Development and Usability Evaluation of an mHealth Application

for Symptom Self-Management in Underserved Persons Living with HIV

Hwayoung Cho

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ABSTRACT

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Hwayoung Cho

Effective symptom management is essential to decrease symptom severity and improve health-related quality of life for persons living with HIV (PLWH). A mobile health (mHealth) application (app) has the potential to be an effective delivery mode of an existing paper-based symptom management manual with self-management strategies for underserved PLWH. The quality of the mHealth app requires a thorough understanding of the needs of the intended end-users and ensuring the app's usability.

The purpose of this study was to translate paper-based health information into an mHealth app for symptom self-management in underserved PLWH, entitled mVIP (mobile Video Information Provider), and assess its usability. To achieve this goal, usability was evaluated rigorously throughout the development process of mVIP. Based on a stratified view of health information technology (IT) usability evaluation framework, usability evaluation was sequentially conducted with the following three levels: 1) user-task, 2) user-task-system, and 3) user-task-system-environment.

At level 1 (user-task), we applied a user-centered design method to guide the information architecture of mVIP. Using a reverse in-person card sorting technique, symptoms and self-management strategies from a paper-based HIV/AIDS symptom management manual were ranked. The rank order of the 13 symptoms and 151 self-management strategies determined the

order of appearance to end-users of the mVIP app, with higher-ranked symptoms and strategies appearing first. Based on the findings, we developed a prototype of mVIP as following: 1) once users log in, they are guided by an avatar through a series of 13 symptom questions ascertaining the nature and severity of their symptoms, and 2) the avatar recommends three self-management strategies for each symptom reported. At level 2 (user-task-system), we conducted a usability evaluation of the mVIP prototype in a laboratory setting through end-user usability testing and heuristic evaluation. In end-user usability testing, we used an eye-tracking and retrospective think-aloud method to examine task performance by 20 PLWH. For the heuristic evaluation, five usability experts in informatics assessed the user interface. In the two usability evaluations conducted in a laboratory setting, we found strong user acceptance of the mVIP prototype while identifying a number of usability issues with this prototype. Based on the recommendations from the end-users and heuristic evaluators, we iteratively refined the app's content, functionality, and interface. We then inserted videos of the finalized symptom self-management strategies into the refined mVIP prototype. At level 3 (user-task-system-environment), the usability of the refined mVIP prototype was evaluated in a real-world setting. Through 10 in-depth interviews and four focus groups conducted at the conclusion of a three-month randomized controlled trial, we explored in-depth understandings of users' experiences, perceptions, and satisfaction of mVIP use. Findings from the study showed that first, mVIP is useful for HIV-related symptom self-management and has the potential for being used as a communication tool with healthcare providers; and second, mVIP is easy to use to monitor symptom experience over time. At the same time, participants suggested mVIP be more sensitively tailored based on years from initial diagnosis of HIV, an individuals' age, and conditions. The overall user satisfaction with the mVIP prototype was high, which reflects strong user acceptance of mVIP.

Integral to the findings from the three-level usability evaluation, we assessed the quality of the mVIP prototype in use and found the prototype was highly accepted by PLWH with high user satisfaction. This study will add to the body of literature on translation of evidence-based health information into an mHealth app and its usability assessment, which highlights the importance of the use of mobile technology for PLWH, specifically racial and ethnic minorities and those from low-socioeconomic groups who have limited health literacy and low level of education.

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Dedication

To my dearest family and my mentor, Dr. Schnall.

세상에서 가장 사랑하는 우리 아빠엄마, 언니, 오빠, 형부,

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Chapter 1. Introduction

In the United States (US), an estimated 1.2 million people are living with HIV (PLWH) and 50,000 Americans are newly infected with HIV every year (Centers for Disease Control and Prevention, 2015a). HIV has disproportionately affected persons from underserved communities, specifically racial and ethnic minorities and those from low-socioeconomic groups (Centers for Disease Control and Prevention, 2016a, 2016b; Hall et al., 2008).

Due to advances in HIV treatment in the past three decades, PLWH's survival rates have increased and HIV has largely become a chronic disease (Clayson et al., 2006). At the same time, PLWH are confronted with persistent symptoms related to HIV infection, medication side effects and comorbidities (Ammassari et al., 2001; Mocroft et al., 2003; Spirig, Moody, Battegay, & De Geest, 2005). Effective management of symptoms by PLWH has been shown to decrease symptom severity, support adherence to antiretroviral medications, increase engagement with healthcare providers, and further improve their health-related quality of life (Bunch, Corless, Bunch, Kemppainen, & Holzemer, 2002; Heaven & Maguire, 1998; Indyk, Belville, Lachapelle, Gordon, & Dewart, 1993; Spirig et al., 2005).

In response to the need for providing PLWH strategies for ameliorating their symptoms, a paper-based HIV/AIDS symptom management manual with self-management strategies was developed by researchers at the University of California San Francisco School of Nursing in 2004 (University of California, 2004) and was validated by HIV-expert clinicians and corroborated through a randomized controlled trial (RCT) with 775 PLWH (Wantland et al., 2008). The manual includes strategies for 21 HIV-related symptoms, which include: anxiety, constipation, cough, depression, diarrhea, dizziness, fever, forgetfulness, fatigue, nausea, night sweats, neuropathy, shortness of breath, skin abscesses, skin blisters, skin rash, swelling of arms/hands/legs/feet, insomnia, weight loss, oral thrush, and vaginal itching/burning/discharge. For each symptom, the information is divided into three sections: 1) Problem section (a brief description of the symptom); 2) Treatment section (ways that the symptom is commonly treated, successful alternative strategies, and the importance of consultation as part of a treatment plan); and 3) Self-care section (multiple identified self-care strategies that may be useful to decrease and/or resolve the symptom). In the 775-person RCT over three months at 12 sites from the US, the manual was found to be efficacious on reducing symptom frequency and intensity for PLWH (Wantland et al., 2008).

To facilitate the behavioral intervention's uptake by PLWH, a web-based symptom self-management tool, Video Information Provider (VIP), was developed with strategies for six symptoms: anxiety, depression, diarrhea, fatigue, nausea, and neuropathy (Schnall, Wantland, Velez, Cato, & Jia, 2014). The web-based tool provided PLWH strategies to better manage adverse symptoms and improve overall health-related quality of life. Once users log in, they are guided by an avatar through a series of questions ascertaining the nature and severity of their symptoms. Upon completing the evaluation, the avatar recommends self-management strategies for specific symptoms. A three-month pilot study to explore the feasibility of using the VIP tool for PLWH showed that participants who used the strategies were more likely to experience a decrease in symptom frequency and intensity (Schnall, Wantland, et al., 2014).

Nonetheless, subsequent use of those symptom management strategies has been limited. In a study exploring the use of the technology in PLWH, one of the barriers that would prevent some participants from utilizing a website for PLWH was the lack of access to a computer (K. J. Horvath et al., 2012). Considering the barrier, the use of mobile health (mHealth) technology such as mobile applications (apps) has the potential to improve communication, access, and information delivery to racial and ethnic minorities and those from low-socioeconomic groups (Klasnja & Pratt, 2012). According to the US Census Bureau, 58.2% of households below the poverty level have computers, whereas 80.9% have cell phones (Siebens, 2013). In fact, smartphones are now the most popular mobile technology (Newswire, 2013), and African Americans and Latinos download mobile apps more frequently than non-Latino whites (Anderson, 2015; Duggan, 2013). Thus, these apps can reduce challenges associated with racial and ethnic disparities by increasing access to health information (Akter & Ray, 2010; Duggan, 2013; R. Schnall, J. P. Mosley, et al., 2015). Moreover, a systematic review demonstrated the potential of mHealth apps in improving symptom management through self-management interventions, with a statistically significant difference in the clinical outcomes in chronic diseases – diabetes mellitus (type I and II) and chronic lung disease (Whitehead & Seaton, 2016). mHealth apps have the potential to more widely disseminate self-care strategies for symptom management to PLWH (Whitehead & Seaton, 2016).

In response to the need for providing underserved PLWH symptom management strategies and encouraging their subsequent use, we developed a mobile-based symptom self-management app for PLWH, by incorporating a paper-based HIV/AIDS manual with self-management strategies and patient-centered research findings from the web-based symptom self-management tool. The mHealth app for symptom self-management for underserved PLWH was named ‘mVIP’ (mobile Video Information Provider). We then evaluated the usability of mVIP several times throughout the development process. This dissertation focused on the development and usability evaluation of mVIP independent of assessing the effect of using mVIP on improvement in health outcomes among underserved PLWH in a three-month RCT. The objective of this dissertation was to translate paper-based health information into an mHealth app and assess its usability, in order to facilitate the implementation and dissemination of evidence-based strategies for HIV symptom management in underserved PLWH.

Problem Statement

Dearth of mHealth Apps for Self-management for PLWH

Approximately two-thirds (66%) of Americans use mHealth apps to manage their health (Makovsky, 2015) and nearly 165,000 mHealth apps are now available in the Apple iTunes and Android app stores in the US (IMS Institute for Healthcare Informatics, 2015). Over the past decade, evidence has grown supporting the efficacy of mHealth apps for the management of chronic disease such as type II diabetes, cardiovascular related health issues and obesity (Wilhide Iii, Peeples, & Anthony Kouyaté, 2016). For example, a meta-analysis of 22 interventions found that mHealth apps for diabetes led to statistically significant improvements in glycemic control and self-management (Liang et al., 2011). mHealth apps employ different strategies such as tracking and texting to offer comprehensive management support (Hunt, 2015). Despite the potential of a mobile platform to disseminate self-management strategies, no mHealth symptom self-management apps for PLWH currently exist.

Problem of Usability for mHealth Technology

In the last decade, one of the most challenging tasks associated with technology development has been not only to provide the required functionality, but also to ensure its quality in use (Bengtsson, Lassing, Bosch, & Vliet, 2000; Folmer & Bosch, 2004b). To support the quality of technology in use, usability must be considered before and after prototyping takes place (Holzinger, 2005). Usability is the measure of the quality of a user's experience when interacting with a system – whether a website, mobile technology, or any user-operated device (Usability.gov). In other words, usability refers to how well users can navigate a system to achieve their goals, and how satisfied they are with the process. A successful system needs to work for its users, and it needs to work well. However, many mHealth technologies have been made available to the public with insufficient scientific effort devoted to their design, development, and evaluation (Nilsen et al., 2012). Technologies produced with poor design and inadequate consideration of the needs of their intended users will be difficult to learn, misused or underutilized, and will ultimately fail to accomplish their objectives (Maguire, 2001). For this reason, usability has been widely recognized as a critical consideration in evaluating the efficacy of technologies (Shackel, 1991).

It is important to take usability issues into consideration during the app development. The quality of mHealth apps in use requires a thorough understanding of the context of its proposed deployment, by identifying the needs of the intended end-users and ensuring the apps' usability

(Ben-Zeev et al., 2013). To address barriers, it is essential to develop the mHealth app with the application of an evidence-based usability evaluation during the app's development process. In this dissertation, we focused on the evidence-based usability evaluation tailored for each stage of the entire development process, by incorporating evidence-based symptom self-management strategies into the information architecture of mVIP and ensuring the app's effectiveness and associated satisfaction among underserved PLWH.

Conceptual Framework

In this dissertation, a conceptual framework was used for the planning and evaluation of an mHealth app for symptom self-management in underserved PLWH. The conceptual framework used is a stratified view of health information technology (IT) usability evaluation model, proposed by Yen and Bakken in 2012 (Yen & Bakken, 2012). It is an integrated health IT usability specification and evaluation framework and combines the usability model of Bennett (Bennett et al., 1985), Shackel (Shackel, 1991), and system development life cycle (Stead et al., 1994) into a comprehensive evaluation framework. In Bennett and Shackel's usability model, usability is evaluated through the interaction of user, system, and task in a specified setting. The meaning of usability in the two models is delineated by four major components: user, tool, task, and environment. Additionally the system development life cycle consists of five stages: 1) specification and needs requirement; 2) component development; 3) integration of components into system; 4) integration of the system into a clinical setting; and 5) routine use of a system. The system development life cycle indicates 'when' an evaluation occurs, while the four components of usability (user, tool, task, and environment) indicate 'what' to evaluate. The comparison of Bennett and Shackel's usability model and the system development life cycle is displayed in *Table 1-1*.

Table 1-1. Comparison of Bennett and Shackel's usability model and system development life cycle

Bennett and Shackel's usability model	System development life cycle stage
Type 0: task Type 1: user-task	Stage 1: specify needs for setting and users
Type 2: system-task Type 3: system-user–task	Stage 2: system component development
Type 2: system-task Type 3: system-user–task	Stage 3: combine components
Type 2: system-task Type 3: system-user-task Type 4: system-user-task-environment	Stage 4: integrate system into setting
Type 2: system-task Type 3: system-user-task Type 4: system-user-task-environment	Stage 5: routine use

The stratified view of health IT usability evaluation framework provides a categorization of study approaches by evaluation types based on the Bennett and Shackel's usability model and the system development life cycle (*Figure 1-1*). There are three levels of stratified views. Level 1 targets system specification to understand user-task interaction for system development. Level 2 examines the task performance to assess system validation and human-computer interaction in a laboratory setting. Level 3 aims to incorporate environmental factors to identify work processes and system impact in a real setting. Task/expectation complexity, user variance, and organizational support are factors that influence the use of the system, but are not problems of the system itself, and need to be differentiated from system-related issues. For example, at level 1, through application of user-centered design, we can control some user variance by recruiting the targeted users as participants. In addition, task/expectation complexity can be measured to identify system specifications. At level 3, we can minimize user variance through user training and by providing organizational support. An evaluation of perceived usability based on the level of task/expectations reveals the system usability at each level of task/expectations. The stratified view of health IT usability evaluation extends the concept of evaluating with users and tasks to considering levels of user-task-system-environment interaction. It also identifies confounding factors, task/expectation complexity, user variance, and organizational support, all of which directly or indirectly influence the results of usability evaluation.

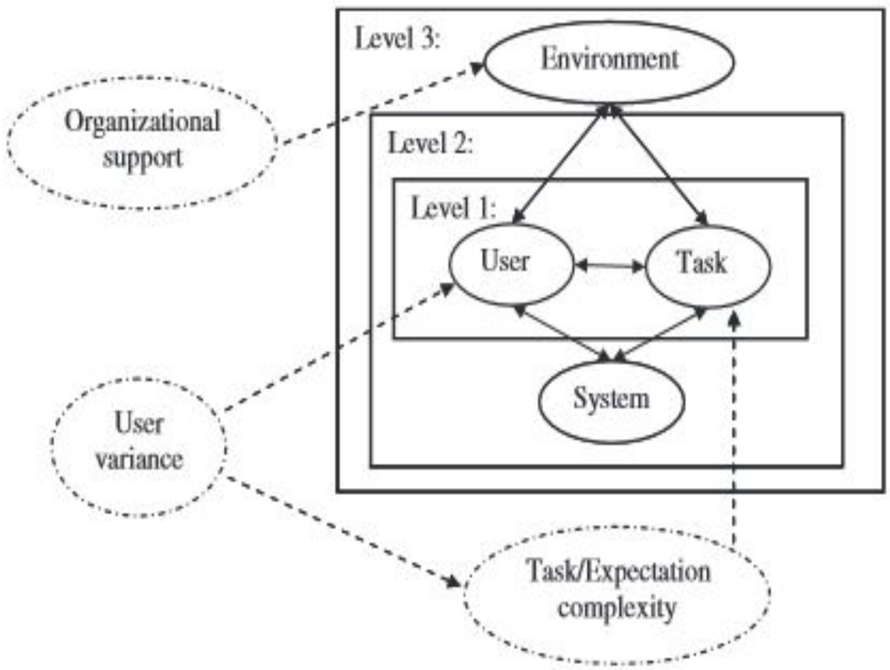

Figure 1-1. A stratified view of health information technology (IT) usability evaluation

As mHealth technology is a component of health IT, the stratified view of health IT usability evaluation framework was used to guide the work in this dissertation. Throughout the development process of the mHealth app for symptom self-management in underserved PLWH, the app's usability evaluation was conducted with the following three levels: user-task, user-task-system, and user-task-system-environment.

Purpose

The purpose of this dissertation was to translate paper-based health information into an mHealth app for symptom self-management, called mVIP, and to assess its usability. Ultimately, mVIP will facilitate the implementation and dissemination of evidence-based strategies for HIV symptom self-management in underserved PLWH in the US.

Study Aims and Research Questions

To achieve the purpose of this dissertation, specific aims and research questions divided into three levels of usability evaluation are described below, based on the stratified view of health IT usability evaluation framework. A summary of the three levels of usability evaluation in this dissertation to address the three aims is presented in *Table 1-2*. The methods of usability evaluation used at each level of this dissertation are specifically described in Chapter 3.

Level 1 (User-Task)

Research questions:

- What is the desired information architecture of symptom self-management strategies for informing the development of mVIP?

Aim 1:

- ✓ Apply a user-centered design method to guide the information architecture of a prototype of mVIP by understanding user-task interaction. This aim was achieved through a card sorting technique.

Level 2 (User-Task-System)

Research questions:

- What usability problems are perceived by end-users in a laboratory setting?
- Are the end-users satisfied with the way mVIP performs the desired tasks in the laboratory setting?
- What usability problems are perceived by usability experts?

Aim 2:

- ✓ Evaluate the usability of the mVIP prototype in a laboratory setting, by exploring user-task-system interaction. This aim was achieved through end-user usability testing and heuristic evaluation.

Aim 2-1 (end-user usability testing): Examine task performance by end-users

Aim 2-2 (heuristic evaluation): Assess a user interface by usability experts

Level 3 (User-Task-System-Environment)

Research questions:

- What usability problems are perceived by end-users in a real-world setting?
- Are the end-users satisfied with the way mVIP helps them to self-manage their symptoms in a real-world setting?

Aim 3:

- ✓ Evaluate the usability of the mVIP prototype in a real-world setting to explore in-depth understandings of users' experiences, perceptions, and satisfaction, by identifying user-task-system-environment interaction. Aim 3 was addressed using in-depth interviews and focus groups in a three-month RCT.

Table 1-2. A summary of three-level usability evaluation

Level of Usability Evaluation	Level 1	Level 2	Level 3
Goal	Understand user-task interaction	Assess user-task-system interaction	Identify user-task-system-environment interaction
Research Question	What is the desired information architecture of symptom self-management strategies for informing the development of mVIP?	What usability problems are perceived by end-users in a laboratory setting? Are the end-users satisfied with the way mVIP helps performs the desired tasks in the laboratory setting?	What usability problems are perceived by end-users in a real-world setting? Are the end-users satisfied with the way mVIP helps them to self-manage their symptoms in a real-world setting?
		What usability problems are perceived by usability experts?	
Aim	Apply a user-centered design method to guide the information architecture of mVIP	Evaluate the usability of mVIP in a laboratory setting to examine the task performance by end-users and to assess a user interface by usability experts	Evaluate the usability of mVIP in a real-world setting to explore in-depth understandings of users' experiences, perceptions, and satisfaction
Methods	Card sorting technique	1) End-user usability testing: eye-tracking think-aloud method	Interviews/Focus groups
		2) Heuristic evaluation	

Sample	20 end-users	1) 20 end-users 2) 5 usability experts	10 end-users/4 groups (36 end-users)
Output	Designed mVIP prototype	Refined mVIP prototype	

Significance of the Study

Using an mHealth App for Supporting Symptom Self-Management in Underserved PLWH

mHealth apps are increasingly intersecting with individuals' health management to extend the impact of healthcare (Hilliard, Hahn, Ridge, Eakin, & Riekert, 2014). In a study of a smartphone app for symptom assessment and management during treatment in patients with prostate cancer, the intervention group reported less urinary-related symptom burden at the end of treatment compared to the control group (Sundberg et al., 2017). mHealth apps with videos can offer a tremendous benefit for symptom and pain management. A study indicated that an educational intervention in which patients watched a 14-minute video that presented information contained in the booklet 'Managing Cancer Pain' was effective in management of cancer symptom and pain in the elderly (Clotfelter, 1999). Moreover, mHealth apps provide unique possibilities for bridging the divide in healthcare delivery among racial and ethnic minorities (Klasnja & Pratt, 2012). According to a Pew Research Center study, ownership of a mobile device is equally as common among African Americans and Whites (94%) and highest among Latinos (98%) (Pew Research Center, 2016a). While mobile internet use in the US has been on the rise across all racial/ethnicity groups, African Americans and Latinos are more likely to use a smartphone for internet use (94% for both groups) compared to Whites (85%) (Pew Research Center, 2015, 2016b). African Americans and Latinos download apps more frequently compared to non-Latino whites (Anderson, 2015; Duggan, 2013). Also, mHealth apps are particularly relevant to low-socioeconomic PLWH since mHealth apps have the potential to increase access to health information by reducing challenges associated with economic disparities (Akter & Ray, 2010; R. Schnall, J. P. Mosley, et al., 2015). Therefore, the use of mHealth apps with videos has the potential to effectively disseminate information about symptom management, supporting underserved PLWH.

Stratified Usability Evaluation of an mHealth App

To ensure the best utilization of IT, it is important to attend to the usability of the technology (Yen & Bakken, 2012). Usability evaluation helps us assess our designs and test our systems to ensure that they actually behave as expected and meet the requirements of the intended user (Wright, 1998). However, more than 95% of mHealth apps have not undergone a usability evaluation (Furlow, 2012). In a systematic review, there were 42 controlled trials of mobile technology interventions for all disease processes and the effects demonstrated were only modestly beneficial (C. Free et al., 2013). Prior to the implementation of mHealth technologies for improving clinical outcomes, it is imperative that health IT designers pay attention to the usability of these technologies to ensure the greatest efficacy (Brown, Yen, Rojas, & Schnall, 2013).

Moreover, the usability evaluation should be a critical part of every design and development process (Greenberg & Buxton, 2008). A user-centered design approach allows for understanding the psychological, organizational, social, and ergonomic factors that affect the use of mHealth technology (Abras, Maloney-Krichmar, & Preece, 2004). This approach can lead to the development of mHealth apps that are more effective, efficient, and safe, and help designers manage users' expectations about the new apps, which often results in higher user satisfaction and smoother integration of the system into the environment (Preece, 2000; Schnall et al., 2016). During the system development, usability evaluations at different stages are necessary to guide system modification, and to further ensure that the final prototype is easy to use and useful for end-users (Lai, 2007).

Prior to developing an mHealth app which incorporates the self-management strategies from the symptom management manual for underserved PLWH, a user-centered design method for understanding user-task interaction was employed to guide the information architecture of mVIP. Once a prototype of mVIP was created through the first level usability evaluation, the next two levels of usability evaluation of the mVIP prototype in both laboratory and real-world settings were employed to identify user-task-system interaction including additional environmental factors. This stratified three-level usability evaluation of mVIP could meet the needs of intended end-users (i.e. PLWH) and guide the mVIP prototype modification iteratively. While this dissertation focused on ensuring that the final mVIP prototype would be easy to use and useful for our end-users, the stratified usability evaluations might make it possible to further improve efficacy, efficiency, and satisfaction of the use of mVIP among PLWH, which will ultimately facilitate the implementation and dissemination of evidence-based strategies for HIV symptom self-management in underserved PLWH in the US.

Review of the Literature

A literature review was conducted prior to the usability evaluation for the development of an mHealth app to help PLWH self-manage HIV-related symptoms. This literature review first provides a brief profile of the US HIV/AIDS epidemic including an overview of HIV-related symptoms. This is followed by a review of mHealth technology in PLWH and usability of technologies.

