. For instance, linking health applications to social networking sites can serve as a source of interpersonal motivation through the encouragement of friends and family to continue or start a healthy behavior.

Another potential theoretical contribution lies in empowerment theory. A psychological theory traditionally linked to community-served systems and behaviors resulting in social change (Rappaport 1981), applications of empowerment can serve as a strong framework for implementation of new technologies within developing countries. The theory has been applied to various management research questions and has been discussed as a potential lens through which to view implementation of various health information technologies (HIT) such as telemedicine (Lober et al. 2011, Tachakra 2003). Potentially novel theoretical contributions can be made by combining empowerment theory to the unique setting of mHealth implementation serving as the basis of a new healthcare system within a developing country.

Conclusions

Our initial goal was to create a taxonomy and derive useful information from the resulting analysis. What eventually happened was an iterative loop, resulting in multiple insights both during and after the design process. Within the loop was the ever-present idea of iteration through taxonomy revision. Throughout all stages of the process, refinement and alterations to the taxonomy were justified through empirical evidence and the meta-characteristic. The end result was the identification of multiple notable patterns within the mHealth project implementation literature. We found that theory is a currently underutilized tool in analyzing mHealth projects and that developing countries are rapidly becoming the new frontier for creating new healthcare systems through mHealth. The discussion of possible theoretical links to this research setting shows the opportunities for insightful questions that remain to be asked and explored in the HIT field.

In the developed world, mobile devices within the healthcare context are conceptually understood as entrenched. The proliferation of technology and increased interconnectivity of all aspects of life have occurred simultaneously and exponentially over the past 20 years. This taxonomy shows that in some areas of the world, the emergence of mobile device utilization in healthcare is just on the cusp of occurring. Scholars in the information systems field can proactively seize the opportunities presented in this paper by utilizing theory in exploring the new phenomena generated by these dynamic and novel settings. Doing so
can lead to new findings and further collective understanding of the reach, impacts, and effectiveness of mHealth.

References