US HIV/AIDS Epidemic

Since the early 1980s, the HIV/AIDS epidemic has emerged as one of the major health challenges in the world (Ortblad, Lozano, & Murray, 2013). Over the past three decades, advances in HIV research and treatment have increased survival rates and lengthened the chronic stage of the illness (Spirig et al., 2005). As a result, PLWH are living healthier and longer lives, with expected life spans of PLWH receiving treatment paralleling those of people uninfected with HIV (Samji et al., 2013). In the US, an estimated 1.2 million people are living with HIV and 50,000 Americans are infected with HIV every year (Centers for Disease Control and Prevention, 2015a).

Health Disparities in HIV

HIV has disproportionately affected persons from underserved communities, specifically racial and ethnic minorities and those from low-socioeconomic groups (Centers for Disease Control and Prevention, 2016a, 2016b; Hall et al., 2008). In the US, African Americans accounted for 43% of PLWH and Latinos accounted for 21% of PLWH (U.S. Department of

Health & Human Services, 2014). HIV prevalence was also higher among those with lower socioeconomic status. According to the National HIV Behavioral Surveillance survey in the low income urban areas during 2006-2007 (Centers for Disease Control and Prevention, 2011), individuals living below the poverty line were twice as likely to be HIV-infected as those who lived in the same community but above the poverty line (2.3% vs. 1.0%). Prevalence for both groups was far higher than the national average of 0.45%. HIV prevalence was inversely related to annual household income – the lower the income, the greater the HIV prevalence rate (2.8% < $10,000 vs. 1.5% $10,000-19,999 vs. 1.2% $20,000-49,999 vs. 0.4% ≥ $50,000). Additionally, HIV prevalence was 2.8% among participants with less than a high school education compared with 1.2% among those with more than a high school education. Finally, HIV prevalence was 2.6% among participants who were unemployed compared with 1.0% among those who were employed. Thus, there is a need to target those underserved PLWH in HIV research.

Symptom Experience of PLWH

Antiretroviral therapy (ART) has become the standard of care for HIV as it is the most effective approach to achieve maximal viral suppression (Spirig et al., 2005). As PLWH on ART achieve lifelong viral suppression, the classic AIDS related conditions are less common. However, PLWH on ART have elevated risk for several 'non-AIDS' complications, many of which are commonly associated with aging (Deeks & Phillips, 2009). More than half of clinical events occurring among PLWH on ART have been classified as non-AIDS, or not attributable to the 26 AIDS-defining conditions identified by the US Centers for Disease Control and Prevention (Justice, 2010; Palella et al., 2006; Smit et al., 2006). Moreover, in a study of those aging with HIV, 65% of HIV-infected individuals between 50 and 59 years of age had at least one comorbid diagnosis, including non-AIDS conditions such as cardiovascular disease, neuropathy, cognitive function, anemia, osteoporosis, liver disease, and kidney disease (Goulet et al., 2007).

As a result, PLWH are confronted with persistent symptoms (Ammassari et al., 2001; Mocroft et al., 2003; Spirig et al., 2005). More specifically, PLWH with comorbidities are more likely to experience multiple adverse symptoms that require attention, evaluation, treatment, and ongoing management (Morgan et al., 2012). The many physiological, psychological, and cognitive symptoms experienced by PLWH, such as pain, diarrhea, fever, fatigue, anxiety, depression, and confusion, have been found to restrict their daily lives significantly (Wantland et al., 2008).

Symptoms play an important role in the patient's experience of disease, since symptoms are the primary reason patients seek care and are often a determinant of the patient's perceived health-related quality of life (Cunningham et al., 1998; Justice et al., 2001; Justice, Rabeneck, Hays, Wu, & Bozzette, 1999; Kroenke & Price, 1993). Among PLWH, the prevalence of individual symptoms and symptom intensity are related to medication adherence (Corless, Corless, Nicholas, Davis, & Dolan, 2005; Holzemer, Hudson, Kirksey, Jane Hamilton, & Bakken, 2001). More specifically, persistent and severe HIV-related symptoms have been shown to negatively affect ART adherence (Ammassari et al., 2002; Hughes, 2004; Nicca, Fierz, Happ, & Moody, 2012). Health-related quality of life decreases as the severity of symptoms increase (Lorenz, Shapiro, Asch, Bozzette, & Hays, 2001).

In order to improve PLWH's experience of disease, effective management of symptoms is essential (Justice et al., 2001). In HIV, effective symptom management has been shown to decrease symptom severity, support adherence to antiretroviral medications, slow disease progression, increase engagement with healthcare providers, and improve PLWH's health-related quality of life (Corless et al., 2002; Heaven & Maguire, 1998; Indyk et al., 1993; Spirig et al., 2005).

Symptom Self-Management in HIV

Self-management of symptoms is increasingly necessary for PLWH, as patients with chronic illnesses are more likely to become their own principal caregivers than those with acute illnesses relatively (Holman & Lorig, 1997; Swendeman, Ingram, & Rotheram-Borus, 2009). The World Health Organization (WHO) includes 'self-management' as a best practice for improving clinical outcomes and health-related quality of life for chronic conditions (World Health Organization, 2001). Self-management of multiple HIV-related symptoms and maintaining optimal health-related quality of life have become major daily tasks for PLWH due to the symptoms' influence on and interference with everyday routines (Hench, Anderson, Grady, & Ropka, 1995; Lorenz, Cunningham, Spritzer, & Hays, 2006; Zeller, Swanson, & Cohen, 1993).

In order to provide those PLWH a simple handbook on how to reduce symptoms, a paper-based HIV/AIDS symptom management manual with self-management strategies was developed at the University of California San Francisco School of Nursing in 2004 (University of California, 2004). The symptom management manual was validated by HIV-expert clinicians and corroborated through a RCT with 775 PLWH. In the RCT over three months at 12 sites from the US, the manual including strategies for 21 common HIV-related symptoms was found to be efficacious on reducing symptom frequency and intensity for PLWH (Wantland et al., 2008). To facilitate uptake by PLWH, a web-based symptom self-management tool was then developed with tailored self-management strategies to address adverse symptoms and improve overall health-related quality of life (Schnall, Wantland, et al., 2014). The web-based tool covers six HIV-related symptoms including depression, anxiety, fatigue, diarrhea, neuropathy, and nausea. A three-month feasibility study of the use of the web-based system for PLWH showed improvement in symptom frequency and intensity (Schnall, Wantland, et al., 2014). *Figure 2-1* displays a screenshot of the web-based symptom self-management tool.

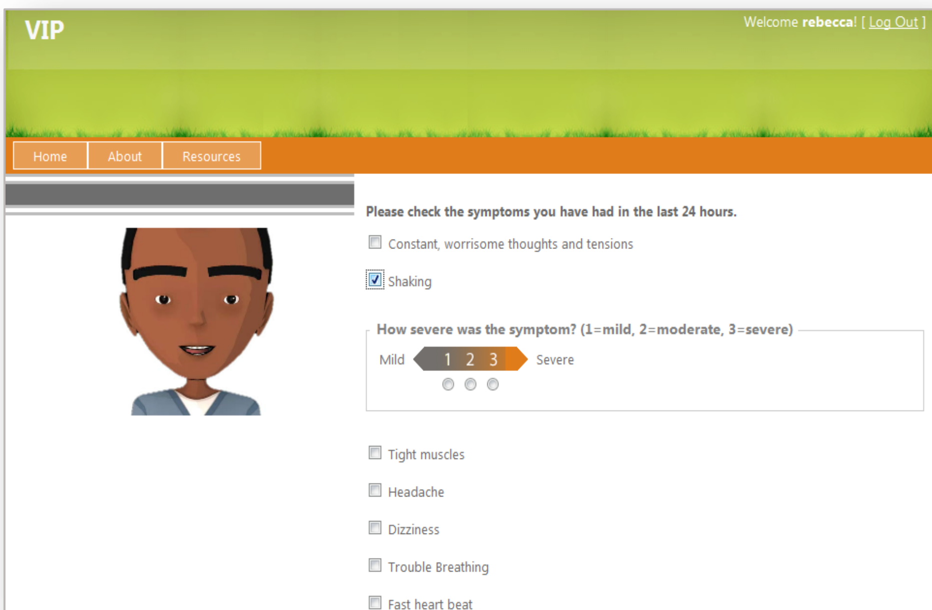

Figure 0-1. Web-based symptom self-management tool

Nevertheless, subsequent use of the symptom management strategies has been limited. Health disparities might reflect differences in access to and use of healthcare services including the web-based tool for PLWH (Carmen DeNavas-Walt, 2013; Centers for Disease Control and Prevention, 2014; Wohl et al., 2011). Moreover, the web-based symptom self-management tool provides tailored strategies for only six symptoms due to funding constraints (Schnall, Wantland, et al., 2014).

mHealth Technology in PLWH

mHealth refers to the use of mobile and wireless devices to improve health outcomes, healthcare services, and health research (Healthcare Information and Management Systems Society, 2012). The mobile and wireless devices include mobile phones; personal digital assistants (PDAs) and PDA phones (e.g. BlackBerry, Palm Pilot); smartphones (e.g. iPhone); enterprise digital assistants (EDAs); portable media players (i.e. MP3-players, MP4-players, e.g. iPod); handheld video-game consoles (e.g. PlayStation Portable, Nintendo DS); handheld and ultra-portable computers such as tablet PCs (e.g. iPad); and smartbooks (Caroline Free et al., 2013). mHealth technologies have a range of functions from mobile cellular communication using text messages (SMS), photos and video (MMS), telephone, and World Wide Web access, to multi-media playback and software application support (Caroline Free et al., 2013). The greatest promise of mHealth using those devices is to empower patients and boost the appropriateness of care and their health-related quality of life (Nasi, Cucciniello, & Guerrazzi, 2015).

mHealth technologies have the potential to be a valuable tool in the management of chronic illnesses, including HIV (Schnall, Bakken, Rojas, Travers, & Carballo-Diéguez, 2015). mHealth technologies have played a particularly significant role in supporting HIV-related treatment for PLWH (Safreed-Harmon, 2012). Emerging evidence suggests that mHealth tools can enable behavior change and improve clinical outcomes. ART adherence is one of many modifiable health behaviors that can be targeted through the use of mobile phones (Thirumurthy & Lester, 2012). Findings from two systematic reviews suggest that text messaging intervention could be used in HIV to improve adherence to medication, as well as biological outcomes such as viral load and/or CD4 levels (Finitsis, Pellowski, & Johnson, 2014; Horvath, Azman, Kennedy, & Rutherford, 2012; Mbuagbaw et al., 2015). In addition to the improvement in clinical outcomes in HIV care, an important goal in our healthcare system is to encourage and support PLWH to adopt healthy behaviors and to self-manage their symptoms related to HIV in a convenient and cost-effective way (Free et al., 2010). Despite the potential of mHealth to improve healthcare delivery in HIV care, there has been a dearth of existing mHealth technology interventions to improve PLWH's self-management in the US. There is a significant need for mHealth apps to be developed for supporting symptom self-management for PLWH.

Moreover, the climate of mHealth technology development has been changing. Recent studies have shown that the development of many mHealth apps is driven by commercial interests more than being research focused (Martínez-Pérez, de la Torre-Díez, & López-Coronado, 2013), and commercial mHealth apps are more engaged by consumers even though the quality of information provided by the commercial mHealth apps is often rated as poor (Gabrielli et al., 2017; Pagoto, Schneider, Jojic, DeBiasse, & Mann, 2013; Zhang, Ho, Hawa, &

Sockalingam, 2016). Though commercial mHealth apps lack evidence-based content, they are often designed by using more engaging design features (e.g. aesthetics and interactive components) (Curtis, 2016). In order to address these gaps, collaboration between researchers and the commercial app industry is recommended (Curtis & Karasouli, 2014), highlighting the importance of using evidence-based health information as well as including engaging design principles for the development of mHealth technologies.

Usability

Definition of Usability

In the field of human-computer interaction, the notion of usability, the relationship between humans and computers, has been defined in a variety of ways by scholars (Nielsen, 1994). The term usability was originally derived from the term 'user friendly'; however, this term had acquired a host of undesirable vague and subjective connotations (Bevan, Kirakowski, & Maissel, 1991). Recently usability was defined as an attribute of software/system quality as well as a higher design objective (Folmer & Bosch, 2004b). The term usability was replaced with the term 'quality in use' (Bevan, 1995).

Shackel (1991)

Shackel was one of the first authors in the field of usability to recognize the importance of usability engineering and the relativity of the concept of usability (Shackel, 1991). He defines a model where product acceptance is the highest concept. Usability is defined as 'the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfill the specified range of tasks, within the specified range of scenarios' (Shackel, 1991). Shackel considers usability to have two facets. The first considers usability a property of the system relative to its users; therefore, evaluation is context dependent, resulting in a subjective perception of the product. The other relates to objective measures of interaction. For a system to be usable it has to achieve defined levels on the following scales:

- Effectiveness: performance in accomplishment of tasks
- Learnability: degree of learning to accomplish tasks
- Flexibility: adaptation to variation in tasks
- Attitude: user satisfaction with the system

Nielsen (1994)

Nielsen, another expert in the field of usability, recognized the importance of usability engineering, and also considers usability to be an aspect that influences product acceptance. Acceptability is differentiated, however, into practical and social acceptability. Nielsen identified five attributes of usability – efficiency, satisfaction, learnability, memorability, and errors (Nielsen, 1994b):

- Efficiency: Resources expended in relation to the accuracy and completeness with which users achieve goals.
- Satisfaction: Freedom from discomfort, and positive attitudes towards the use of the product.

• Learnability: The system should be easy to learn so that the user can rapidly start getting work done with the system.

• Memorability: The system should be easy to remember so that the casual user is able to return to the system after some period of not having used it without having to learn everything all over again.

• Errors: The system should have a low error rate, so that users make few errors during the use of the system and that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.

In addition, Nielsen defines 'utility' as the ability of a system to meet the needs of the user. He does not consider this to be part of usability, but a separate attribute of a system. A product fails to provide utility when it does not offer the features and functions required; the usability of the product becomes irrelevant as the system will not allow the user to achieve their goals.

ISO 9241 (1998) and ISO 9126 (2001)

The International Organization for Standardization (ISO) organization has developed various human-computer interaction and usability standards over the last decades (Folmer & Bosch, 2004b). According to the ISO, the concept of usability is defined as follows: 1) the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO 9241-11, 1998); 2) the capability of the software product to be understood, learned, used, and attractive to the user, when used under specified conditions (ISO/IEC 9126, 2001). *Table 2-1* displays the concepts related to usability and their definitions by ISO.

Table 0-1. Usability definition of International Organization for Standardization (ISO)

Usability	Concept	Definition
The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO 9241-11, 1998)	effectiveness	the accuracy and completeness with which users achieve specified goals
	efficiency	the resources expended in relation to the accuracy and completeness with which users achieve goals
	satisfaction	freedom from discomfort, and positive attitude to the use of the product
	context of use	characteristics of the users, tasks and the organizational and physical environments
The capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions (ISO/IEC 9126, 2001)	understandability	the capability of the software product to enable the user to understand whether the software is suitable, and how it can be used for particular tasks and conditions of use
	learnability	the capability of the software product to enable the user to learn its application
	operability	the capability of the software product to enable the user to operate and control it
	attractiveness	the capability of the software product to be attractive to the user
	usability compliance	the capability of the software product to adhere to standards, conventions, style guides or regulations relating to usability

In ISO 9126, usability compliance is one of five product quality categories, in addition to understandability, learnability, operability, and attractiveness, which the usability focuses on 'ease of use'. The ISO 9126 definition is closer to previous definitions of usability, such as Shackel (1984) and Nielsen (1993) where usability is identified with ease of use and learning, and excludes utility (Bevan, 2001). Meanwhile, the ISO 9241 definition includes not only utility but also computer efficiency and reliability, and uses the term 'quality in use' to describe usability more broadly (Bevan, 2001). 'Quality in use' is defined as 'the capability of the software product to enable specified users to achieve specified goals with effectiveness, productivity, safety, and satisfaction in specified contexts of use' (ISO/IEC 9126, 2001).

In this dissertation, we used the broader definition of usability – quality in use. We chose the term 'usability' as a more suitable one than 'quality in use' since there are critiques related to weaknesses in the ISO 9126, such as unclear architecture at the detailed level of the measures, overlapping concepts, lack of a quality requirement standard, lack of guidance in assessing the results of measurement, and ambiguous choice of measures (Abran, Khelifi, Suryn, & Seffah, 2003).

Usability Evaluation Methods

Usability evaluation is an elementary activity to test technologies. This method is a procedure composed of a set of well-defined activities for collecting usage data related to end-user interaction with a system, and/or how the specific properties of the system contribute to achieving a certain degree of usability (Fernandez, Insfran, & Abrahão, 2011; Heo, Ham, Park, Song, & Yoon, 2009). Based upon the specific definitions of usability described in the previous section in this dissertation, many evaluation tools and techniques have been used.

Zhang (2003) has identified three types of usability evaluation methods: 1) usability testing; 2) usability inspection; and 3) usability inquiry (Zhang, 2003). The usability testing approach requires representative users to work on typical tasks using the system or a prototype of the system (Folmer & Bosch, 2004a). The evaluators use the results to see how the user interface supports the users as they attempt their tasks. The usability inspection approach requires usability specialists or software developers, users, and other professionals to examine and judge whether each element of a user interface or prototype follows established usability principles. Usability inquiry requires usability evaluators to obtain information about users' likes, dislikes, needs, and understanding of the system by talking to them, observing them using the system in real work or letting them answer questions verbally or in written form. Commonly used methods at each type of usability evaluation are presented in *Table 2-2*.

In a review, Yen and Bakken (2012) categorized health IT usability study methods into the five stages of the system development life cycle described above (Stead et al., 1994), which was used to propose a three-level stratified view of health IT usability evaluation (Yen & Bakken, 2012). Those usability evaluation methods at each stage of the system development life cycle are displayed in *Table 2-3*.

Table 0-2. Usability evaluation methods by Zhang (2003)

Type of usability evaluation	Methods

Usability testing	Coaching method Co-discovery learning Performance measurement Question-asking protocol Remote testing Retrospective testing Teaching method Think-aloud protocol
Usability inspection	Heuristic evaluation Cognitive walkthrough Feature inspection Pluralistic walkthrough Perspective-based inspection Standards inspection/guideline checklists
Usability inquiry	Field observation Interviews/focus groups Surveys Logging actual use Proactive field study Questionnaires

Table 0-3. Usability evaluation methods by Yen and Bakken (2012)

System development life cycle stage	Type	Methods
Stage 1: Specify needs for setting and users	Task-based	Literature review for system criteria Log file analysis

	User-task	Focus group/expert panel/meeting Interview Observation Task analysis Card sorting
Stage 2: System component development	System-task	N/A
Stage 3: Combine components	User-task-system	Log analysis/observation Think-aloud protocol Cognitive walkthrough + think-aloud Heuristic evaluation Questionnaire Interview Focus group
Stage 4: Integrate system into setting	User-task-system-environment	Questionnaire Interview Focus group Observation Time-and-motion Chart review/log analysis
Stage 5: Routine use	User-task-system-environment	Questionnaire Interview Focus group Observation Task analysis Log analysis Time-and-motion Work-sampling

	Chart review/log analysis

Usability Evaluation of mHealth Technology

As mHealth apps have great potential to improve patients' self-management of HIV and other chronic diseases (Liang et al., 2011; Schnall, Bakken, Rojas, Travers, & Carballo-Dieguez, 2015), usability of the mHealth apps should be evaluated to ensure these apps are perceived as usable and useful by the intended end-users. In a recent systematic review investigating the usability of existing mHealth apps for self-management of chronic diseases for diverse populations, researchers found that many of the top-rated mHealth apps were not easy to use and the users struggled to complete basic tasks related to using the self-management tools, especially low-income and underserved users, who are the target audience (Hamine, Gerth-Guyette, Faulx, Green, & Ginsburg, 2015). Also, the study pointed out that the mHealth apps were not designed with the user's interests in mind. This demonstrates the gap between the potential and reality of mHealth technology for self-management, particularly with regards to underserved populations. The mHealth apps might be aesthetically appealing and give users the information they need for care management, but if the mHealth apps are too difficult to use, intended users will become frustrated and unwilling to use the apps for their symptom management (Hamine et al., 2015). Thus, it is necessary that researchers and IT designers pay attention to the usability of mHealth technologies (Brown et al., 2013). In other words, research is needed to ensure mHealth apps are appropriately designed and targeted to the end-users' needs before they are used for their symptom self-management.

It is of great importance that mHealth app developers be not only aware of various usability methods, but also able to quickly determine which method is best suited to every stage of the development of mHealth apps to be used on mobile platforms. In this dissertation, we sought to enhance the usability of an mHealth app for symptom self-management in PLWH, by applying a comprehensive evaluation framework with proper usability evaluation for mobile technologies. Based on the literature review of usability evaluation methods described above, we operationalized each of those levels using a card sorting technique at level 1, end-user usability testing and heuristic evaluation at level 2, and in-depth interviews/focus groups at level 3. A detailed description of these methods is presented in Chapter 3.

Methodology

This dissertation was comprised of a three-level usability evaluation as guided by a stratified view of health IT evaluation framework (*Figure 1-1*), in order to translate paper-based health information into an mHealth app for symptom self-management in underserved PLWH and to assess its usability. *Figure 3-1* displays an outline of the three-level usability evaluation. Level 1 of the study was intended to increase our understanding of a user-task interaction and design a prototype of mVIP. This was done through applying a user-centered design method, the card sorting technique. Second, we conducted a usability evaluation of the mVIP prototype in a laboratory setting to examine a user-task-system interaction. End-user testing and heuristic evaluation were used as the evaluation methods for achieving level 2. Additionally, we conducted a usability evaluation of the mVIP prototype in a real-world setting to explore a user-task-system-environment interaction at level 3. Level 3 of the study was done through in-depth interviews and focus groups in a three-month RCT. The Institutional Review Board of Columbia University Medical Center approved all study activities. In this chapter, methods including background, sample and recruitment, study procedures, data collection, and data analysis at each level are described.

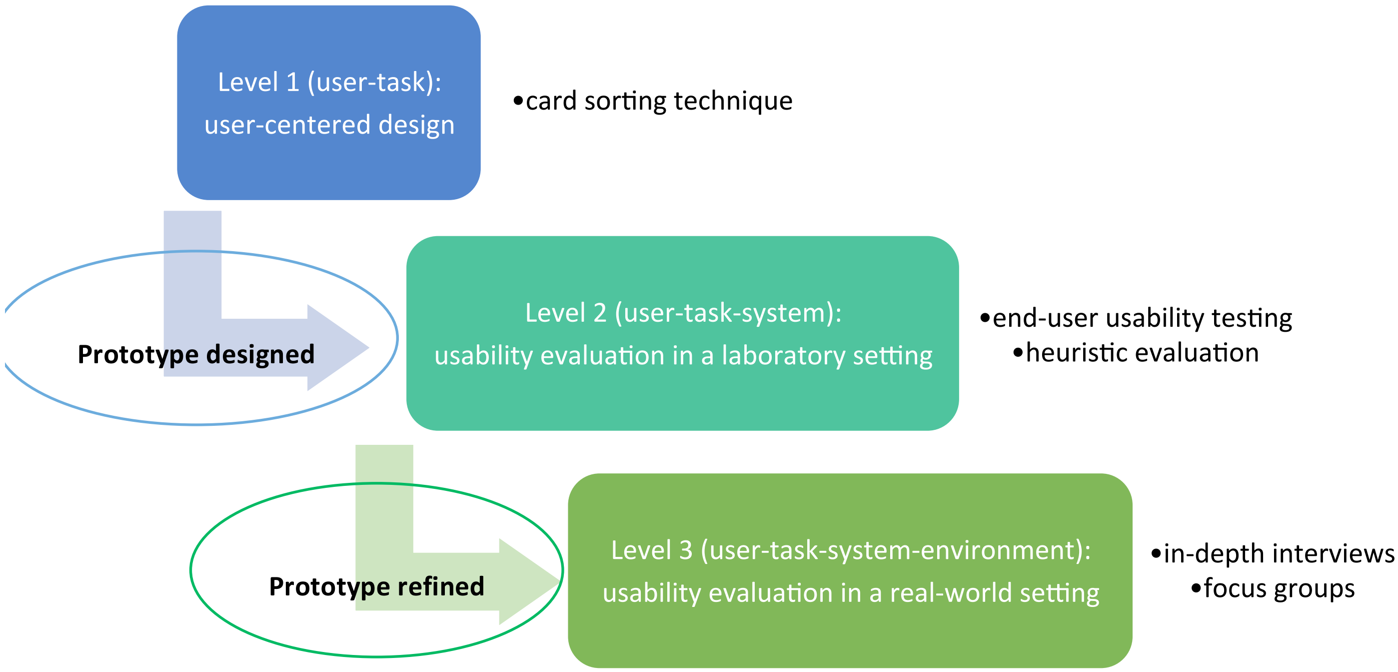

Figure 0-1. An outline of studies: a three-level usability evaluation

Level 1 (User-Task): User-Centered Design

The level 1 evaluation targeted the first aim of this dissertation to apply a user-centered design method to guide the information architecture of a prototype of mVIP. Integral to the user-centered design is the principle that having a thorough understanding of the end-user's needs and capabilities is essential to creating the most effective technology (Endsley, 2011). In order to explore the needs of underserved PLWH via a participatory design process at level 1, we used a card sorting technique. While there are various usability evaluation methods used to understand a user-task interaction (e.g. interviews, focus groups, or questionnaires), a card sorting technique is one of the most effective methods for acquiring categorical and hierarchical data about existing domains (Maiden & Rugg, 1996). As we had information of HIV-related symptoms and self-management strategies from a paper-based HIV/AIDS symptom management manual, a card sorting technique was the most appropriate approach for our user-centered design of the mVIP prototype.

Background of Methods

Card Sorting Technique

Card sorting is a user-centered design method that information architects use to gain an understanding of how users understand and model information (Nielsen, 1995; Paul, 2008). Card sorting applies to a variety of activities involving the grouping and/or naming of objects or concepts. These may be represented on physical cards, virtual cards on computer screens, or photos in either physical or digital form (Soegaard & Dam, 2005).

Card sorting methods are broadly classified as ‘open card sorting’, ‘closed card sorting’, and ‘reverse card sorting’, either online or in person (Paul, 2008; Soegaard & Dam, 2005). In an open card sort, participants create their own names for the categories. The open card sort is typically used to discover patterns in how participants classify, which in turn helps generate ideas for organizing information. In a closed card sort, participants are provided with a predetermined set of category names. They then assign the index cards to these fixed categories. The closed card sort is typically used to judge whether a given set of category names provides an effective way to organize content. Similar to the closed card sort but more specific, a reverse card sort (also called tree testing), tests an existing structure of categories and sub-categories. Users are given tasks and are asked to complete them by navigating a collection of cards. Each card contains the names of subcategories related to a category, and the user should find the card most relevant to the given task starting from the main card with the top-level categories. This ensures that the structure is evaluated in isolation, nullifying the effects of navigational aids, visual design, and other factors (Paul, 2008). The reverse card sort is used to determine whether a predetermined hierarchy provides a good way to find information.

In this dissertation, a reverse card sorting exercise was used to examine the most relevant symptoms and self-management strategies for PLWH as a user-centered design method. The reverse card sorting exercise was also used to further determine the hierarchy of symptoms and self-management strategies in mVIP. With an online card sorting study, researchers may miss out on the insights and comments users can provide in person (Hawley, 2008). For this reason, physical index cards were used in person for the reverse card sort in the level 1 study to give a clear picture of participants’ reactions and thought processes.

Methods

A reverse in-person card sorting exercise was conducted to guide the information architecture of a prototype of mVIP. During the reverse in-person card sorting exercise, users were presented with a pile of cards representing symptoms and self-management strategies. 154 self-management strategies for 13 symptoms, based on the HIV/AIDS symptom management manual with self-management strategies for PLWH (University of California, 2004), were used in the reverse card sorting exercise. The 13 symptoms and the number of self-management strategies included each symptom are list in *Table 3-1*.

Table 0-1. 13 symptoms used in the study and number of strategies included in each symptom

Symptom	# of self-management strategies
Anxiety	8
Cough/shortness of breath	12
Depression	9
Diarrhea	11
Dizziness	9
Fatigue	9
Fever	12
Forgetfulness	8
Insomnia	11
Nausea/vomiting	15
Neuropathy	11

Skin problems	17
Weight loss	22

Sampling and Recruitment

For the recruitment of participants, study flyers were posted and distributed at one HIV Medicaid clinic in New York-Presbyterian Hospital and four community-based organizations that predominantly serve minorities in New York City (NYC). In order to participate in this study, participants must: 1) be diagnosed with HIV/AIDS; 2) be over the age of 18; 3) be able to communicate in English; 4) have experienced at least two of 13 HIV-related symptoms in the past week; and 5) have met the cognitive state minimum score as measured by the Mini–Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). Since an mHealth app for HIV symptom self-management would be developed in English, participants in this study needed to be able to communicate in English. In a study of HIV-related symptom prevalence during the preceding six months in a nationally representative sample of HIV-infected adults in the US, the total number of symptoms per patient varied from 0 to 13 out of 14 HIV-related symptoms, and 50% of the population reported between two and seven symptoms (Mathews et al., 2000). Considering the prevalence of HIV-related symptoms among PLWH in the US, we recruited participants who experienced at least two symptoms in the prior seven days. For the cognitive state assessment, a modified version of the standard MMSE (Folstein et al., 1975) with six items was used, which included four domains of orientation, registration, attention/calculation, and recall.

Potential participants were screened over the telephone to determine initial eligibility. Additional eligibility criteria included technology skills. Since we used a survey software, Qualtrics®, to collect additional information (e.g. demographic information), participants were deemed to have adequate technology skills to participate in the study if they reported they could complete a survey using a computer. Participants who met the eligibility criteria were invited to participate in the study and asked to bring identification and documentation from a medical provider to confirm their HIV status.

Nielsen recommends at least 15 participants for a card sorting exercise. The correlation between the results from users and the ultimate results may increase from 0.90 (for 15 users) to 0.93 (for 20 users) (Nielsen, 2004). For more reliable results, 20 participants were recruited for this study.

Study Procedures

All participants were given an explanation of the study procedures with a consent form, which includes: purpose of the study, their rights as a participant, how the data they provided would be protected and used, and contact information for the research team. Participants were given the opportunity to ask questions about the study before providing written consent to participate.

A reverse in-person card sorting exercise consisted of three stages: 1) selecting symptoms, 2) organizing self-management strategies, and 3) adding comments. In the first stage, participants were provided with 13 index cards of symptoms and asked to select the index cards of symptoms they experienced in the past seven days. Participants were allowed to select as many index cards as the number of symptoms they experienced during the past week. In the second stage, participants were provided with index cards of self-management strategies for each symptom they chose in the first stage. The participants were then asked to place the index cards of self-management strategies in order of individual priority applicable to the selected symptom.

Additionally, participants were allowed to place the index cards of self-management strategies on an 'irrelevant or unhelpful' pile for any self-management strategies they thought were not relevant to the symptom, or any self-management strategies they were unwilling to try. In the third stage, participants were asked to add comments on a blank index card if needed.

Once participants completed the reverse card sorting exercise, they were asked to complete a survey administered via Qualtrics® comprised of a demographic questionnaire and technology use assessment. All participants received $25 at the completion of the study session as compensation for their time.

Data Collection

During the level 1 study, data were collected using a reverse in-person card sorting exercise and a survey at a private office at the Columbia University School of Nursing. All data collection activities took between one and two hours to complete for each participant. At the end of the reverse in-person card sorting exercise, all index cards including symptoms, self-management strategies, and comments added by participants were photographed. The pictures were kept on a strong password-encrypted computer only accessible to the researchers.

Demographic information on all of participants including age, gender, race/ethnicity, marital status, education level, current employment status, annual income, and health insurance provider was collected. Data on experiences of technology use, including use of both computers and mobile devices, were also collected. All of these data were collected through a Qualtrics® survey.

Data Analysis

A hierarchy analysis was conducted for establishing the rank order of symptoms and self-management strategies. Index cards showing self-management strategies for each symptom were randomly coded with a number (e.g. card_1, card_2, and card_3). For data analysis, an Excel spreadsheet was created for each of 13 symptoms. In each spreadsheet, the strategy index card codes were listed in the rows, and participants' study IDs were listed in the columns. We entered ordinal numbers of index cards (e.g. 1, 2, and 3) into the spreadsheet, followed by the order that participants placed the index cards of self-management strategies per each symptom. *Figure 3-2* depicts an example of the Excel spreadsheet created for our hierarchy analysis. The mean scores of the ordinal numbers of the index cards for self-management strategies were then calculated for each of the symptoms. A lower mean score indicates a higher priority order of self-management strategies for each symptom. Index cards in the 'irrelevant or unhelpful' pile and the index cards with added comments were reviewed.

	P_21	P_22	P_23	P_25	P_26	P_27	P_28	P_29	P_30	P_31	P_14	P_15	P_16	P_17	P_18	P_19	P_20	mean
Card 1	5	7	9	7	9	9	7	9	8	3	7	9	8	7	3	8	9	7.294117647
Card 2	2	5	1	6	2	4	3	4	6	6	4	4	3	4	1	4	4	3.705882353
Card 3	8	3	8	5	4	8	8	3	7	7	5	2	7	1	6	6	6	5.529411765
Card 4	1	4	5	2	5	5	5	2	3	5	3	6	4	5	8	3	3	4.058823529
Card 5	4	6	3	9	7	7	2	8	5	2	6	7	6	6	7	2	8	5.588235294
Card 6	3	8	4	3	3	2	6	1	2	8	8	8	5	8	2	5	7	4.882352941
Card 7	7	1	2	8	8	3	4	7	4	4	9	5	2	9	9	9	5	5.647058824
Card 8	6	2	7	4	1	6	1	6	1	1	2	1	1	2	4	7	1	3.117647059
Card 9	9	9	6	1	6	1	9	5	9	9	1	3	9	3	5	1	2	5.176470588

Figure 0-2. Spreadsheet created for a hierarchy analysis

SPSS version 24.0 (IBM Corp, 2015) was used for analysis. Demographic information and additional information including technology use were analyzed with descriptive statistics. Counts (*N*) and percentages were reported for categorical variables whereas continuous variables were expressed as means and standard deviations (*SD*s) and/or medians.

Level 2 (User-Task-System): Usability Evaluation in a Laboratory Setting

A prototype of mVIP was designed and implemented by software developers at Northwestern University based on findings from a card sorting study at level 1. Usability of this app was iteratively evaluated to ensure its quality in use. As a variety of usability evaluation methods have been used to detect usability problems related to technology, it is important to use the most appropriate evaluation methods. In the field of human-computer interaction, a combination of usability evaluation techniques from both expert and system end-user perspectives has been recommended to provide the most effective and thorough usability evaluation results (Yen & Bakken, 2009). Hence, level 2 consisted of two usability evaluations, one completed by intended end-users and another completed by usability experts, in order to achieve the second aim of this dissertation, which was to evaluate the usability of the mVIP prototype in a laboratory setting by exploring user-task-system interaction. The two usability evaluations conducted at level 2 were end-user usability testing and heuristic evaluation. The end-user usability testing examined task performance by intended end-users, and usability experts assessed the user interface through heuristic evaluation. These approaches were chosen since they are two methods most frequently used to guide system modification (Lai, 2007). A study comparing usability evaluation methods found that heuristic evaluation performed by usability experts revealed more general interface design problems, while end-users' think-aloud protocols identified more obstacles to task performance (Yen & Bakken, 2009). The usability evaluation methods used in level 2 are described below. These methods include think-aloud protocols and eye-tracking method for evaluation by end-users, and heuristic evaluation by usability experts.

Level 2-1. End-User Usability Testing

Background of Methods

Think-Aloud Protocols

Think-aloud protocols were developed by Lewis in 1982 and are a standard data collection method imported from the cognitive sciences and applied to translation research (Lewis, 1982). Think-aloud protocols have been widely used to gather information about the cognitive behavior of humans performing tasks in usability testing for system design and development (Nielsen, 1993; van den Haak, De Jong, & Jan Schellens, 2003). The basic principle of this method is that potential users are asked to complete a set of tasks using a system while continuously thinking out loud and verbalizing their thoughts as they perform the tasks (Nielsen, 1993). This method is popular since it has been thought to directly provide insight into users' thoughts and strategies during the task performance (Ericsson & Simon, 1980; Haak & Jong, 2003). By applying think-aloud protocols, researchers can identify the information utilized during problem solving processes and determine how that information is used to facilitate problem resolution (Fonteyn, Kuipers, & Grobe, 1993). As the data obtained reflect the actual use of an artifact, the method has high face validity (van den Haak et al., 2003).

Think-aloud protocols are generally categorized into concurrent and retrospective protocols (Ericsson & Simon, 1980). In a concurrent think-aloud protocol, users are asked to think and talk aloud at the same time while performing cognitive tasks. It is considered to be consistent and complete because it provides direct verbalization of cognitive processes. In a retrospective think-aloud protocol, users are asked to recall what they were thinking during a prior experience completing tasks. Since it involves the retrieval of information from past experiences, the latter could provide a more complete description of one's reasoning in performing tasks.

Eye-Tracking

Eye-tracking is the process of measuring either the point of gaze – where one is looking – or the motion of one's eye relative to the head (Coster & Norman, 2009). The two measurements of eye-tracking include fixation and saccade. Fixation refers to the moments when the eyes are relatively stationary, indicating the moments when the brain is processing information received by the eyes (Asan & Yang, 2015; Poole & Ball, 2005). Different patterns of fixation indicate different forms of human information processing (Asan & Yang, 2015). For example, high fixations usually indicate an area of great interest, which attracts the user's attention, whereas an extremely long fixation indicates uncertainty and difficulty with information processing, and successive fixations are indications of inefficient visual search (Asan & Yang, 2015; Velazquez & Pasch, 2014). Another measurement, saccade, is defined as a rapid eye movement from one target to another between two consecutive fixations (Lai et al., 2013). Typically, it is assumed that the eyes remain in place until some critical cognitive event occurs, at which time a saccade is initiated (Yang & McConkie, 2001).

For these two measurements, eye-tracking technology focuses on the pupil of one's eye and determines the direction and concentration of the gaze. The eye-tracking technology collects and uses data about these actions to generate two different types of visualizations: heat maps and gaze plots (Heaven & Maguire, 1998). Heat maps display three-dimensional data in two dimensions, with the third dimension represented by color (Freedman & Osicka, 2008), where the observed areas and unobserved areas on an interface appear in different colors (Asan & Yang, 2015; Heaven & Maguire, 1998). The heat maps represent where the person directed his/her gaze and how long they concentrated on a given point. Generally, the color scale moving from blue to red indicates the duration of focus (Heaven & Maguire, 1998). For example, a red spot over an area of the screen indicates the user focused on that area for a longer period of time. Another type of visualization is a gaze plot. Gaze plots trace the eye's movement between areas of focus (Heaven & Maguire, 1998). The gaze plots display gaze motions by representing the sequence of saccades and fixations in the form of a scan path (Asan & Yang, 2015). The data collected from the eye movements are presented as red circles and lines. Here, the red circle indicates the area of focus, while the red line indicates the movement between foci. In this dissertation, a gaze plot was used for eye movement analysis, which is described in Chapter IV. Each example of a heat map and a gaze plot displays in *Figure 3-3* and *Figure 3-4*.

Figure 0-3. Heat map

Figure 0-4. Gaze plot

End-User Usability Testing: An Eye-Tracking and Retrospective Think-Aloud Method

The eye-tracking data described above can be integrated and synthesized in usability testing; therefore, the use of eye-tracking data has the potential to improve usability of health IT, including mHealth technologies (Asan & Yang, 2015). In usability testing, eye-tracking makes it possible to gain more insights into human behavior, find more usability errors, and produce compelling and incontrovertible physiological data (i.e. ocular data) since real-time eye-tracking data provide for a better observation experience (Cooke, 2006; Lorigo, Haridasan, Brynjarsdóttir, & Xia, 2008). It is hard to understand the precise cognitive reasons behind a participant's gaze patterns based solely on the eye-tracking data; therefore, it is strongly suggested that researchers integrate qualitative research methods (Asan & Yang, 2015). Eye-tracking data can be used to provide a cue to participants to improve the quality of data from think-aloud protocols, as the protocol analysis of thinking aloud alone does not provide sufficient information for whether a specific screen element was found, or whether the element's meaning was unclear (Karn, Ellis, & Juliano, 1999). The think-aloud method provides subjective information regarding the user's experience, whereas eye-tracking data collected represent an objective indication of eye movements. Thus, an integrated approach of the think-aloud method with eye-tracking was proposed for end-user usability testing in order to improve the validity of usability data in this dissertation.

A concurrent think-aloud protocol is the predominant data collection method in usability testing, compared to the retrospective think-aloud protocol (Nielsen, Clemmensen, & Yssing, 2002). Nonetheless, the concurrent think-aloud protocol has received criticism since the verbal process requires attention and thus may distract the participants, causing them to feel uncomfortable and make more errors (Hertzum & Holmegaard, 2015; Nielsen et al., 2002).

Specifically, in usability testing, the participants may not be proficient at verbalizing their thoughts, even after they have been trained in speaking as they concurrently perform tasks (Cooke, 2006). Furthermore, the concurrent think-aloud protocol has limitations when used in conjunction with eye-tracking data. Since users might be tempted to look at the researcher for conversation during the concurrent think-aloud protocol, it has the risk of disrupting the calibration of eye-tracking technology and thus causing loss of eye-tracking data (Asan & Yang, 2015; Bavelas, Coates, & Johnson, 2002). While uncommon, in a retrospective think-aloud protocol, users' eye movements are recorded while they use the system and then they are asked to verbalize their thoughts afterward while watching a replay of their eye movements (Elling, Lentz, & Jong, 2011). To avoid interference with task performance and to avoid the risk of losing eye-tracking data, a retrospective think-aloud protocol was chosen for our end-user usability testing, which was combined with eye-tracking data at the level 2 study of this dissertation. The retrospective think-aloud protocol with eye-tracking has been found to be valid and reliable in a usability evaluation (Elling et al., 2011).

Methods

This end-user usability testing of a prototype of mVIP was guided by a theoretical framework. The theoretical framework used is the Health IT Usability Evaluation Model (Health-ITUEM) developed by Yen (2010) (*Figure 3-5*) (Yen, 2010). The Health-ITUEM is an integrated model of multiple usability theories and produces a robust usability evaluation framework, which includes nine concepts informed by four constructs: perceived usefulness, perceived ease of use, effectiveness, and efficiency. The nine concepts composing the framework include error prevention, completeness, memorability, information needs, flexibility/customizability, learnability, performance speed, competency, and other outcomes (Yen, Wantland, & Bakken, 2010). Definitions of the nine concepts of Health-ITUEM are presented in the data analysis section. Usefulness of the Health-ITUEM in understanding usability issues related to mHealth technology has been demonstrated (Brown et al., 2013).

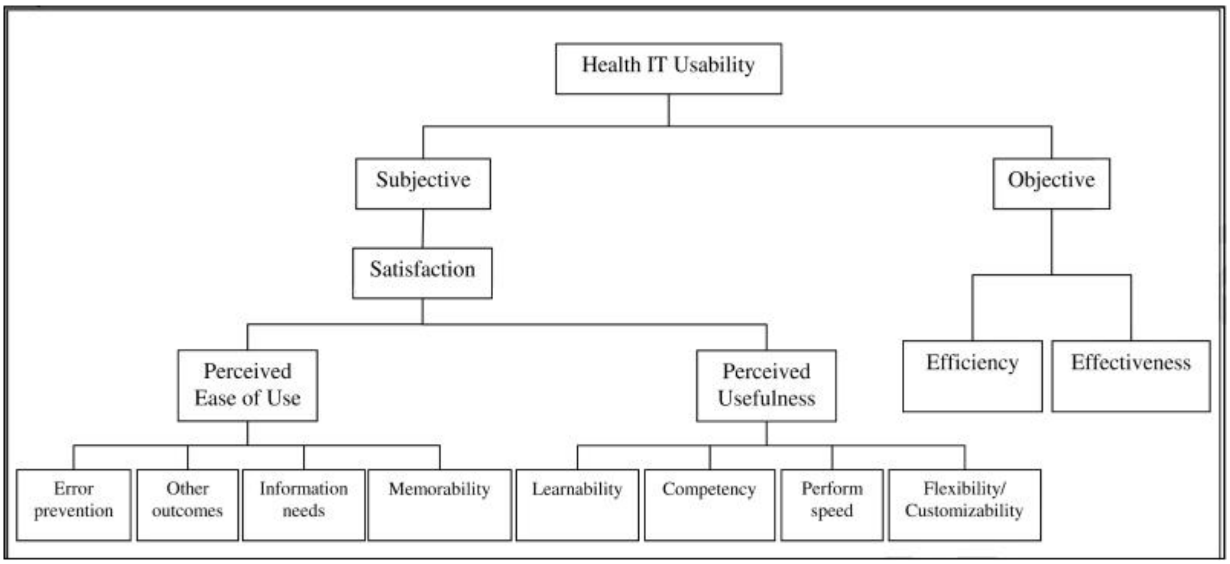

Figure 0-5. Health IT Usability Evaluation Model (Health-ITUEM)

Based on the usability evaluation framework, we executed end-user usability testing with an eye-tracking and retrospective think-aloud method to evaluate the usability of the mVIP prototype in a laboratory setting. This method enabled examination of task performance (user-task-system interaction). The mVIP prototype included 151 self-management strategies for 13 symptoms based on findings from a card sorting technique in level 1 of the study. Upon logging into the mVIP prototype, users were guided by an avatar through a series of questions ascertaining the nature and severity of their symptoms. The avatar then recommended targeted self-management strategies for addressing the user's self-reported symptoms.

Since the mVIP prototype was developed with the most widely used versions of Android and iOS, the two types of smartphones used in this end-user usability testing were: 1) Samsung Galaxy Core Prime™ (4.5 inch touchscreen display); and 2) iPhone 4S (4 inch touchscreen display). All features of the mVIP prototype between the Android and iPhone were the same. An eye tracker, Tobii Pro X2-60, and Tobii Pro Studio Version 3.2.3 (Tobii Technology, Stockholm, Sweden) were used to track eye movements. This technology has a sampling rate of 60 Hz (meaning 60 gaze points were collected per second for each eye). A mobile device stand designed to be compatible with both of the two smartphone types used held the smartphones during eye-tracking (Tobii Technology, Stockholm, Sweden). *Figure 3-6* depicts the mobile device stand with an eye tracker and a mobile device (Tobii Technology, Stockholm, Sweden).

Figure 0-6. Mobile device stand with eye tracker and mobile device (Tobii Pro™)

Sampling and Recruitment

We recruited participants through flyers posted at one HIV Medicaid clinic and one oral health clinic in New York-Presbyterian Hospital as well as at six neighboring community-based organizations in NYC. Eligible participants met the following criteria: 1) diagnosed with HIV/AIDS; 2) over the age of 18 years; 3) able to communicate in English; 4) reported having experienced at least two out of 13 HIV-related symptoms in the past seven days; 5) met the cognitive state minimum score as measured by MMSE (Folstein et al., 1975); and 6) identified as a heavy smartphone user. Eligibility was determined during an initial telephone screening. In this end-user usability testing, participants who indicated familiarity with smartphones during the telephone screening were asked technology-related questions including whether they owned a smartphone, the frequency of their smartphone use, their app downloading habits, and the time period that they have owned a smartphone. A smartphone heavy user in this study was defined as a person who has used a smartphone for more than one year and who also used a mobile app more than three hours per day on average (Cáliz & Alamán, 2014). This could help us ensure that usability issues identified from this study would occur not from participants' lack of technology skills, but from shortcomings with the app related to its usability. Participants who wore bifocal or progressive glasses were excluded during the pre-enrollment screening, since these types of glasses could affect the accuracy and the precision of the gaze estimation while collecting participants' eye-tracking data (Tobii Technology). PLWH who participated in the card sorting technique did not participate in the end-user usability testing.

In a study examining benefits of increased sample sizes in usability testing, researchers found that the minimum percentage of problems identified rose from 82% up to 95% when the number of users was increased from 10 to 20 (Faulkner, 2003). Hence, we recruited total 20 PLWH as follows: 10 PLWH for an Android group and 10 PLWH for an iPhone group for the end-user usability testing. Based on the type of smartphone participants owned, eligible participants were assigned into either the Android group or iPhone group.

Study Procedures

Once positive HIV status was confirmed, the purpose of this study, study procedure, and retrospective think-aloud protocol were explained to participants. Participants were asked to sign a consent form and turn off their smartphones. Participants were introduced to the eye tracker and smartphone, then asked to sit down at the desk with the equipment. Once participants were ready, the eye tracker (e.g. Tobii Pro X2-60) was calibrated with a five-point where the participant watched a green circle move across the screen and pause at one of five fixed points. With the moving calibration test, the accuracy was provided within 0.5 degrees providing an error of less than 0.5 cm between measured and intended gaze points (Tobii Technology). Participants were advised to remain as still as possible during the testing in order for the eye tracker to avoid losing the eye movements. *Figure 3-7* depicts a sample picture of the eye tracker calibration.

Figure 0-7. Sample picture of eye tracker calibration (taken of a research team member with permission)

End-user usability testing consisted of the following three processes: 1) eye-tracking app testing; 2) think-aloud protocol, and 3) survey. First, participants were provided with a use case scenario designed to determine usability of the mVIP prototype and asked to complete two app sessions using the mVIP prototype (*Appendix A*). The tasks in the first app session were: 1) log in to mVIP; 2) update the password to XXX; 3) start the app session to get some strategies on how to self-manage the two symptoms of 'feel fatigued', and 'difficulty falling or staying asleep'; and 4) review strategies provided after completing the app session. The tasks in the second app session were: 1) log in to mVIP; 2) review the strategies previously provided; and 3) start a session to get more strategies on how to self-manage the symptom of 'trouble sleeping' since you do not have 'fatigue' anymore. *Figure 3-8* depicts a sample picture taken during the app testing. While participants were completing the tasks, their eye movements and smartphone screen were video-recorded using the eye tracker. All participants were allowed to ask any questions related to the testing before starting the tasks. After completing the tasks, participants were asked to watch a recording of their task performance that depicted their eye movements overlaid on the app screen. They were encouraged to think aloud retrospectively. They were also asked to verbalize their thoughts about the tasks they completed, including whatever may come to mind, while watching the recording. All verbalizations were audio-recorded. Participants were asked to complete the following survey administered via Qualtrics: a demographic questionnaire, health literacy assessments, technology use assessment, and user satisfaction assessment. Participants were compensated with $40.

Figure 0-8. Sample picture of eye-tracking app testing (taken of a research team member with permission)

Data Collection

During the end-user usability testing, data were collected at a private office at the Columbia University School of Nursing, where study equipment, including an eye tracker and smartphone, was set up. The overall study activities took between 2-2.5 hours to complete for each participant.

Eye-tracking data and audio/video-recordings were collected using Tobii X2-60 with a mobile device stand with embedded camera and microphone and saved into a software, Tobii Pro Studio (Tobii Technology, Stockholm, Sweden). The software with data was kept on a strong password protected computer.

All data from surveys were collected electronically using the survey software, Qualtrics®. Data on demographics and technology use were collected. In order to identify the ability of PLWH to read and understand health-related materials needed to make appropriate health decisions (Berkman et al., 2004), data on health literacy were collected using the Short Test of Functional Health Literacy in Adults (S-TOFHLA) (Baker, Williams, Parker, Gazmararian, & Nurss, 1999) and the Newest Vital Sign (NVS) (Weiss et al., 2005). The S-TOFHLA is a shorter version of a practical measure of functional health literacy, and can take seven to eight minutes to administer (Baker et al., 1999). The S-TOFHLA includes two reading comprehension passages with 36 missing words; the first passage is at the 4th grade reading level and the second passage is at the 10th grade reading level. Scores on the S-TOFHLA range from 0-36 and are divided into three categories of health literacy: inadequate (0-16), marginal (17-22), and adequate (23-36). The NVS was developed in 2005 as a new screening instrument to assess level of health literacy (Weiss et al., 2005). The NVS consists of a nutrition label and six questions based on the information provided in the nutrition label, and takes approximately three minutes to administer. Scores of 0-1 suggest high likelihood (50% or more) of limited literacy, scores of 2-3 indicate the possibility of limited literacy, and scores of 4-6 almost always indicate adequate literacy.

Data on user-perceived satisfaction were collected using the following two instruments: Health IT Usability Evaluation Scale (Health-ITUES) (Yen et al., 2010) and Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 2002). The Health-ITUES, derived from a theoretic framework of the Health-ITUEM in this level 2 study, is a customizable questionnaire with a four-factor structure: quality of work life, perceived usefulness, perceived ease of use, and user control. At the Health-ITUES development, 'quality of work life' referred to the system impact on work life (Yen et al., 2010); in this dissertation, the quality of work life represents the system impact on daily life and has been re-named 'quality of life'. The Health-ITUES consists of 20 items rated on a 5-point Likert scale from strongly disagree (1) to strongly agree (5). A higher scale value indicates higher perceived usability of the technology. Items customized for this study are illustrated in *Appendix B*. We also used PSSUQ version 3, consisting of a 16-item usability questionnaire. The PSSUQ items produce an overall score as well as three subscales: system quality, information quality, and interface quality. Each item is measured on a 7-point Likert scale. Responses range from strongly agree (1) to strongly disagree (7). A lower score indicates higher perceived usability.

Data Analysis

Data analysis was based on the Tobii Pro recordings, including audio/video-recordings of eye movements and the smartphone screen, collected during the eye-tracking app testing and think-aloud protocol. Gaze plots were created from screen-recordings synchronized with eye movements. Transcripts were made of the participants' vocalizations from the audio-recordings. Notes of critical incidents, characterized by comments, silence, repetitive actions, and error messages participants had received during the app testing, were compiled from the audio/video-recordings. Three data analyses were performed with the purpose of making objective, replicative, and valid inferences from the data. These analyses included: task performance and time analysis, eye movement analysis, and content analysis. SPSS version 24.0 (IBM Corp, 2015) was used for analysis related to descriptive statistics.

Task performance and time analysis

Screen-recordings were reviewed for analyzing participants' task performance through identification of task completion and trouble completing tasks during the eye-tracking app testing. Time stamps of the start and end of each task were captured, and mean task performance time was calculated. The mean performance time of each task was compared among participants with/without trouble using a two-sample t-test. Comparison of the mean of total amount of time spent on all task performance between participants with more/less mobile device experience was also conducted using a two-sample t-test. A p-value less than 0.05 was considered to be statistically significant.

Eye movement analysis

Gaze plots depicting participants' eye movement were reviewed in conjunction with notes of critical incidents. The gaze plots were compared among participants with/without trouble.

Content analysis

Transcripts were reviewed and free text was excerpted from the transcripts. The free text was coded based on nine concepts of our framework model, Health-ITUEM (*Figure 3-5*). The nine concept codes were broken into positive, negative, and neutral codes (i.e. a total of 27 codes). Concept codes for identifying positive sentiment were designated with a plus sign (+), negative sentiment concept codes were designated using a minus sign (−), and neutral codes had no sign. The description of the nine concepts and a total of 27 codes of the Health-ITUEM concepts is presented in *Table 3-2*. Once the initial coding framework was identified based on the Health-ITUEM concepts, two reviewers examined 10% of the free text together to clarify the coding framework and determine agreement on the coded data. Any questions about the framework and potential disagreements about the coding were discussed until a resolution was reached. The remaining data were then coded independently according to the framework. Codes were later compared and consensus reached when there were differences in initial coding, with a third consulted in instances of uncertainty or discrepancy.

Table 0-2. Description of nine concepts and 27 codes of Health-ITUEM

Title	Description

Error prevention	System offers error management, such as error messages and error correction through an undo function, or error prevention, such as instructions or reminders, to assist users performing tasks
+ Error prevention	Positive occurrence or response related to Parent Code Error prevention
- Error prevention	Negative occurrence or response related to Parent Code Error prevention
Completeness	System is able to assist users to successfully complete tasks. This is usually measured objectively by system log files for completion rate
+ Completeness	Positive occurrence or response related to Parent Code Completeness
- Completeness	Negative occurrence or response related to Parent Code Completeness
Memorability	Users can easily remember how to perform tasks through the system
+ Memorability	Positive occurrence or response related to Parent Code Memorability
- Memorability	Negative occurrence or response related to Parent Code Memorability
Information needs	The information content offered by the system for basic task performance, or to improve task performance
+ Information needs	Positive occurrence or response related to Parent Code Information needs
- Information needs	Negative occurrence or response related to Parent Code Information needs
Flexibility/Customizability	System provides more than one way to accomplish tasks, which allows users to operate system as preferred
+Flexibility/Customizability	Positive occurrence or response related to Parent Code Flexibility/Customizability

-Flexibility/Customizability	Negative occurrence or response related to Parent Code Flexibility/Customizability
Learnability	Users are able to easily learn how to operate the system
+ Learnability	Positive occurrence or response related to Parent Code Learnability
- Learnability	Negative occurrence or response related to Parent Code Learnability
Performance speed	Users are able use the system efficiently
+ Performance speed	Positive occurrence or response related to Parent Code Performance speed
- Performance speed	Negative occurrence or response related to Parent Code Performance speed
Competency	Users are confident in their ability to perform tasks using the system, based on Social Cognitive Theory
+ Competency	Positive occurrence or response related to Parent Code Competency
- Competency	Negative occurrence or response related to Parent Code Competency
Other outcomes	Other system-specific expected outcomes representing higher level of expectations (uses of non-phone app technology (e.g. phone, books), non-mobile resources (e.g. parents, friends, siblings), other health-related entities not directly related to the usability of mHealth (outside of study protocol))
+ Other outcomes	Positive occurrence or response related to Parent Code Other outcomes
- Other outcomes	Negative occurrence or response related to Parent Code Other outcomes

Level 2-2. Heuristic Evaluation

Background of Methods

Heuristic Evaluation

Heuristic evaluations are a usability inspection method commonly used in the field of human-computer interaction (Holzinger, 2005; Nielsen, 1994b). Heuristic evaluations, proposed by Nielsen, are assessments conducted by a small group of evaluators against a pre-established set of guidelines, called heuristics (Nielsen, 1994b, 2005). Nielsen's set of usability heuristics are detailed in *Table 3-3*.

Table 0-3. Nielsen's 10 usability heuristics

Usability Factor	Heuristics
Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within a reasonable time.
Match between system and the real world	The system should speak the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. The system should also follow real-world conventions, making information appear in a natural and logical order.
User control and freedom	Users often choose system functions by mistake and will need a clearly marked 'emergency exit' to leave the unwanted state without having to go through an extended dialogue. The system should support undo and redo functions.
Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Thus, the system should follow platform conventions.
Error prevention	Even better than good error messages is a careful design which

	prevents a problem from occurring in the first place. The design should eliminate error-prone conditions or check for them, and present users with a confirmation option before they commit to any action.
Recognition rather than recall	The system should minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
Flexibility and efficiency of use	Accelerators may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. The system should allow users to tailor frequent actions.
Aesthetic and minimalist design	Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Heuristic evaluators, who are generally experts in the field of human-computer interaction, examine a user interface and judge its compliance with recognized usability principles. In order to ensure independent and unbiased evaluations from each evaluator, heuristic evaluation is performed by having each individual evaluator inspect the interface independently. During the evaluation session, the evaluator goes through the interface several times to inspect various dialogue elements and compares them with a checklist of general heuristics. In addition to the checklist, the evaluator may also provide feedback on any additional usability issues that come to mind that may be relevant for any specific dialogue element. Bright et al. developed a heuristic evaluation form based on Nielsen's 10 heuristics (Bright, Bakken, & Johnson, 2006). In level 2-2 of the study detailed in this dissertation, a paper-based heuristic evaluation form was used to facilitate experts' evaluation.

Methods

A heuristic evaluation was conducted by usability experts to evaluate the usability of a web version of the mVIP prototype, which was designed specifically to assess the user interface. Due to the timeframe related to the development process, the mVIP prototype was designed first and was followed by the web version of the prototype. The web-based mVIP prototype was a temporary version that could be used on a computer, which was utilized exclusively for the heuristic evaluation. The web version worked the same as the mVIP prototype used during the end-user usability testing, and included the same 151 self-management strategies for 13 symptoms.

Sampling and Recruitment

Since all the participants in a heuristic evaluation are experts, a sample size of three to five participants is considered acceptable, as no additional information is likely to be collected with a larger sample (Nielsen, 1993). Hence, five usability experts in informatics were invited via email to participate in the heuristic evaluation of the web version of the mVIP prototype. As the quality of the heuristic evaluation is dependent on the skills and experience of the usability experts (Po, Howard, Vetere, & Skov, 2004), each expert must be at minimum Master's prepared in the field of informatics and have had training in human-computer interaction.

Study Procedures

Heuristic evaluators were provided with the same use case scenario used in end-user usability testing. Each heuristic evaluator was encouraged to explore the user interface of the web version of the mVIP prototype at least twice, and to think/talk aloud while they performed the evaluation. The process was recorded using Morae software™ (TechSmith Corporation, Okemos, MI), which enables the researcher to record and analyze the audio-recording and screenshots captured during the heuristic evaluation (TechSmith, 1995). Following completion of the tasks, heuristic evaluators were asked to rate the severity of each factor that violated the usability principles. Severity of identified usability problems was categorized into five categories: no usability problem (0), cosmetic problem only (1), minor usability problem (2), major usability problem (3), and usability catastrophe (4). They were also asked to provide additional comments regarding the user interface. At the completion of the surveys, heuristic evaluators received $150 as compensation.

Data Collection

During the heuristic evaluation, experts' verbal comments of the heuristics and screenshots were collected and recorded using Morae software™ (TechSmith, 1995) at a private office or conference room at the Columbia University School of Nursing. The severity of the identified heuristic violations and additional comments were collected using a paper-based heuristic evaluation form (Bright et al., 2006). All data from surveys were collected electronically using the same instruments utilized in the end-user testing, Qualtrics®. The data collection activities took between 2-2.5 hours to complete per evaluator.

Data Analysis

All experts' comments about usability problems on a heuristic evaluation form were compiled and reviewed. Transcriptions made of the experts' vocalizations from the audio-recordings collected using Morae software™ (TechSmith, 1995), were reviewed and content-analyzed according to the usability factors of Nielsen's 10 heuristics. Descriptive statistical methods were used to characterize the study sample and to analyze the severity of the usability factors collected using a heuristic evaluation form, using SPSS version 24.0 (IBM Corp, 2015). The mean severity scores of the identified heuristic violations were calculated for each heuristic principle.

Level 3 (User-Task-System-Environment): Usability Evaluation in a Real-World Setting

Once a prototype of mVIP was refined based on findings from the end-user usability testing and heuristic evaluation at level 2, a three-month RCT was conducted to explore the feasibility of using the refined mVIP prototype for PLWH to improve their HIV-related symptoms. In the RCT, PLWH in the intervention group were provided with self-management strategies for self-reported symptoms through the app, while PLWH in the control group were not provided with any self-management strategies. As part of the study, usability of the mVIP prototype was evaluated through in-depth interviews and focus groups at the end of the three-month RCT. This level 3 evaluation targeted the third aim of this dissertation, to evaluate the usability of the mVIP prototype in a real-world setting in order to explore in-depth understandings of users' experiences, perceptions, and satisfaction by identifying user-task-system-environment interactions. Interviews and focus groups are the most common methods for data collection in qualitative health research to gain in-depth insights (Harrell, 2009). We utilized in-depth interviews to gain individual-level insights and focus groups to gain group-level insights regarding usability of the app.

Background of Methods

In-Depth Interviews

An in-depth interview is a qualitative technique designed to explore personal and sensitive themes (Tong, Sainsbury, & Craig, 2007). In an in-depth interview, researchers encourage participants to talk about the research topic by asking open-ended questions. This technique is effective to elicit a vivid picture of the individual perspective on the research topic (Milena, Zaharia Rodica, & Grundey, 2008).

Focus Groups

Focus groups are an informal qualitative technique used to assess user needs and feelings after the interface has been in use for some time (Nielsen, 1993). Focus groups are carefully planned discussions, designed to obtain the perceptions of group members on a defined area of interest (Kontio, Lehtola, & Bragge, 2004). In a focus group, several users are brought together to discuss their attitudes and feelings toward the topic over a period of about two hours, with a moderator facilitating the discussion using a preplanned script (Nielsen, 1993). The size of a focus group often ranges between six and 12 individuals (Guest, Namey, & McKenna, 2017).

Thus, in-depth interviews and focus groups are considered best suited for exploring and gaining an in-depth understanding of end-users' experiences, opinions, expectations, wishes, and concerns, especially after they have used the technologies in a real-world setting.

Methods

The same theoretical framework used during the end-user usability testing, Health-ITUEM (*Figure 3-5*), was used for the planning and evaluation of level 3 of the study. Based on the framework, in-depth interviews and focus groups were conducted at the end of the three-month RCT to explore the feasibility of using a prototype of mVIP in underserved PLWH. The interviews and focus groups were intended to evaluate the usability of the mVIP prototype in a real-world setting, by exploring in-depth understandings of users' experiences, perceptions, and satisfaction of mVIP prototype use. The prototype included a set of symptoms and self-management strategies that was modified based on findings from the end-user usability testing and heuristic evaluation in the level 2 study (i.e. 143 self-management strategies for 13 symptoms). Once users logged into the mVIP prototype, an avatar guided them through a series of questions related to HIV-related symptoms. Based on the nature and severity of their symptoms (e.g. did you have fatigue in the past seven days? If yes; how much did it bother you?), the avatar recommended targeted self-management strategies with videos to participants in the intervention group, whereas the avatar did not recommend any of the strategies/videos to participants in the control group.

Sampling and Recruitment

For the recruitment of participants for the three-month RCT, flyers were posted and distributed at one HIV Medicaid clinic, one HIV dental clinic in New York-Presbyterian Hospital, and at 10 NYC community based organizations. In order to participate in the RCT, individuals must: 1) be diagnosed with HIV/AIDS; 2) be over the age of 18; 3) be able to communicate in English; 4) have experienced at least two of 13 HIV-related symptoms in the past week; 5) have met the cognitive state minimum score measured by MMSE (Folstein et al., 1975), and 6) own a smartphone or tablet. Using the same process of recruitment as used in the previous studies, potential participants were screened over the telephone to determine initial eligibility. The criterion that participants own a mobile device (e.g. a smartphone or tablet) ensures they would be able to use the mVIP prototype in a real-world setting. 80 PLWH who fulfilled the eligibility criteria were recruited into the three-month RCT and were randomly assigned into either an intervention or control group in a 1:1 ratio (e.g. 40 PLWH in the intervention and 40 PLWH in the control group). As a single-blinded study, the allocation sequence of participants was concealed so that participants were unaware of which group they were allocated to.

Among the participants who completed the three-month RCT, purposive sampling was used for in-depth interviews and focus groups. For in-depth interviews, we intended to recruit a total of 12 participants: 1) two light users from each of the two study groups (e.g. intervention and control groups), 2) two moderate users from each study group, and 3) two heavy users from each study group. In this study, a moderate user was defined as a participant who completed 10-14 sessions of responding to the set of questions using the mVIP prototype during the three-month RCT (i.e. every week or almost every week). A light user was defined as a participant who completed fewer than 10 sessions, and a heavy user was defined as a participant who completed more than 14 sessions. In a study of individual interviews about environmental risks, the first five to six interviews produced the majority of new data, and little new information was gained as the sample size approached 20 interviews (Scheufele & Scheufele, 2003). For focus groups, it is recommended each focus group consists of six to 12 participants (Guest et al., 2017). In order to get six to 12 participants per focus group, we over-recruited to control for cancellations and no-shows, scheduling 12-14 participants for each focus group session as recommended by previous researchers (Seal, Bogart, & Ehrhardt, 1998). As empirical findings in the existing literature revealed three focus groups were enough to identify all of the most prevalent themes within the data set (Guest et al., 2017), we included three focus groups among participants assigned to the intervention group, and one focus group for those assigned to the control group. As in-depth interviews were intended to gain individual-level insights and focus groups were intended to capture group-level insights, participation in both the in-depth interviews and focus groups was allowed.

Study Procedures

At the baseline visit of the three-month RCT, participants were provided with a link to the mVIP prototype and a username to access their account via email. Participants set their own password within the app. After participants completed a session using the mVIP prototype on their own mobile device, they were asked to complete a survey administered via Qualtrics® consisting of a demographic questionnaire, health literacy assessments, technology use assessment, and user satisfaction assessment. Participants were asked to complete an app session of the mVIP prototype on their mobile device for three months, with frequency of use dependent on personal preference, but at least once a week. While participants in both groups were asked to report their symptoms using the mVIP prototype, participants in the intervention group received self-management strategies based on the symptoms that they reported and additionally answered questions regarding the helpfulness of the strategies they received in previous sessions. Participants received a reminder email if they had not completed a session of the mVIP prototype in more than one week. At the follow-up visit of the three-month RCT, participants were asked to complete another survey that included measures of user satisfaction with the mVIP prototype.

Interviews took place immediately following a participant's follow-up visit of the three-month RCT, and focus groups took place on four different dates before or after participants' follow-up visit. During the in-depth interviews and focus groups, all participants were given an explanation of the study and asked to sign a consent form. During the in-depth interviews, a Master-level research coordinator facilitated each interview one-on-one using a semi-structured interview guide designed to gain individual-level insights. Participants were encouraged to talk about their experiences, perceptions, and satisfaction of their mVIP prototype use. Participants were compensated with $10. During the focus groups, a PhD-level professor and three Master-level researchers facilitated each of four focus groups using a semi-structured focus group guide designed to gain group-level insights. Seven to 12 participants per focus group were brought together and encouraged to discuss issues regarding their experiences, perceptions, and satisfaction of the app use. Participants were compensated with $40. Both the in-depth interviews and focus groups were audio-recorded.

Data Collection

In-depth interviews and focus groups were conducted in-person in one of two private conference rooms at the Columbia University School of Nursing. Interviews were approximately 30 minutes in length and focus groups lasted one to two hours. Semi-structured guides used in the in-depth interviews and focus groups were developed based on a theoretical framework of Health-ITUEM (*Figure 3-5*). An in-depth interview guide is presented in *Table 3-4* and a focus group guide is presented in *Table 3-5*. All in-depth interviews and focus groups were audio-recorded with two digital recorders to safeguard against mechanical failure. Researchers took field notes as needed. Data collection continued until saturation of themes was reached.

Table 0-4. In-depth interview guide

While you have been using the VIP app during the last 3 months:

Personal experiences and perceptions of mVIP

- Describe your general perceptions and expectations of the app.
- Where did you use the VIP app most frequently and why?
- How often did you use the app? Why?
- If you used the app several times on the same day, why?
- How did you access the app? What do you think about accessing the app?
- Have you had a problem on 'Log-in'? How did you resolve the problem?
- Have you ever changed your password? Why or why not? How easy/difficult was it?
- What were some of the inconveniences/difficulties/problems you experienced while using the app?
- Do you have any feedback on the reminder emails?

  Probe: Have you received reminder emails? How did the reminder emails affect you? When did you use the app after you received the reminders? What are your thoughts of SMS/Email reminders?
- What did you want to achieve by using the app?
- How helpful was the app for reducing your HIV-related symptoms?
- What do you think is the best frequency for using the app to improve your HIV-related symptoms?
- What would you change or improve about the app?
- Tell us any of your experiences related to the app you didn't mention so far.

(Only in the intervention group)

- How often did you watch videos in the VIP app and why? (Probe: patterns related to watching the videos)
- What do you prefer to see both content and videos or either of them (read the strategies vs. watch the videos) and why?

Table 0-5. Focus group guide

While you have been using the VIP app during the last 3 months:

General perceptions of mVIP

- Please tell us about your general perceptions and expectations of the app.
  - Probe: What's your first impression of the app? Did it behave as you expected?
- How comfortable were you in using the VIP app in social settings?
  - Probe: where and when used it mostly (house/workplace/clinic/café; after breakfast/when commuting, etc)
- How long did it feel like it took you to complete each app session?
  - Probe: how this fit into your lifestyle & schedule?

(Only in the Intervention Group)

- What are your thoughts about the videos displayed in the VIP app?
  - Probe: watching videos vs. reading the content; videos with sounds, the type of sounds; data plan affect watching the videos

Use of mVIP

1) After your first app use, how difficult was it for you to use in follow up uses?
2) Please describe your experience with any technical problems.
   - Probe: crash/error/back button/Continue button
3) Can you tell us about your experience with the instructions provided through the app?
   - Probes: how our app works, reminder/email, error messages
4) Please describe your experience navigating the app pages and remembering the basic structure of the app.
5) *(Only intervention group)* What was your experience using the app to review your symptoms and strategies (=Your History)?
6) What are your thoughts about the design of VIP?
   - Probe: main logo/avatars; font/color; progress bar; Save ID&PW; Log-in Help; Continue button
   - *(Only intervention group)* helpfulness response options of Yes/No/Didn't Try

Impact of mVIP

7) How did this app help you gain information about relieving your symptoms?
8) How confident are you in your ability to self-manage your HIV-related symptoms?
9) How do you think that your HIV-related symptoms improved after using the VIP app for 3 months?
10) Please tell us how the app did/can change your current personal, professional or healthcare provider relationships

11) Please explain how the app did/can change your quality of life.

All data from surveys were collected electronically using Qualtrics®, through the same instruments used in the end-user usability testing at level 2. Data on health literacy using S-TOFHLA (Baker et al., 1999) and NVS (Weiss et al., 2005), and user-perceived satisfaction using Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002), were collected.

Data Analysis

After the in-depth interviews and each focus group, the research team conducted peer debriefing. Audio-recordings from the in-depth interviews and focus groups were transcribed. The transcripts and field notes taken by researchers were reviewed and analyzed. Two reviewers coded the transcripts after repeated readings of each transcript at least twice using NVivo™ Version 11 (QSR International, Victoria, Australia) software, each independently generating a set of codes based on a line-by-line analysis. A codebook was then developed and discrepancies in coding were discussed until consensus was achieved. A thematic analysis was conducted to explore emerging similar patterns and themes across in-depth interviews and focus groups. Data analysis continued until saturation was reached.

SPSS version 24.0 (IBM Corp, 2015) was used for analysis. Demographic information and additional information including technology use, health literacy, and user-perceived satisfaction were analyzed with descriptive statistics. Counts (*N*) and percentages were reported for categorical variables whereas continuous variables were expressed as means and standard deviations (*SD*s) and/or medians. We compared normally-distributed continuous variables using analysis of variance or the two-sample *t* test, and we compared non-normally distributed variables using the Kruskal-Wallis test. For example, comparison of the mean of user satisfaction scores rated by Health-ITUES and PSSUQ between study groups and between baseline and follow-up was conducted using the Kruskal-Wallis test. In addition, a regression analysis, adjusted for potential confounders inclding app use frequency, age, sex, race/ethnicity, education level, annual income status, and health literacy level was conducted. Level of significance was set at $\alpha = 0.05$ for all analyses.

Results

The results presented in this chapter describe the findings of a three-level usability evaluation as guided by the stratified view of health IT evaluation framework (*Figure 1-1*). In the level 1 study to understand a user-task interaction, we applied a user-centered design method to guide the information architecture of our app, mVIP. Using a reverse in-person card sorting technique, we designed a prototype of mVIP. Then, in the level 2 study, we conducted a usability evaluation of the mVIP prototype in a laboratory setting to examine a user-task-system interaction through end-user usability testing and heuristic evaluation. In the level 3 study, the usability of the mVIP prototype was evaluated in a real-world setting to explore a user-task-system-environment interaction through in-depth interviews and focus groups during a three-month feasibility study. *Figure 4-1* depicts a flow diagram of the three level studies.

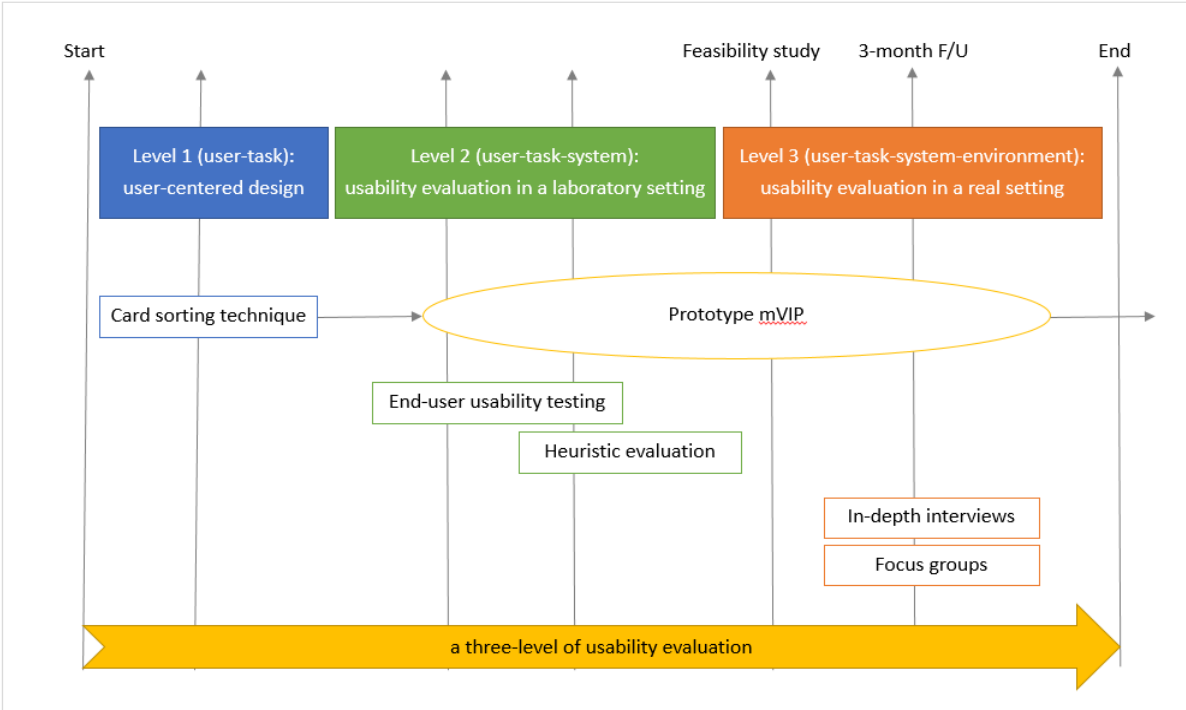

Figure 0-1. A flow diagram of studies: a three-level of usability evaluation

Level 1 (User-Task): User-Centered Design

We recruited 20 PLWH aged 18 and older from 1 HIV Medicaid clinic and 4 community based organizations in NYC between December 2015 and May 2016 to participate in a reverse in-person card sorting exercise to guide the information architecture of a prototype of mVIP. The following research question was answered: What is the desired information architecture of symptom self-management strategies for informing the development of mVIP?

Descriptive statistics of the demographics and self-reported technology use are presented below. Findings from the reverse card sorting technique used to inform the development of the mVIP prototype are presented.

Sample

Our sample in this level 1 study included 20 PLWH. The mean age of participants was 55.30 years (*SD* = 6.13; range = 38-64 years of age). 55% (*N* = 11) of participants were African American, and 40% (*N* = 8) of participants self-identified as Latino. Characteristics of the study participants are reported in *Table 4-1*.

35% (*N* = 7) of participants used a desktop or laptop computer several times every day, and 90% (*N* = 18) of participants used a mobile device several times every day. 70% (*N* = 14) of participants had used a mobile device such as a smartphone, tablet, or cellphone for more than two years. 90% (*N* = 18) of participants reported using mobile devices to send or receive text messages, and 60% (*N* = 12) of participants reported using mobile devices to access the Internet. Descriptive statistics regarding the use of technology, including computers and mobile devices, are reported in *Table 4-2*.

Table 0-1. Characteristics of study sample: card sorting exercise (*N* = 20)

Characteristics	N (%)
Gender	
Male	8 (40)
Female	12 (60)
Race	
African American / Black	11 (55)
White	3 (15)
Native Hawaiian or Other Pacific Islander	1 (5)
Other	5 (25)

Ethnicity	
Hispanic / Latino	8 (40)
Marital Status	
Single	15 (75)
Divorced	2 (10)
Domestic partnership	3 (15)
Education Level	
Some high school	3 (15)
High school graduate / Got GED	7 (35)
Some college	5 (25)
Associate's degree / Technical degree	2 (10)
College graduate (4 years)	2 (10)
Professional or Graduate Degree	1 (5)
Current Employment Status	
Retired	3 (15)
Not currently working	16 (80)
Annual Income	
Less than $10,000	10 (50)
$10,000-$19,999	5 (25)
$20,000-$39,999	3 (15)
$60,000-$79,999	1 (5)
Health Insurance Provider	
Public (e.g. government, Medicare, Medicaid, Ryan White)	19 (95)
Private (e.g. through employer or relative's employer)	1 (5)

Table 0-2. Technology use: card sorting exercise (*N* = 20)

Technology Use	N (%)
Frequency of desktop or laptop computer use	

Several times every day	7 (35)
Once a day	1 (5)
Several times per week	3 (15)
Several times per month	1 (5)
Once a month or less often	5 (25)
Never	3 (15)
First start of desktop or laptop computer use	
In the past six months	2 (10)
In the past year	1 (5)
More than two years	14 (70)
Frequency of mobile device use (e.g. Smartphone, tablet, cellphone)	
Several times every day	18 (90)
Several times per week	2 (10)
First start of mobile device use	
In the past six months	2 (10)
In the past year	4 (20)
More than two years	14 (70)
Current use of mobile devices	
Smartphone (e.g. iPhone, Samsung galaxy)	11 (55)
Basic cellphone (text messaging only)	5 (25)
Tablet (e.g. iPad)	2 (10)
Used mobile devices to:	
Send or receive text messages	18 (90)
Access the Internet	12 (60)
Send or receive email	9 (45)
Download apps	11 (55)
Get directions or other location-based information	6 (30)
Listen to music	11 (55)

Participate in a video call or video chat	4 (20)
‘Check in’ or share your location	2 (10)
Numbers of texts per day	
1-10	13 (65)
11-50	5 (25)
51-100	1 (5)
More than 200	1 (5)

Card Sorting

Symptoms

A total of 13 index cards representing HIV-related symptoms were used in a reverse in-person card sorting exercise. Frequency of symptoms experienced during the past seven days was obtained by counting the number of participants selecting the symptom index cards. 85% (*N* = 17) of participants reported fatigue, 60% (*N* = 12) of participants reported difficulty sleeping, and 50% (*N* = 10) of participants reported difficulty remembering in the prior seven days. Rank order of the 13 symptoms was established based on the frequency of symptoms, then by alphabetical order. The frequency and rank order of the 13 symptoms are listed in *Table 4-3*.

Table 0-3. Frequency of reported symptoms (*N* = 20)

Symptom	N (%)	Rank
Fatigue	17 (85)	1
Insomnia	12 (60)	2
Forgetfulness	10 (50)	3

Depression	9 (45)	4
Anxiety	8 (40)	5
Neuropathy	8 (40)	6
Cough / Shortness of breath	6 (30)	7
Dizziness	4 (20)	8
Skin problems	3 (15)	9
Fever	2 (10)	10
Diarrhea	1 (5)	11
Nausea / Vomiting	1 (5)	12
Weight loss	1 (5)	13

Self-Management Strategies

A total of 154 index cards of self-management strategies for 13 HIV-related symptoms were used in a reverse in-person card sorting exercise. The number of strategy index cards included for each symptom is listed in *Table 4-4*. Each of strategy index cards per symptom was coded with an ordinal number according to each participant's placement of that strategy in order of priority. For example, the top index card was coded as 1, and the second index card was coded as 2. Based on the mean scores of the ordinal numbers coded to index cards, we established the rank order for the 154 self-management strategies. As a lower mean score indicates a higher priority order, the self-management strategy with the lowest mean score was ranked the first. For example, 'fatigue', reported by 17 participants, had nine self-management strategies index cards; the mean scores of the ordinal numbers (i.e. 1-9) of the nine index cards of self-management strategies for this symptom ranged from 3.12 to 7.29. The self-management strategy with the mean score of 3.12 was ranked as 1 and the self-management strategy with the mean score of 7.29 was ranked as 9. The mean scores of the ordinal numbers and the established rank order of the 154 self-management strategies for 13 symptoms are listed in *Table 4-5*. A sample picture taken during the card sorting exercise is displayed in *Figure 4-2*.

Table 0-4. Number of self-management strategies index cards per symptom

Symptom	# of Strategy Index Cards
Fatigue	9
Insomnia	11
Forgetfulness	8
Depression	9
Anxiety	8
Neuropathy	11
Cough / Shortness of breath	12
Dizziness	9
Skin problems	17
Fever	12
Diarrhea	11
Nausea / Vomiting	15
Weight loss	22
Total	154

Table 0-5. Mean scores and rank order of self-management strategies ($N = 20$; *Card* = 154)

Index cards of self-management strategies per symptom	Mean	Rank
Did you feel fatigued or have a loss of energy? (N = 17; Card = 9)		
Take your medication as prescribed. Report any side effects or irregularities to your doctor or nurse.	3.12	1
Try relaxing or stress-reducing activities such as deep-breathing exercises, meditation, personal “quiet time”, massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath, Tai-Chi, etc.	3.71	2
Go for a walk every day at your own pace, in your home or outside. Exercise has been shown to reduce anxiety, depression, and fatigue.	4.06	3
Limit the following foods: sugary foods, fast foods and other high fat foods. Reduce alcohol and caffeine intake, as these tend to make you sluggish later.	4.88	4
Avoid or reduce your use of alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed, dagga, glue).	5.18	5
Take breaks at work, mid-morning and mid-afternoon.	5.53	6
Eat more of the following foods: oatmeal and other whole grain cereals, fruit and raw vegetables, whole grain baked goods, yoghurt and low or non-dairy products.	5.59	7
Develop a routine of going to bed in the evening and getting up each morning at the same time. A good night’s sleep can help you think more clearly. Naps are okay, but keep them short and early in the day.	5.65	8
When cooking vegetables ensure that they are not overcooked as vitamins get destroyed.	7.29	9
Did you have difficulty falling or staying asleep? (N = 12; Card = 11)		
Develop a routine of going to bed in the evening and getting up each morning at the same time. Naps are okay, but keep them short and early in the day.	4.08	1
Read before going to sleep.	4.58	2
Take a warm bath before going to bed.	5.42	3

Get a massage.	5.92	4
Avoid over-the-counter sleep aids because you could become dependent on them.	5.92	4
Turn on a fan or soft music to block out street noise.	6.00	6
Exercise four to six hours before going to bed. Exercising close to bedtime may increase sleep problems.	6.17	7
Listen to music or books on tape.	6.17	7
Use several pillows to make yourself comfortable.	6.42	9
Drink a cup of warm milk or herbal chamomile tea before going to bed, but do not drink so much fluid that you have to get up to go to the bathroom during the night.	7.00	10
Wear earplugs.	8.33	11
Did you have difficulty remembering? (N = 10; Card = 8)		
Ask your health care provider to call you before your appointments to remind you of the date and time of the appointment.	3.80	1
Organize your medications in an easy way (e.g. pillbox) to help you remember to take them.	3.90	2
Write-up a daily/weekly schedule and try to stick as close to the same schedule as possible.	4.00	3
Use a date book to write down your appointments or schedule. Remember to write down the appointment or schedule item right away so that it is not forgotten later.	4.10	4
Develop a routine (e.g. keep your keys and date book in the same place every day).	4.30	5
Develop a routine of going to bed in the evening and getting up each morning at the same time. A good night's sleep can help you think more clearly. Naps are okay, but keep them short and early in the day.	4.30	5
Avoid or reduce your use of alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed, glue).	5.00	7

Ask friends or family members to help you remember things and keep your appointments or schedule.	6.60	8
<u>Did you feel sad, down or depressed? (N = 9; Card = 9)</u>		
Take your medication as prescribed. Report any side effects or irregularities to your doctor or nurse.	3.22	1
Try relaxing or stress-reducing activities such as deep-breathing exercises, meditation, personal "quiet time", massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath, Tai-Chi, etc.	4.22	2
Consider attending a support group. These are usually free of charge and are often offered by HIV organizations in your community. If appropriate, check your phone book under "AIDS" or "HIV", or with your local church. Be sure to check whether a group you are planning to attend has a specific focus and that you are interested in that topic; participate actively.	4.44	3
Go for a walk every day at your own pace, in your home or outside. Exercise has been shown to reduce anxiety, depression, and fatigue.	4.67	4
Get up, wash, and get dressed at a regular time each day.	4.67	4
Develop a routine of going to bed in the evening and getting up each morning at the same time. A good night's sleep can help you think more clearly. Naps are okay, but keep them short and early in the day.	5.00	6
Read and learn about depression.	5.11	7
Get involved in activities such as community groups, support groups, church groups, social clubs or sport activities.	6.22	8
Avoid or reduce your use of alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed, dagga, glue).	7.44	9
<u>Did you feel nervous or anxious? (N = 8; Card = 8)</u>		
Try relaxing or stress-reducing activities such as deep-breathing exercises, meditation, personal "quiet time", massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath, Tai-Chi, etc.	3.75	1
Go for a walk every day at your own pace, in your home or outside. Exercise	4.25	2

has been shown to reduce anxiety, depression, and fatigue.

Take your medication as prescribed. Report any side effects or irregularities to your doctor or nurse.	4.25	2
You may also want to keep a diary to record your thoughts and feelings.	4.38	4
Consider attending a support group. These are usually free of charge and are often offered by HIV organizations in your community. If appropriate, check your phone book under "AIDS" or "HIV", or with your local church. Be sure to check whether a group you are planning to attend has a specific focus and that you are interested in that topic; participate actively.	4.50	5
Drink a cup of warm milk or herbal chamomile tea before going to bed.	4.50	5
Eat fewer products containing sugar (including sodas).	4.63	7
Drink less caffeine (coffee, tea, and sodas).	5.75	8
Did you have pain, numbness or tingling in your hands or feet? (N = 8; Card = 11)		
Massage your hands/arms/legs/feet.	3.63	1
Keep your hands/feet warm, but not so warm that they sweat.	4.38	2
Try relaxing or stress-reducing activities such as deep-breathing exercises, meditation, personal "quiet time", massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath, Tai-Chi, etc.	4.63	3
Have yourself checked by a health professional to exclude diabetes mellitus as the cause of the pain.	5.13	4
Do passive exercises with your hands/arms/legs/feet, or ask family member or friend to assist.	5.50	5
Wear loose fitting comfortable shoes with padded soles.	5.63	6
Elevate your hands/feet above the level of your head.	6.13	7
Avoid long periods of standing or walking.	6.63	8
Soak in cold water for heat-related pain, but no more than 10 minutes.	7.75	9
Consider wearing white cotton socks to reduce wetness due to sweating.	8.00	10

Apply hot compresses for cold-related pain.	8.63	11
Did you have a cough or trouble catching your breath? (N = 6; Card = 12)		
Sit up straight to expand the chest as much as possible.	4.33	1
Try relaxing or stress-reducing activities such as deep-breathing exercises, meditation, personal "quiet time", massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath, Tai-Chi, etc.	4.50	2
Drink sips of hot water or warm fluids. You may add generous amounts of lemon.	5.33	3
Inhale steam, using hot water with Vicks.	5.67	4
Pursed Lips Breathing: Breathe in normally through the nose while counting s-l-o-w-l-y to two; purse lips, as if about to whistle; breathe out slowly through your pursed lips (take twice as long as you did to breathe in - count slowly to four).	5.83	5
Try to use these breathing strategies. The key is to inhale and breathe out slowly, where possible.	6.17	6
Controlled or Paced Breathing: This is the use of Pursed Lips Breathing with activities which make you winded, such as climbing stairs, walking quickly or lifting heavy objects. The key is to inhale slowly (at rest if possible) and exhale through pursed lips while performing the work. Focus on breathing out slowly and evenly.	6.67	7
Use a cough mixture.	7.00	8
Contact your physician or nurse/clinic for further instructions or other breathing strategies.	7.17	9
Take a walk daily at your own pace, in your home or outside. Muscles that are weak from lack of activity or exercise can make you feel short of breath with any movement. Routine exercise can reduce your shortness of breath related to muscle weakness.	7.67	10
Drink tea or coffee.	8.67	11
Avoid rough foods that irritate the throat.	9.00	12

Did you feel dizzy or lightheaded? (N = 4; Card = 9)

Rise slowly when waking up – sit up first.	2.25	1
Drink plenty of fluids (water, juice, non-caffeinated beverages) – at least six to eight 8-ounce glasses per day.	4.00	2
Ensure adequate ventilation.	4.00	3
Lie down and raise your feet to above your head.	5.25	4
Sit down and lower your head to below your knees to encourage circulation to the brain.	5.50	5
Eat a balanced diet.	5.75	6
Eat high-energy foods.	6.00	7
Loosen tight-fitting clothing.	6.00	7
Eat green leafy vegetables in order to increase iron intake.	6.25	9

Did you have skin problems such as rash, dryness or itching? (N = 3; Card = 17)

Bathe or shower with a mild, non-perfumed soap (such as Cetaphil ™, Dove™, Sunlight ™ bath soap / Sunlight ™ bar soap) and lukewarm water. Avoid hot tubs; they dry your skin.	5.33	1
Use a warm mist humidifier in dry climates or in very warm apartments. Dry air can irritate the skin.	5.67	2
Pay special attention to new skin changes and report these to your doctor or nurse.	6.00	3
Avoid cold water – always use lukewarm water.	6.33	4
Drink plenty of fluids.	6.33	4
Check in your drugstore for anti-irritants or use an oatmeal and water mixture on affected areas of body to reduce the itch.	6.33	4
Apply moisturizing creams or lotions that do not contain alcohol.	7.33	7
Do not share towels or linens.	7.67	8

Bathe with antiseptics diluted with water.	8.00	9
Wash your hands frequently.	8.67	10
Use unscented moisturizing lotions or creams that do not contain alcohol. Lotions or creams containing aloe vera / natural plant extracts may help.	9.67	11
Try not to scratch. Keep your fingernails short and clean.	9.67	11
Keep sheets and blankets off sensitive skin. For example, use a pillow at the foot of the bed to hold sheets off your feet.	11.00	13
Use bandages or a clean cloth for any bleeding discharges or drainage to prevent the spread of the infection to other parts of your body or to other people.	13.00	14
Air dry or pat dry your skin after bathing.	13.33	15
Wear light, non-irritating clothing and a hat when in the sun.	13.67	16
Use some oils, such as sweet almond, to nourish dry skin.	15.00	17
Did you have fevers, chills, or sweats? (N = 2; Card = 12)		
Take your temperature when you feel sick. If it is more than 99ºF (38ºC), take it again in 3 to 4 hours. Keep a diary to help your health care provider treat your fever. New onset of fevers with temperatures above 101ºF degrees (39ºC) should be reported to your doctor or nurse within 24 hours. Where clinic nurses visit the patient, they will monitor the temperature and do the necessary referral.	2.50	1
Take tablets or other medicine as directed by your doctor or nurse to lower your fever or high temperature.	3.00	2
Drink plenty of fluids (water, juice, non-caffeinated beverages) – at least six to eight glasses per day.	3.50	3
Get plenty of rest to conserve energy and avoid fatigue.	3.50	4
If you are taking antibiotics, be sure to take all of the medication (complete the course).	5.50	5
Wrap each arm (including the fingers) and each leg (including the toes) with towels or blankets. The rest of your body should be lightly covered with your clothing. It is better not to cover your entire body as this may cause your	5.50	6

fever to rise.		
Avoid sponge baths or using fans as these may cause you to have chills and shivering. Shivering causes the temperature to rise even higher and should be avoided when possible.	6.50	7
Keep the skin dry and covered.	7.50	8
Avoid drinking chilled or cold liquids. Drink warm liquids.	7.50	9
Change clothes when sweat soaked.	10.50	10
Avoid baths.	10.50	11
Wear socks or shoes when walking on cold floors.	12.00	12
Did you have diarrhea or a loose bowel movement? (N = 1; Card = 11)		
Foods / drinks to avoid: Caffeine, fast foods, fried foods, luncheon meats, hot dogs, bacon, chips, dairy products (except for yogurt), whole grains, cornmeal, bran, granola, wheat germ, nuts, seeds, Caffeinated, alcoholic and carbonated beverages.	1.00	1
Supplements: Acidophilus (you can purchase this nutritional supplement at a health food or drug store). Share your plan to take acidophilus with your doctor or nurse before starting this product to make sure it does not interfere with the rest of your treatment plan Metamucil TM.	2.00	2
Foods/drinks to consume: Oatmeal, strawberries, potatoes, apples (peeled and allowed to brown), pears, bananas, yogurt, porridge.	3.00	3
Ten glasses of water per day, oral rehydration solution, energy drinks (e.g. Gatorade TM), ginger ale, diluted fruit juice, or ginger tea.	4.00	4
Keep your skin clean by washing with warm water after each bowel movement if you can. Dry the skin thoroughly.	5.00	5
When planning activities away from home, consider the availability of bathrooms.	6.00	6
Consider taking an extra change of underpants with you if you will be away from your home for an extended period of time and an extra roll of toilet paper. Bring along (hand wipes) to clean your hands.	7.00	7
Use absorbent shields to prevent the leakage of diarrhea onto clothing.	8.00	8

Eat frequent, small meals.	9.00	9
If the skin is intact (no open cut), apply a cream containing petroleum (such as Vaseline or A&D ointment TM) to protect the skin. (If the skin is open, contact your health care provider in case of infection, or for a prescription-strength ointment).	10.00	10
Consider carrying a squeeze bottle filled with warm water and a spray cleaner with you when you go out, for personal hygiene.	11.00	11

Did you have nausea or vomiting? (N = 1; Card = 15)

Remain sitting for at least 30 minutes after eating.	1.00	1
Take your medication as prescribed. Report any side effects or irregularities to your doctor or nurse.	2.00	2
Take frequent sips of water or suck on ice chips.	3.00	3
Try eating dry foods such as toast and crackers.	4.00	4
Avoid greasy foods, fried foods, and alcohol.	5.00	5
Breathe in fresh air.	6.00	6
Breathe in pleasant smells such as lemon or lime peels, and ginger.	7.00	7
Use oral rehydration solution.	8.00	8
Eat small portions of food when least sick.	9.00	9
Save your favorite foods for when you are feeling well.	10.00	10
Try to focus your mind on something pleasant (imaging). Look far away to relax your eyes.	11.00	11
Try relaxing or stress-reducing activities such as deep-breathing exercises, meditation, personal “quiet time”, massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath, Tai-Chi, etc.	12.00	12
Avoid odors, sights or sounds that trigger the feeling.	13.00	13
Use aromatherapy, such as extract of wild strawberry or ginger.	14.00	14

Try to eat and drink when you are not feeling sick.	15.00	15

Did you have problems with weight loss or wasting? (N = 1; Card = 22)

Keep track of your weight by weighing yourself or by looking for changes in the way your clothes fit.	1.00	1
Do some light exercise to boost your appetite.	2.00	2
Take a multivitamin with at least 100% Recommended Daily Allowance (RDA) every day.	3.00	3
Eat cold foods (e.g. popsicles and ice cream) and soft/liquid foods (e.g. mashed potatoes, applesauce, pasta and soups).	4.00	4
Eat frequent, small meals.	5.00	5
If food doesn't taste good to you: Add spices (e.g. basil, oregano, garlic) or other flavor enhancers such as lemon juice, lime juice, or vinegar. Marinate meats in sweet wine, fruit juices, beer, Italian dressing or soy sauce.	6.00	6
Add instant breakfast drinks, milk shakes or other supplements to your diet and drink them any time of the day.	7.00	7
Eat high-protein, high-calorie foods and snacks such as peanut butter and jelly sandwiches, crackers and cheese, pudding and yogurt.	8.00	8
Eat and drink a lot.	9.00	9
Take multivitamins.	10.00	10
Add garlic to your food.	11.00	11
Eat fresh fruits and vegetables.	12.00	12
When traveling, take high-calorie snack bars or powdered calorie supplements along.	13.00	13
Keep foods that are easy to prepare on hand (e.g. frozen and canned foods).	14.00	14
See your health care provider for possible treatment of your mouth sores.	15.00	15
Drink liquids through a straw to bypass mouth sores.	16.00	16
If it is difficult to chew or swallow, or if you have mouth sores:	17.00	17

Soften foods by soaking them in milk or soup, or by putting them in a blender.	18.00	18
Avoid spicy, salty, or crunchy foods, and acidic drinks (e.g. orange juice, tomato juice).	19.00	19
Take good care of your teeth (e.g. brush regularly, see your dentist at least every six months).	20.00	20
Gargle with a lemon juice solution.	21.00	21
Cook and eat with friends or family to make meals enjoyable.	22.00	22

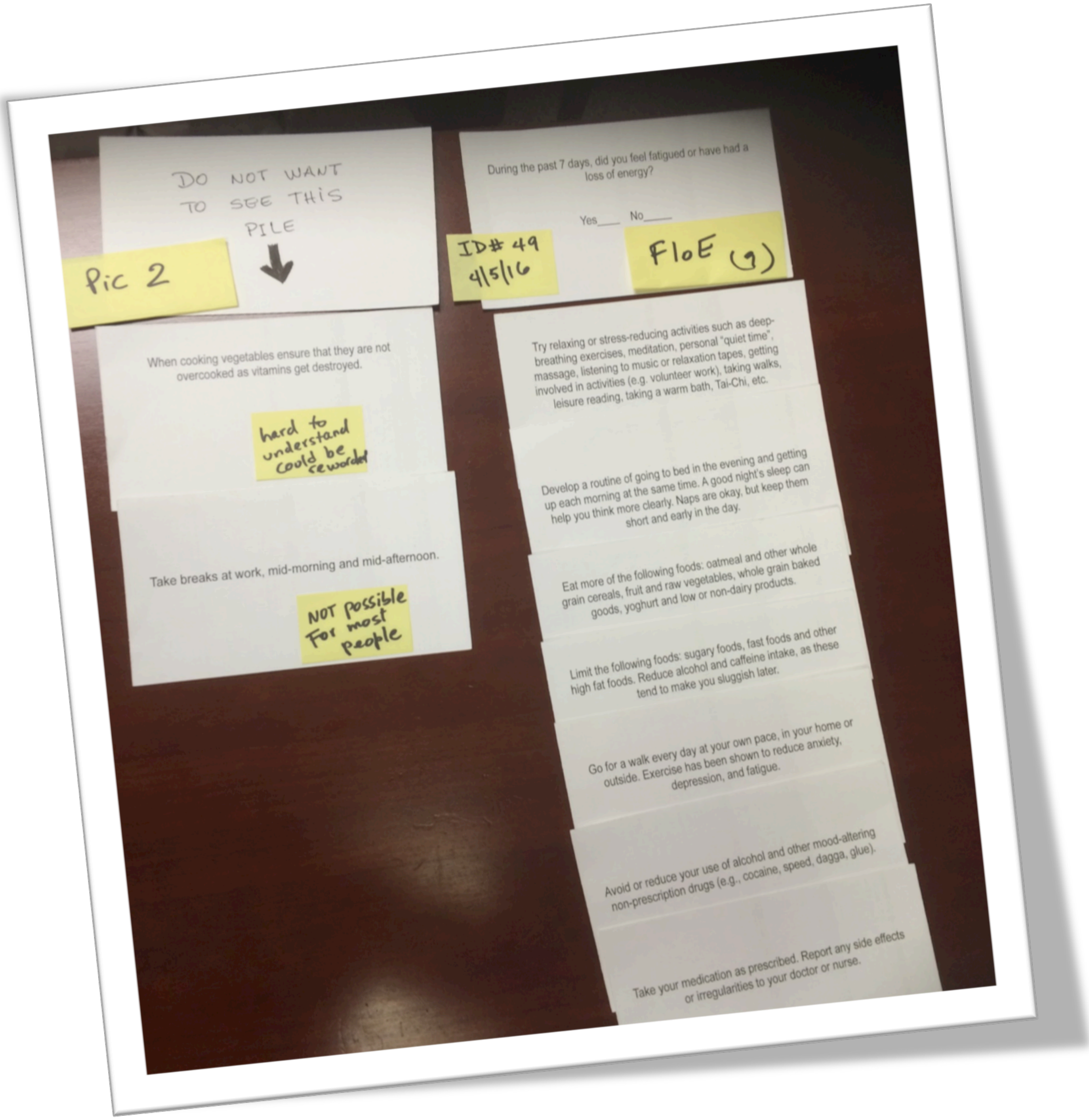

Figure 0-2. Sample picture of card sorting activities

A total of 59 changes to the self-management strategies were made based on the review of the comments made by participants. Three self-management strategies for the symptom of weight loss were removed in response to participants identifying those strategies as 'irrelevant or unhelpful'. The self-management strategies that were deleted were: if it is difficult to chew or swallow, or if you have mouth sores (it was incomplete); take good care of your teeth (e.g. brush regularly, see your dentist at least every six months); gargle with a lemon juice solution. 151 self-management strategies remained after excluding these three strategies. Of those, 56 self-management strategies were re-worded, including six for fatigue, one for difficulty sleeping, four for difficulty remembering, six for depression, four for anxiety, three for neuropathy, six strategies for cough/shortness of breath, four for dizziness, three for skin problems, four for fever, five for diarrhea, five for nausea/vomiting, and five for weight loss. Examples of re-worded self-management strategies are presented in *Table 4-6*.

Table 0-6. Total numbers and examples of re-worded self-management strategies

Symptom	# of changes	Example of initial self-management strategy	Example of re-worded self-management strategy
Fatigue	6	When cooking vegetables ensure that they are not overcooked as vitamins get destroyed.	Vitamins can help you gain energy. Vegetables are a good source of vitamins. Do not overcook vegetables since this makes the vegetables loose vitamins.
Difficulty sleeping	1	Exercise four to six hours before going to bed. Exercising close to bedtime may increase sleep problems.	Do not exercise too close to bedtime since this may increase sleep problems. Exercise at least 4-6 hours before going to bed.
Difficulty remembering	4	Use a date book to write down your appointments or schedule. Remember to write down the appointment or schedule item right away so that it is not forgotten later.	Use a date book to write down your appointments or schedule right away so that they are not forgotten later.

Depression	6	Avoid or reduce your use of alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed, dagga, glue).	Avoid alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed).
Anxiety	4	Consider attending a support group. These are usually free of charge and are often offered by HIV organizations in your community. If appropriate, check your phone book under "AIDS" or "HIV", or with your local church. Be sure to check whether a group you are planning to attend has a specific focus and that you are interested in that topic; participate actively.	Attend a free support group offered in your community. Check if the group has a specific focus and that you are interested in that topic; participate actively.
Neuropathy	3	Have yourself checked by a health professional to exclude diabetes mellitus as the cause of the pain.	Get checked by a health professional for diabetes as the cause of the pain.
Cough / Shortness of breath	6	Controlled or Paced Breathing: This is the use of Pursed Lips Breathing with activities which make you winded, such as climbing stairs, walking quickly or lifting heavy objects. The key is to inhale slowly (at rest if possible) and exhale through pursed lips while performing the work. Focus on breathing out slowly and evenly.	Try controlled or Paced Breathing: The key is to inhale slowly and exhale through pursed lips while performing the work. Focus on breathing out slowly and evenly.
Dizziness	4	Rise slowly when waking up – sit up first.	Rise slowly when waking up – sit up first, then stand.
Skin problems	3	Use a warm mist humidifier in dry climates or in very warm apartments. Dry air can irritate the skin.	Use a warm mist humidifier – Dry air can irritate the skin.
Fever	4	Take your temperature when you feel sick. If it is more than 99ºF (38ºC), take it again in 3 to 4 hours.	Take your temperature when you feel sick. If it is more than 99ºF (38ºC), take

		Keep a diary to help your health care provider treat your fever. New onset of fevers with temperatures above 101ºF degrees (39ºC) should be reported to your doctor or nurse within 24 hours. Where clinic nurses visit the patient, they will monitor the temperature and do the necessary referral.	it again in 3 to 4 hours. If your fever is above 101ºF degrees (39ºC) call your doctor or nurse within 24 hours.
Diarrhea	5	Supplements: Acidophilus (you can purchase this nutritional supplement at a health food or drug store). Share your plan to take acidophilus with your doctor or nurse before starting this product to make sure it does not interfere with the rest of your treatment plan Metamucil TM.	Try these Supplements: Acidophilus or Metamucil TM. (You can purchase these nutritional supplements at a health food or drug store). Share your plan to take nutritional supplements with your doctor or nurse before starting.
Nausea / Vomiting	5	Remain sitting for at least 30 minutes after eating.	Do not lie down for at least 30 minutes after eating.
Weight loss	5	See your health care provider for possible treatment of your mouth sores.	If you have mouth sores: See your health care provider (including your dentist) for possible treatment.

Application of Findings for Designing a Prototype of mVIP

Findings from the reverse in-person card sorting exercise were incorporated into the information architecture of the mVIP prototype. The rank order of the 13 symptoms and 151 self-management strategies determined the order of appearance to end-users of the mVIP app, with higher-ranked symptoms and strategies appearing first. For example, if an end-user starts an app session using mVIP, the end-user would be first given a symptom question for fatigue (i.e. did you feel fatigued or have a loss of energy?) since fatigue had the highest rank with rank order 1. If the end-user answers 'yes,' mVIP provides three self-management strategies related to fatigue, in rank order 1, 2, and 3 – i.e. Take your medication as prescribed. Report any side effects or irregularities to your doctor or nurse (rank 1); Try relaxing or stress-reducing activities such as deep-breathing exercises, meditation, personal "quiet time", massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath, Tai-Chi, etc. (rank 2); Go for a walk every day at your own pace, in your home or outside. Exercise has been shown to reduce anxiety, depression, and fatigue (rank 3).

Incorporating the findings into the information architecture, we developed a prototype of mVIP, which works as follows: 1) once users log in, they are guided by an avatar through a series of 13 symptom questions ascertaining the nature and severity of their symptoms, and 2) upon completing the evaluation for each symptom, the avatar recommends three self-management strategies for each symptom reported. *Figure 4-3* depicts screenshots of the designed mVIP prototype.

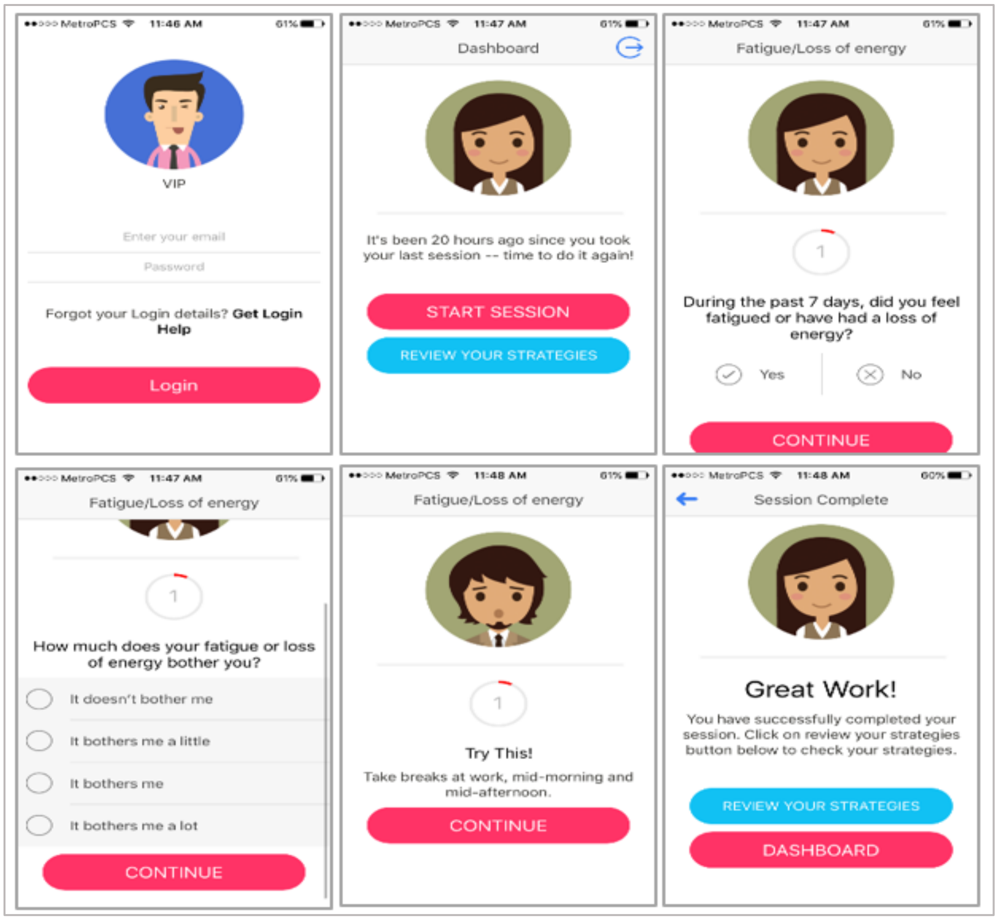

Figure 0-3. Designed mVIP prototype

Level 2 (User-Task-System): Usability Evaluation in a Laboratory Setting

Based on the findings from the level 1 study using a card sorting technique, we designed a prototype of mVIP which included a total of 151 self-management strategies for 13 symptoms. The level 2 study consisted of two usability evaluations of the mVIP prototype in a laboratory setting. This included: 1) end-user usability testing to examine task performance by intended end-users; and 2) heuristic evaluation to assess the user interface by usability experts. Our goal in this level was to explore a user-task-system interaction to identify usability issues with the mVIP prototype and refine its content, functionality, and interface for further development of mVIP.

Level 2-1. End-User Usability Testing

We recruited 20 PLWH from June to July 2016 to participate in end-user usability testing which used an eye-tracking and retrospective think-aloud method to evaluate the usability of the mVIP prototype in a laboratory setting. The following research questions were answered: What usability problems are perceived by end-users in a laboratory setting? Are the end-users satisfied with the way mVIP performs the desired tasks in the laboratory setting?

Descriptive statistics of the demographics, health literacy measured by S-TOFHLA and NVS (Baker et al., 1999; Weiss et al., 2005), and technology use obtained by self-report are presented. Findings from the eye-tracking and retrospective think-aloud method are presented with the Health-ITUEM concepts and representative quotes (Brown et al., 2013). The user-perceived satisfaction scores rated via Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002) are sequentially presented.

Sample

Our sample of 20 PLWH included 10 Android smartphone users and 10 iPhone users. 70% (*N* = 14) of participants were male, 70% (*N* = 14) of participants self-identified as African American, and 20% (*N* = 4) of participants self-identified as Hispanic. The mean age for participants was 45.45 years (*SD* = 10.71; range = 25-59 years of age). The characteristics of our study sample (*N* = 20) are displayed in *Table 4-7*.

Descriptive statistics on technology use, including use of computers and mobile devices, are reported in *Table 4-8*. All 20 participants reported they started using mobile devices more than two years ago, and 90% (*N* = 18) of participants reported they usually used mobile devices several times every day. The mean duration of the participants' use of mobile devices per day was 7.30 hours (*SD* = 3.05; range = 3-12 hours/day). All participants reported using mobile devices to send/receive text messages, and 95% (*N* = 19) of participants reported using mobile devices to send/receive email, access the Internet, and download apps.

Table 0-7. Characteristics of study sample: end-user usability testing (*N* = 20)

Characteristics	Overall N (%)	Android	iOS
Gender			
Male	14 (70)	6	8
Female	5 (25)	4	1
Transgender Male / Transman / FTM	1 (5)	0	1

Race			
African American / Black	14 (70)	8	6
White	2 (10)	0	2
American Indian or Alaska Native	1 (5)	1	0
Other	3 (15)	1	2
Ethnicity			
Hispanic / Latino	4 (20)	1	3
Marital Status			
Married	2 (10)	2	0
Divorced	2 (10)	1	1
Separated	3 (15)	1	2
Never married	13 (65)	6	7
Education Level			
Some high school	3 (15)	3	0
High school graduate / Got GED	4 (20)	0	4
Some college	8 (40)	5	3
Associate's degree / Technical degree	1 (5)	0	1
College graduate (4 years)	4 (20)	2	2
Current Employment Status			
Employed full-time	1 (5)	1	0
Employed part-time	4 (20)	2	2
Unemployed looking for work	6 (30)	1	5
Unemployed not looking for work	1 (5)	1	0
Student	2 (10)	1	1
Disabled	9 (45)	6	3
Annual Income			
Less than $10,000	6 (30)	3	3
$10,000-$19,999	6 (30)	3	3
$20,000-$39,999	5 (25)	2	3

$40,000-$59,999	1 (5)	1	0
$60,000-$79,999	1 (5)	0	1
$80,000-$99,999	1 (5)	1	0
Health Insurance Provider			
Public (e.g. Medicare, Medicaid, Ryan White)	19 (95)	9	10
Private (e.g. through employer or relative's employer)	1 (5)	1	0

Table 0-8. Technology use: end-user usability testing (*N* = 20)

Technology Use	Overall N (%)	Android	iOS
Frequency of desktop or laptop computer use			
Once a day	7 (35)	5	2
Several times per week	5 (25)	2	3
Several times per month	4 (20)	2	2
Once a month or less often	4 (20)	1	3
Frequency of mobile device use (e.g. Smartphone, tablet, cellphone)			
Several times every day	18 (90)	9	9
Several times per week	1 (5)	1	0
Once a day	1 (5)	0	1
First start of mobile device use			
More than two years	20 (100)	10	10
Current use of mobile devices			
Smartphone (e.g. iPhone, Samsung galaxy)	19 (95)	9	10
Basic cellphone (text messaging only)	3 (15)	2	1
Tablet (e.g. iPad, Amazon Fire)	3 (15)	1	2
Used mobile devices to:			

Send or receive text messages	20 (100)	10	10
Access the Internet	19 (95)	9	10
Send or receive email	19 (95)	9	10
Download apps	19 (95)	9	10
Get directions, recommendations or other location-based	17 (85)	9	8
Listen to music	17 (85)	7	10
Participate in a video call or video chat	10 (50)	5	5
'Check in' or share your location	9 (45)	4	5
Others	1 (5)		1
Numbers of texts per day			
1-10	7 (35)	4	3
11-50	10 (50)	4	6
51-100	1 (5)	1	0
101-200	1 (5)	1	0
More than 200	1 (5)	0	1
Duration of mobile device use (hours/day) (mean ± SD)	7.30 ± 3.05		

Table 4-9 lists health literacy scores of the study participants, measured by S-TOFHLA (Baker et al., 1999) and NVS (Weiss et al., 2005). S-TOFHLA scores ranged from 12 to 36, with a mean of 32.05 and *SD* of 5.25. The majority of the participants were rated as having 'adequate' health literacy (95%; *N* = 19), while 5% (*N* = 1) had 'inadequate' health literacy. NVS scores ranged from 0 to 5, with a mean of 1.65 and *SD* of 1.57. 85% of the study participants (*N* = 17) obtained scores of 3 or less, indicating a strong possibility of low health literacy.

Table 0-9. Health literacy: end-user usability testing (*N* = 20)

S-TOFHLA Total Score (36 items)	N (%)
0 – 16 (inadequate)	1 (5)
17 – 22 (marginal)	0
23 – 36 (adequate)	19 (95)
NVS Total Score (6 item)	N (%)
0 – 1 (high likelihood of limited)	13 (65)
2 – 3 (possibility of limited)	4 (20)
4 – 6 (almost always adequate)	3 (15)

Eye-Tracking and Retrospective Think-Aloud

Eye-Tracking App Testing – Task Performance and Time Analysis, and Eye Movement Analysis

<u>Task performance and time</u>

Participants were given a use case scenario and asked to follow designated tasks during two sessions using the mVIP prototype. Each task included in the app sessions is listed in *Table 4-10*. The first session included four tasks: log in, update password, start a session and get strategies for the first two symptoms, and review the recommended strategies. The second session did not include the second task, since a password update was required for the end-users who logged into the app for the first time to set up their own passwords, but not for end-users who had already set up a password. *Figure 4-4* depicts screenshots of the mVIP prototype related to the four tasks our participants performed.

Table 0-10. Definition of tasks provided with a use case scenario

Session_1		Session_2	
Task 1	Log-in	Task 1	Log-in
Task 2	Update a password	Task 2	N/A
Task 3	Start a session – Get strategies for the first two symptoms, fatigue and difficulty sleeping	Task 3	Start a session – Get strategies for one symptom, difficulty sleeping
Task 4	Review the recommended strategies	Task 4	Review the recommended strategies

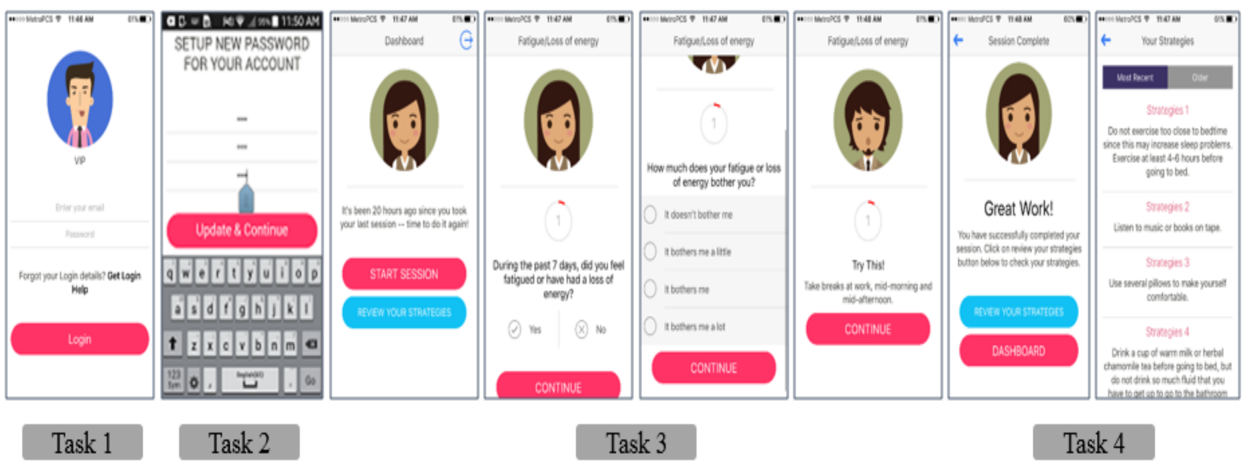

Figure 0-4. Screenshots of tasks participants performed

We captured the time stamps of all of the tasks except for task 4 as this time varied according to the number of strategies participants received during task 3 (i.e. we asked participants to select at least the first two symptoms of fatigue and difficulty sleeping, but some selected additional symptoms). We added the time stamp of hitting the first ‘Continue’ button after a new session was started in task 2. The time results of each task, compared between participants with/without trouble, are listed in *Table 4-11*.

The total amount of time it took participants to complete all tasks varied among participants, since some participants performed more tasks than were requested. The time it took to complete the tasks ranged from 251 to 1193 seconds in the first session and from 122 to 706 seconds in the second session. There was no significant difference in total task performance time between participants with more/less experience with mobile devices ($p > .05$). Participants with trouble in this study were defined as those who received error messages during the app testing and self-reported difficulties during the think-aloud protocol. In task 1 at the first session, 50% of the participants ($N = 10$) had trouble and their mean time was 241.00 seconds, whereas the mean time for participants without trouble was 49.50 seconds ($p = .002$). The mean time to perform each task during the second session was much lower than during the first session, which reflects a high learnability in navigating the app.

Table 0-11. Time results of each task ($N = 20$)

Session_1				
	N (%)	Mean ± SD (seconds)	Median (range; seconds)	*p*-value
Task 1				
No trouble	10 (50)	49.50 ± 20.01	47.50 (18-85)	.002
Trouble	10 (50)	241.00 ± 165.63	179.50 (74-492)	
Total	20 (100)	145.25 ± 151.11	78.50 (18-492)	
Task 2				
No trouble	16 (80)	74.38 ± 41.69	58.50 (31-188)	< .001
Trouble	4 (20)	286.75 ± 104.45	287.50 (185-387)	

	N (%)	Mean ± SD (seconds)	Median (range; seconds)	*p*-value
Total	20 (100)	116.85 ± 103.40	65.00 (31-387)	
Task 3				
No trouble	16 (80)	141.13 ± 61.36	131.50 (64-339)	.001
Trouble	4 (20)	276.00 ± 70.39	293.50 (176-341)	
Total	20 (100)	168.10 ± 82.57	145.50 (64-341)	
First Continue button				
No trouble	16 (80)	29.56 ± 39.18	18.50 (12-173)	< .001
Trouble	4 (20)	160.75 ± 68.62	160.50 (77-245)	
Total	20 (100)	55.80 ± 69.67	20.50 (12-245)	

Session_2

	N (%)	Mean ± SD (seconds)	Median (range; seconds)	*p*-value
Task 1				
No trouble	16 (80)	35.38 ± 16.65	30.50 (13-74)	.033
Trouble	4 (20)	58.75 ± 24.28	47.50 (45-95)	
Total	20 (100)	40.05 ± 20.10	39.50 (13-95)	
Task 3				
No trouble	19 (95)	70.32 ± 26.66	74.00 (16-133)	.004
Trouble	1 (5)	161.00 ± .00	161.00 (161.00)	
Total	20 (100)	74.85 ± 32.93	74.00 (16-161)	
First Continue button				
No trouble	20 (100)	15.10 ± 7.64	13.00 (6-40)	N/A

Eye movements

Based on eye movements collected during the participant's app testing process, we were able to determine where participants looked at a particular area of the user interface and how long they fixated on the target, with a longer duration indicating problems occurred. In gaze plots tracing their eye movements we captured/reviewed, the eye-tracking data were presented with red circles and lines. An extremely long eye fixation, displayed as a large red circle, indicates uncertainty and difficulties with information processing. A rapid eye movement from one target to another between two consecutive fixations indicates that the eyes remain in place until some critical cognitive event occurs.

For example, in task 3, when participants started the first app session and selected 'Yes' for the first symptom question (i.e. during the past seven days, did you feel fatigued or have had a loss of energy?), they had trouble finding a 'Continue' bar button, since it was placed under the response options, which required participants to scroll down (*Figure 4-4*; task 3). In another example, a participant had a problem with finding a 'Log-in' button since it was covered by the smartphone keypad (*Figure 4-4*; task 1). In these cases, the eye-tracking data showed a larger red circle resulting from the long eye fixation, or showed longer red lines resulting from distractive eye movements, compared to those shown while the participant was reading the symptom questions aloud without any trouble. *Figure 4-5* depicts an example of gaze plot tracing eye movements from a participant who did not encounter challenges in navigating the app. *Figure 4-6* depicts examples of gaze plots resulted from a participant who encountered challenges in navigating the app. These challenges were specific to ambiguity regarding the 'Continue' and 'Log-in' button, which showed as an extremely long eye fixation and distractive eye scan path up and down the smartphone screen.

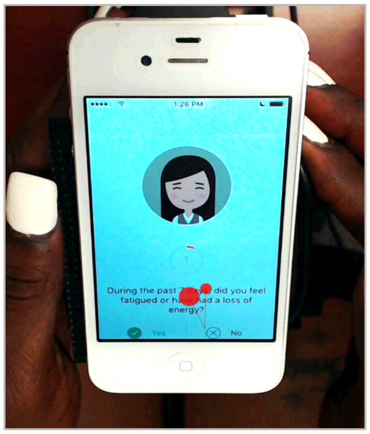

Figure 0-5. Sample gaze plot for a participant without trouble

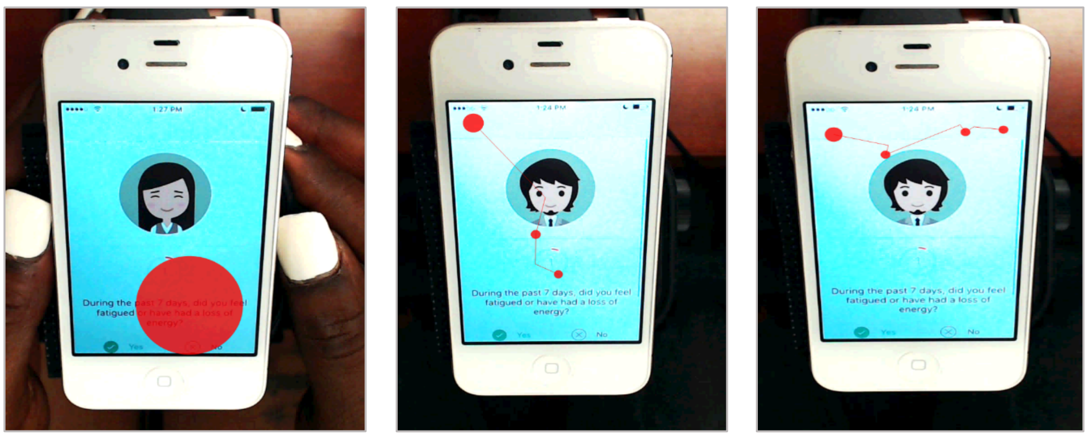

Figure 0-6. Sample gaze plots for a participant with trouble

Think-Aloud Protocol – Content Analysis

While our participants were watching a replay of the screen-recordings of their task performance synchronized with their eye movements, we conducted an interview using a retrospective think-aloud protocol by asking participants to verbalize their thoughts about the task performance they completed. Transcripts made from the audio-recorded interviews were reviewed and free text was excerpted from the transcripts. The free text was then coded using 27 codes from the nine concepts of Health-ITUEM (i.e. positive, neutral, and negative codes for each concept). All excerpts were rated first by two independent reviewers, with a third consulted in instances of uncertainty. Sample excerpts for each code of the nine Health-ITUEM concepts are presented in *Table 4-12*. None of the excerpts were coded as neutral for any of nine concepts. *Completeness*, one of the nine Health-ITUEMS concepts, was measured objectively. 80% of our participants (N = 16) successfully completed all of the tasks provided with a use case scenario. The reasons resulting in the task failure were revealed by the review of video-recordings. For example, a participant accidentally hit the 'Continue' button three times without selecting any option of 'Yes'/'No' and did not notice, even if it led to the task failure.

Table 0-12. Health-ITUEM concepts, codes, and representative quotes

Concepts	Description and Representative Quotes
Error prevention	mVIP offers error management, such as error messages as feedback, error correction through undo function, or error prevention, such as instructions or reminders, to assist users in performing tasks.
+ Error prevention	*"It was very nice that it told me that I made a mistake instead of going right into it even if I did make a mistake. That alerted me that I put in the wrong email. The error message was pretty clear."*
- Error prevention	*"I didn't understand what 'please check your credentials' meant. I didn't understand that at all. What exactly did it mean?" (unclear error messages)* *"It tells me if the password failed, and it tells me it was updated, so that's wrong. Because it's giving me two different messages. That's pretty confusing." (contradictory information in error messages)* *"It might be beneficial to have a back feature, because you know, you*

	never know and you might be just rushing through, or something like that." (back button) *"Give it a back button on certain pages. Maybe give it a menu screen. maybe like three lines right here that you can hit the menu and maybe it will bring up dashboard" (home menu)* *"Well, for those who don't know how to use apps, they would need more instructions. They would need more instructions, more simple instructions for them to adapt to. For them not to frustrated, but some way of making it fun, to where they will enjoy using the app, or enjoy getting into the app. You know, instead of saying, Okay, alright, I've been in this app. What am I supposed to do?" (instruction for how the app works)*
Completeness	mVIP is able to assist users to successfully complete tasks.
+ Completeness	Task success rate: 80% ($N = 16$)
- Completeness	Task failure rate: 20% ($N = 4$)
Memorability	Users can remember easily how to perform tasks in mVIP.
+ Memorability	*"I remember the steps. I logged in and created a new password after I logged in. And then, I had started a session, which asked me about various symptoms that I may have experienced in the past week."*
- Memorability	None
Information needs	The information content offered by the mVIP for basic task performance, or to improve task performance.
+ Information needs	*"You can use the app to gain a lot of information. If you're not feeling too well and you have certain symptoms that match with the ones that are on this app, then it would give you helpful information right then and there."*
- Information needs	*"The one thing I had to question is, these 13 strategies are related to what particular? They don't tell you what category. Is it fatigue or…what?"*
Flexibility/Customizability	mVIP provides more than one way to accomplish tasks, which allows users to operate system as preferred.
+Flexibility/Custo	*"There are different kinds of expression on the avatar's face. So I also look at that as well. It is meaningful. The reason being because if you've*

mizability	*a man and thinking of yourself, it's good to remember okay, this is me, so they're talking about me."*
- Flexibility/Customizability	*"I would like to save it there…at least the ID, then the password. I can have my own password, but at least the ID can be saved there so I don't have to be typing the ID and then the password all the time." (option of saving ID&PW)* *"I don't see any here that represent me, but you at least have a choice. I don't think any of them. You should be able to create your own avatar, make it look like you. Because I have an app and I made it look like me." (option of choosing an avatar)* *"If I can review this information before I fax it off or send it off to someone else, email it to someone else." (option of Fax/email)*
Learnability	Users are able to easily learn how to operate mVIP.
+ Learnability	*"It was very easy to follow after the first use. I found the questions easy. They were precise and they were straight to the point. Once I answered the question, the suggestions they gave were easy. They were easy to follow, so I think I can self-manage myself quite well with this app."*
- Learnability	*"I didn't see the continue button. I thought this system was automatic, when I checked 'yes,' I thought it would move on." (continue button)* *"Well, the way I saw it was that it was checked already, so I guessed it continued, leave it as is because there is no change. Unless they were both blank, then there is 'no' and 'yes,' and then I'll check. But since it was checked for 'yes,' I left it at that. So then I hit the Continue. But I didn't think to hit it because it was already checked. If it had been blank, then I would have checked it. But I didn't see it unchecked to put a check in. I left it as it was and hit Continue." (checkmark)*
Performance speed	Users are able use mVIP efficiently.
+ Performance speed	*"It was very short so it was real quick. I know I had to go with 'yes' for most of them and 'no' with everything else."*
- Performance speed	None
Competency	Users are confident in their ability to perform tasks using mVIP, based on social cognitive theory.

+ Competency	*"I would feel very confident, very, very confident, because I mean it gives you pretty much straightforward strategies to try. Like I said, trial and error, so whichever ones do work, then do, if none of them work, then it's time to see the doctor. But chances are if everything else is going the way it's supposed to go, as far as you taking care of yourself, then you know, your symptoms should be able to be relieved with these strategies."*
- Competency	*"And I think I was done. I wasn't sure if there was anything else to be done that didn't get done. So that's why I didn't understand that question. Was it complete, or is there something else I have to follow through with? But I guessed I was done. So I was confused as to whether there was something else I needed to do."*
Other outcomes	Other mVIP-specific expected outcomes representing higher level of expectations (uses of non-phone app technology (i.e. phone, books), non-mobile resources (i.e. parents, friends, siblings), other health related entities not directly related to the usability of mHealth (outside of study protocol))
+ Other outcomes	*"I mean, not just mine, but I mean everybody that the virus, it could change their quality of life, giving them a better quality of life, you know, it's kind of like being your own doctor these days, without having to go to the doctor. And, being able to take better care of yourself through the app."* *"In my current life, in all honesty, I'm the type to go to Google for a lot of information, so being that I would have this app. I think I would rather go to this app being that it's specialized for people with HIV status, and I feel as if the doctors or the medial staff, and my input of information to the app, it would be more beneficial, and Google is generalized information."*
- Other outcomes	*"I don't think the app can very much change my life."*

User-Perceived Satisfaction

End-users' satisfaction rated using Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002) is reported in *Table 4-13*. The items included in the Health-ITUES and PSSUQ are displayed in *Appendix B and C*. The mean score of the overall Health-ITUES was 4.66 (*SD* = .38; range = 3.75-5.00), indicating a high user satisfaction of the mVIP app. The overall PSSUQ scores ranged from 1.00 to 2.88, reflecting strong user acceptance of the app.

Table 0-13. End-user's satisfaction: end-user usability testing (*N* = 20)

Health-ITUES (20 items; rating score from 1-worst, to 5-best)	Mean ± SD	Median (range)
Quality of Life (average items 1 through 3)	4.73 ± .61	5.00 (2.67-5.00)
Perceived Usefulness (average items 4 through 12)	4.62 ± .53	4.83 (3.00-5.00)
Perceived Ease of Use (average items 13 through 17)	4.91 ± .18	5.00 (4.40-5.00)
User Control (average items 18 through 20)	4.28 ± .90	4.67 (2.33-5.00)
Overall (all the items)	4.66 ± .38	4.78 (3.75-5.00)
PSSUQ (16 items; rating score from 1-best, to 7-worst)	**Mean ± SD**	**Median (range)**
System Quality (average items 1 through 6)	1.34 ± .41	1.34 (1.00-2.17)
Information Quality (average items 7 through 12)	1.92 ± .76	1.92 (1.00-3.50)
Interface Quality (average items 13 through 15)	1.80 ± .74	1.80 (1.00-3.33)
Overall (all the items)	1.66 ± .54	1.66 (1.00-2.88)

Application of Findings for Refining a Prototype of mVIP

Several usability issues of the mVIP prototype were identified through our end-user usability testing using an eye-tracking and retrospective think-aloud method. Based on the end-users' recommendations and integration of the results above, the content, functionality, and interface of the mVIP prototype were refined. For example, the error message 'Please check your credentials' was changed to 'The email address or password you entered is not valid. Please try again' since the term 'credentials' was unfamiliar to several participants. We implemented a new error message of 'Please select at least one option' to be displayed when hitting the 'Continue' button without answering, in order to prevent erroneously continuing when no response was selected. We changed an arrow-shaped button (←), used to return to home page after reviewing the suggested strategies, to a home-shaped button ( ) since the arrow-shaped button was unclear to several participants, resulting in delayed performance. We also fixed typos and incorrect error messages. An error message contradicted other text on the screen regarding the success of updating a password, and these contradictions confused end-users. We reworded two symptom titles which were identified as difficult to understand for several participants (e.g. fatigue → fatigue/tiredness, insomnia → difficulty sleeping). These changes to address severe usability problems were made before conducting a heuristic evaluation with usability experts.

Moreover, we implemented an additional function that allowed users to save their ID and password. Several participants expressed they would like to have their username and password saved on their own phones so that they would only need to log in one time. We added instructions for 'how our app works' on the home page in order to help participants more easily use the app. The username was simplified from the user's email address to a short code for easier text entry. The 'Log-in' and 'Continue' button were moved up on the page so they would not be covered by the smartphone keypad or the app's response options. Several participants suggested changing the main logo of mVIP to look more informative and professional. The original main logo was an image of a winking light-skinned man wearing a pink shirt with his tongue out, and was replaced with an image of a neutral-skinned man wearing a green shirt with a small smile (*Figure 4-7*).

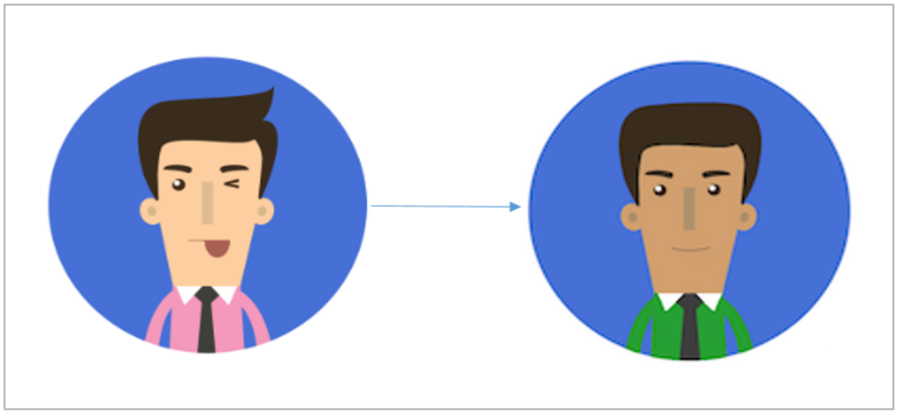

Figure 0-7. Change of mVIP main logo

Level 2-2. Heuristic Evaluation

We recruited five usability experts in informatics between August 15th and 22th, 2016, to participate in a heuristic evaluation of a web version of a prototype of mVIP before the mVIP prototype (e.g. mobile version) was completely refined based on the end-user usability testing results. Due to the timeframe related to the development process, the web version of the mVIP prototype was momentarily implemented for the heuristic evaluation only. The following research question was answered: What usability problems are perceived by usability experts? Findings from a heuristic evaluation are presented with the mean severity scores of the identified heuristic violations from Nielsen's heuristic principles.

Sample

Our sample in this level 2 study included five usability experts. The mean number of years of experience in the field of informatics was 11.00 (*SD* = 4.64; range = 5-16 years).

Heuristic Evaluation

Violations of Heuristics

Mean scores and sample comments for each of 10 usability factors related to the mVIP prototype, identified through a heuristic evaluation, are listed in *Table 4-14*. In terms of *Visibility of System Status* and *Match between System and the Real World*, an expert pointed out the 'Your history' section showed all the recommended strategies by the numbering order (e.g. Strategy 1, Strategy 2, Strategy 3…) without including sub-headers of the relevant symptoms. In response to a usability factor of *Match between System and the Real World*, an expert suggested that the term 'Dashboard' be changed as the system should speak the user's language rather than system-oriented terms. Another expert recommended that the helpfulness assessment question for each of the strategies suggested in the previous session (i.e. was this strategy helpful?) should have more response options. Considering *User Control and Freedom,* an expert suggested that end-users should be able to skip any questions they do not want to answer. Another expert recommended that a home button should be placed on every page so that end-users can quit the app or go to a home page to review the previously reviewed strategies at any time. To maintain *Consistency and Standards*, an expert suggested that the same avatar be displayed consistently on every screen, so that the visual layout remains consistent in all screens within the app. To improve *Flexibility and Efficiency of Use*, an expert recommended additional options to email 'Your history' to the user, or download it as a PDF.

Heuristic evaluators recommended rewording several strategies. For instance, an expert suggested the app consistently provide the specific brand names of over-the counter sleep aids, similar to how it provided brand names of body soaps. Of the 151 self-management strategies incorporated into the mVIP prototype from the symptom management manual and modified at the level 1 study through a card sorting technique, a total of 63 strategies were reworded and eight redundant strategies were removed. The numbers and examples of re-worded self-management strategies by symptom are presented in *Table 4-15*.

Table 0-14. Mean scores and sample comments of heuristic evaluation of mVIP

Usability Factor	Mean ± SD*	Sample Comments
Visibility of System Status	1.60 ± 1.14	Headers not very noticeable; should have a sub-header for strategies
Match between System and the Real World	0.80 ± 1.10	Collapse strategies into relevant symptoms and organize the symptoms depending on the severity; shouldn't use the IT jargon; more response options for end-users who didn't get a chance to try strategies; when a symptom isn't bothersome, no strategy should be given
User Control and Freedom	2.20 ± 1.10	No skip function; should have a home button on every single page so that users have the ability to quit/log off/keep the questions
Consistency and Standards	0.80 ± 1.10	Add the function of avatar selection and display it consistently on every page; lines, color, font style/size and image should be followed consistently in all pages within the app (visual layout consistently)
Help Users Recognize, Diagnose, and Recover From Errors	0.40 ± 0.89	Some error messages repeated; add the red color for the error message related to the failure (e.g. 'Password updated failed')
Error Prevention	0.40 ± 0.89	Not sure how to go back; not sure where the menu button is
Recognition Rather Than Recall	0.80 ± 0.84	No instructions on how the app works
Flexibility and Efficiency of Use	1.40 ± 1.34	Include an option of download/email of the 'Your history'
Aesthetic and Minimalist Design	0.60 ± 0.89	Avatars too big, rather strategies with larger font size; main logo's skin color could be more neutral related to the racial issue
Help and Documentation	1.20 ± 0.84	No help function apart from the Log-in page

*Rating score from 0-best to 5- worst; no usability problem (0), cosmetic problem only (1), minor usability problem (2), major usability problem (3), and usability catastrophe (4)

Table 0-15. Numbers and examples of re-worded self-management strategies by symptom

Symptom	# of changes	Example of initial self-management strategy	Example of re-worded self-management strategy
Fatigue	8	Take your medication as prescribed. Report any side effects or reactions that are not normal for you to your doctor or nurse.	Stick to your medication(s) as prescribed. Talk to your doctor/nurse about any side effects or reactions that are not normal for you.
Difficulty sleeping	3	Avoid over-the-counter sleep aids because you could become dependent on them.	Avoid over-the-counter sleep aids because you could become dependent on them (such as Unisom™, Kirkland™ Sleep-Aid).
Difficulty remembering	5	Avoid alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed).	Avoid alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed) as these tend to make you sluggish later.
Depression	9	Develop a routine of going to bed in the evening and getting up each morning at the same time. Naps are okay, but keep them short and early in the day.	Develop a routine sleeping schedule – go to sleep at the same time every night and wake up at the same time each morning. Naps are okay, but keep them short (45 minutes or less).
Anxiety	7	Attend a free support group offered in your community. Check if the group has a specific focus and that you are interested in that topic; participate actively.	Attend a free support group offered in your community. Check if the group has a specific focus that interests you.
Neuropathy	3	Elevate your hands/feet above the level of your head.	Elevate your hands/feet above your head.

Cough / Shortness of breath	4	Try relaxing or activities that reduce stress such as deep-breathing exercises, meditation, personal "quiet time", massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath.	Try relaxing or activities that reduce stress, such as: meditation (personal "quiet time"); listening to music; taking a warm bath.
Dizziness	3	Loosen tight-fitting clothing.	Wear loose-fitting clothing.
Skin problems	6	Drink plenty of fluids.	Drink plenty of fluids (water, non-caffeinated beverages) – at least six 8-ounce glasses per day.
Fever	4	Take tablets or other medicine as directed by your doctor or nurse to lower your fever or high temperature.	Take fever reducing medicine (e.g. Tylenol™, Advil™) as directed by your doctor/nurse.
Diarrhea	2	Acidophilus or Metamucil ™ (You can purchase these nutritional supplements at a health food or drug store). Share your plan to take nutritional supplements with your doctor or nurse before starting.	Try these Supplements: Acidophilus or Metamucil ™ (You can purchase these nutritional supplements at a health food or drug store). Share your plan to take nutritional supplements with your doctor/nurse before starting.
Nausea / Vomiting	4	Try relaxing or activities that reduce stress such as deep-breathing exercises, meditation, personal "quiet time", massage, listening to music or relaxation tapes, getting involved in activities (e.g. volunteer work), taking walks, leisure reading, taking a warm bath.	Try relaxing or activities that reduce stress, such as: deep-breathing exercises; meditation (personal "quiet time"); massage; listening to music; taking a warm bath.

Weight loss	5	If you have mouth sores: Soften foods by soaking them in milk or soup, or by putting them in a blender.	If you are having difficulty chewing/swallowing due to mouth sores: Soften foods by soaking them in milk or soup, or by putting them in a blender.

Application of Findings for Refining a Prototype of mVIP

The content, functionality, and interface of the mVIP prototype were refined based on the heuristic evaluators' recommendations. For example, strategies listed in the 'Your history' section, without sub-headers, were collapsed into relevant symptoms and the symptoms were organized by the order of the severity. The term 'Dashboard' was changed to 'VIP Home,' which was a more familiar term to our end-users. To make the app's functionality more generalizable, we added a response option of 'Didn't try' in addition to the 'Yes'/'No' options when assessing helpfulness of previously suggested strategies. Based on an expert's recommendation, we modified the system logic for symptom severity so that the questions would flow in a more logical manner: if our end-users experienced a symptom in the last seven days but it didn't bother them at all, no strategy would be provided by the app. To address the usability issue related to *User Control and Freedom*, we added a 'Skip' button under the 'Continue' button on the symptom question pages, a home button and sign-out button on every screen, and a 'Resume session' button into the home page, which end-users can use to return to an incomplete session. The mVIP visual layout remained consistent in all screens within the app. To improve the app's flexibility, we added options to email 'Your history' to the user, or to download it as a PDF.

Refined mVIP Prototype

Based on the findings from the level 2 usability evaluation in a laboratory setting through end-user usability testing and heuristic evaluation, our mVIP prototype was iteratively refined. After excluding and rewording some of the 151 original strategies per the usability results, 143 self-management strategies for 13 symptoms (*Appendix D*) were implemented in the refined mVIP prototype. 143 videos were created by computer programmers using the GoAnimate software (GoAnimate Corporation, San Francisco, CA) to present each of the 143 self-management strategies. The videos were inserted into the refined mVIP prototype with the existing text strategies.

While our prototype was initially designed as a native app for mobile devices, the refined mVIP prototype was developed as a mobile web-app, due to different capabilities between Android and iOS platforms. A native app is written in the programming language specific to a platform, such as Objective-C or Swift for Apple devices and Java for Android devices (Al-Darmaki, Badursha, Al Shibli, & Sarrab, 2015). To address the usability problems identified in our study, it was most appropriate to develop the refined mVIP prototype with a mobile web-app which could be used across platforms. The differences between the two types of mobile apps from end-users' point of view are that native-apps are installed directly onto the mobile device through an app store, such as the Apple App Store or Google Play, whereas web-apps are accessed through the mobile device's web browser (i.e. Safari by default on the iPhone) and they don't need to be installed on the device (Budiu, 2013). *Figure 4-8* depicts screenshots of the refined mVIP prototype with a mobile web-app, which were subsequently evaluated its usability in a real-world setting at the next level 3.

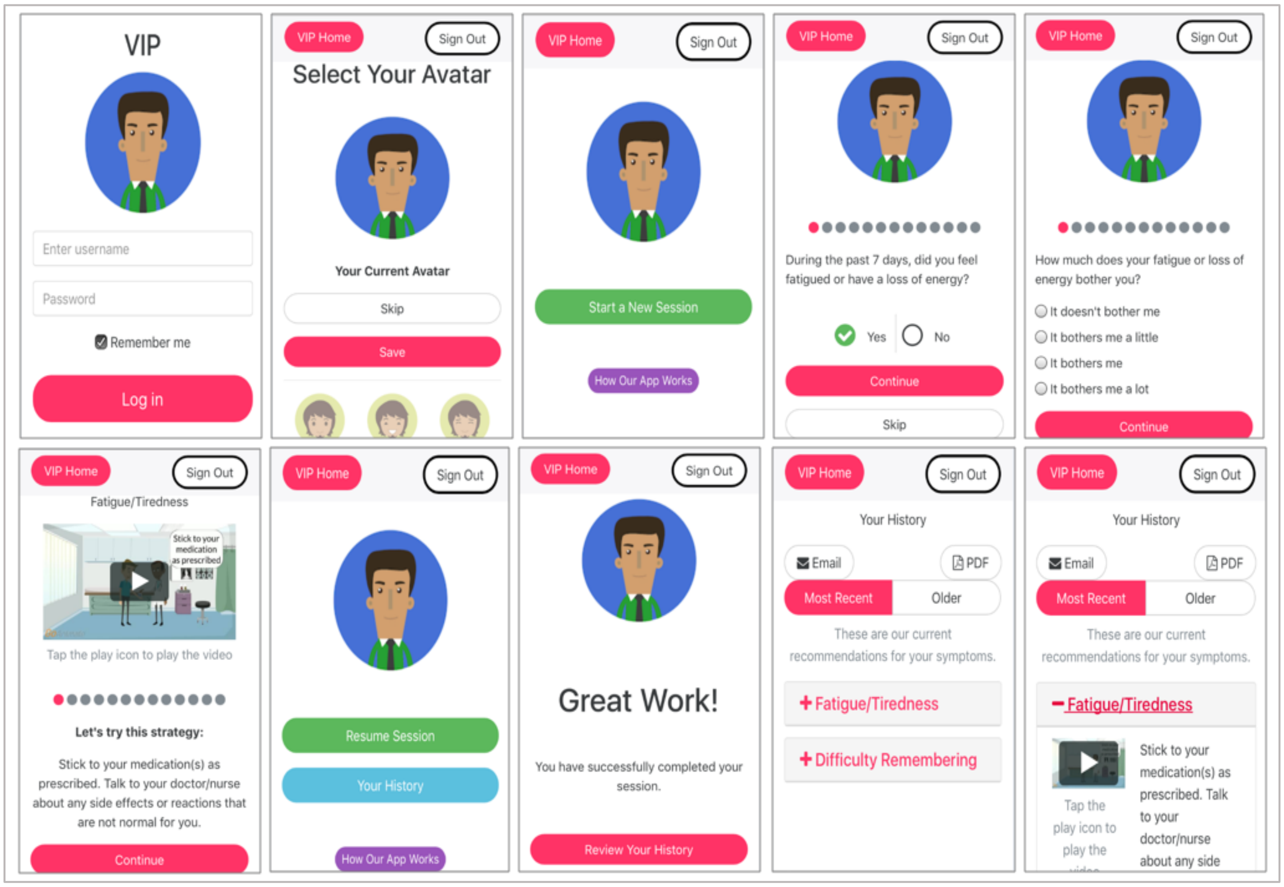

Figure 0-8. Refined mVIP prototype screenshots

Level 3 (User-Task-System-Environment): Usability Evaluation in a Real-World Setting

We recruited 10 PLWH from March to May 2017 to participate in in-depth interviews and 36 PLWH from April to May 2017 to participate in focus groups. The interviews and focus groups were intended to evaluate the usability of a prototype of mVIP in a real-world setting. The following research questions were answered: What usability problems are perceived by end-users in a real-world setting? Are the end-users satisfied with the way mVIP helps them to self-manage their symptoms in a real-world setting?

Descriptive statistics of the demographics, health literacy measured by S-TOFHLA and NVS (Baker et al., 1999; Weiss et al., 2005), and technology use obtained by self-report are presented. Findings from the in-depth interviews and focus groups are presented, and user-perceived satisfaction scores rated by participants via Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002) are sequentially presented.

Sample

Our sample for the in-depth interviews included 10 PLWH. Initially, we planned to recruit two participants among each of heavy, moderate, and light users; however, it was difficult to reach most light users as their smartphones were disconnected. We recruited a total 10 participants including two heavy users, two moderate users, and one light user from each of the intervention and control groups. As reported in *Table 4-16*, most participants were African American and had an annual median income of less than $20,000. The mean age for participants was 55.80years (*SD* = 3.70; range = 53-62 years of age) in the intervention and 52.00 years (*SD*

= 7.75; range = 39-58 years of age) in the control group. The mean number of app sessions participants completed over three months was 30.80 (*SD* = 29.42; range = 6-77) in the intervention and 21.40 (*SD* = 13.59; range = 8-38) in the control group. Nearly all of our participants used their mobile devices at least once per day.

A total of 36 PLWH included 24 PLWH from the intervention group for three focus groups (i.e. seven to nine PLWH for each of three focus groups) and 12 PLWH from the control group for a focus group. The majority of participants among the four focus groups reported their race as African American, and almost half of the participants had an annual median income of less than $10,000. The mean age for participants was 50.54 years (*SD* = 13.02; range = 23-72 years of age) in the intervention and 52.25 years (*SD* = 6.64; range = 39-63 years of age) in the control group. The mean number of app sessions participants completed over three months was 19.96 (*SD* = 14.35; range = 6-77) in the intervention and 20.58 (*SD* = 11.02; range = 11-47) in the control group. The majority of participants reported they use mobile devices several times every day.

The majority of the participants in the interviews and focus groups used mobile devices several times every day, and nearly all participants send/receive text message or email and download apps. Descriptive statistics on technology use including use of computers and mobile devices, are reported in *Table 4-17*.

Table 4-18 lists health literacy scores of the study participants, measured by S-TOFHLA (Baker et al., 1999) and NVS (Weiss et al., 2005). Among our sample in the in-depth interviews, all participants were rated as having ‘adequate’ health literacy (100%; *N* = 10) in the S-TOFHLA.

60% of the study participants in the intervention group (*N* = 3) and 80% of the participants in the control group (*N* = 4) obtained scores of 3 or less, indicating a strong possibility of low health literacy in the NVS. Among our sample in the focus groups, 12% of participants in the intervention (*N* = 3) were rated as having ‘inadequate’ health literacy and 8% of participants in the control (*N* = 1) as having ‘marginal’ health literacy in the S-TOFHLA (Baker et al., 1999). The majority of participants in both groups (88% in intervention; 92% in control) had a high likelihood/possibility of limited health literacy as rated by the NVS (Weiss et al., 2005).

Table 0-16. Characteristics of study sample: interviews (*N* = 10) and focus groups (*N* =36)

Characteristics	Interviews; N (%)		Focus Groups; N (%)	
	Intervention=5	Control=5	Intervention=24	Control=12
Gender				
Male	1 (20)	5 (100)	7 (29)	7 (58)
Female	4 (80)	0	17 (71)	5 (42)
Race				
African American / Black	3 (60)	4 (80)	17 (71)	11 (92)
White	0	0	3 (12)	0
Other	2 (40)	1 (20)	4 (17)	1 (8)
Ethnicity				
Hispanic / Latino	2 (40)	2 (40)	4 (17)	2 (17)
Marital Status				
Single	4 (80)	3 (60)	13 (54)	9 (75)

Married/ In a relationship	1 (20)	1 (20)	6 (25)	2 (17)
Divorced	0	1 (20)	3 (12)	1 (8)
Widowed	0	0	1 (4)	0
Education Level				
Elementary school	0	0	1 (4)	0
Some high school	4 (80)	0	5 (21)	2 (17)
High school graduate/ Got GED	0	2 (40)	7 (29)	4 (33)
Some college	0	2 (40)	6 (25)	2 (17)
Associate's degree	1 (20)	0	2 (8)	0
College graduate (4 years)	0	1 (20)	1 (4)	4 (33)
Professional or graduate degree	0	0	2 (8)	0
Current Employment Status				
Employed full-time	0	1 (20)	1 (4)	2 (17)
Employed part-time	0	0	1 (4)	0
Unemployed looking for work	3 (60)	2 (40)	7 (29)	1 (8)
Unemployed, not looking for work	3 (60)	2 (40)	2 (8)	2 (17)
Disabled	2 (40)	2 (40)	9 (38)	5 (42)
Annual Income				
Less than $10,000	3 (60)	2 (40)	13 (54)	5 (42)
$10,000-$19,999	1 (20)	1 (20)	6 (25)	2 (17)

$20,000-$39,999	0	1 (20)	0	3 (25)
$40,000-$59,999	0	0	1 (4)	0
Don't know	1 (20)	0	2 (8)	1 (8)
Prefer not to answer	0	1 (20)	0	0
Health Insurance Provider				
Public (e.g. Medicare, Medicaid, Ryan White)	5 (100)	5 (100)	23 (96)	11 (92)
Private (e.g. through employer or relative's employer)	0	0	1 (4)	1 (8)

Table 0-17. Technology use: interviews (*N* = 10) and focus groups (*N* =36)

Technology Use	Interviews; N (%)		Focus Groups; N (%)	
	I = 5	C = 5	I = 24	C = 12
Frequency of desktop or laptop computer use				
Several times every day	3 (60)	0	9 (38)	2 (17)
Once a day	0	0	2 (8)	1 (8)
Several times per week	0	3 (60)	4 (17)	2 (17)
Several times per month	0	0	2 (8)	1 (8)
Once a month or less often	1 (20)	2 (40)	4 (17)	4 (33)
Never	1 (20)	0	3 (13)	2 (17)
Frequency of mobile device use (e.g. Smartphone, tablet, cellphone)				
Several times every day	5 (100)	3 (60)	21 (88)	9 (75)
Once a day	0	2 (40)	1 (4)	3 (25)
Several times per week	0	0	1 (4)	0
Several times per month	0	0	1 (4)	0

First start of mobile device use				
In the past 6 months	2 (40)	1 (20)	4 (17)	1 (8)
In the past year	0	1 (20)	1 (4)	1 (8)
In the past two years	0	0	2 (8)	0
More than two years	3 (60)	3 (60)	17 (71)	10 (83)
Current use of mobile devices				
Smartphone (e.g. iPhone, Samsung)	4 (80)	5 (100)	21 (88)	12 (100)
Tablet (e.g. iPad, Amazon Fire)	1 (20)	0	2 (8)	0
Used mobile devices to:				
Send or receive text messages	5 (100)	5 (100)	24 (100)	12 (100)
Access the Internet	5 (100)	3 (60)	22 (91)	9 (75)
Send or receive email	5 (100)	4 (80)	23 (96)	10 (83)
Download apps	5 (100)	4 (80)	22 (91)	11 (92)
Get directions (location-based information)	5 (100)	4 (80)	20 (83)	7 (58)
Listen to music	5 (100)	4 (80)	20 (83)	11 (92)
Participate in a video call or video chat	3 (60)	2 (40)	11 (46)	6 (50)
'Check in' or share your location	2 (40)	2 (40)	9 (38)	5 (42)
Others	1 (20)	1 (20)	2 (8)	0
Numbers of texts per day				
1-10	3 (60)	4 (80)	12 (50)	9 (75)
11-50	2 (40)	0	9 (38)	1 (8)
51-100	0	1 (20)	2 (8)	2 (17)
More than 500	0	0	1 (4)	0
Duration of mobile device use (hours/day) (mean ± SD)	5.80±3.19	4.00±4.53	6.33±3.58	5.33±3.66

Table 0-18. Health literacy: interviews (*N* = 10) and focus groups (*N* =36)

S-TOFHLA total score (36 items)	Interviews; N (%)		Focus Groups; N (%)	
	I = 5	C = 5	I = 24	C = 12
0 – 16 (inadequate)	0	0	3 (12)	0
17 – 22 (marginal)	0	0	0	1 (8)
23 – 36 (adequate)	5 (100)	5 (100)	21 (88)	11 (92)

NVS total Score (6 item)	Interviews; N (%)		Focus Groups; N (%)	
	I=5	C=5	I=24	C=12
0 – 1 (high likelihood of limited)	3 (60)	4 (80)	16 (67)	9 (75)
2 – 3 (possibility of limited)	1 (20)	1 (20)	5 (21)	2 (17)
4 – 6 (almost always adequate)	1 (20)	0	3 (12)	1 (8)

Interviews and Focus Groups

We analyzed the transcripts of 10 in-depth interviews and four focus groups for emerging themes regarding the usability of the mVIP prototype perceived by end-users in a real-world setting based on our participants' experiences, perceptions, and satisfaction of mVIP app use. While both the intervention and control groups received symptom and intensity questions (e.g. did you have fatigue? If yes; how much did it bother you?), only the intervention group was provided with self-management strategies for the symptoms that bothered the participants (i.e. enhanced mVIP). A total 15 themes were identified from the interviews and focus groups; the first nine themes were identified in the intervention group and the next six themes were identified in the control group. Of the subjective constructs of Health-ITUEM (*Figure 3-5*) used as a theoretical framework in level 3 of the study, themes identified in the intervention group related to *Perceived usefulness* and those identified in the control group related to *Perceived ease* *of use*. The results are organized by the two major constructs below. Specifically, as in-depth interviews were intended to get individual-level insights and focus groups were intended to gain group-level insights, the similarities (i.e. general insights) and differences of findings from the interviews and the focus groups were identified. Themes and quotes from the content analysis conducted from the interviews and focus groups are reported in *Table 4-19*.

Perceived usefulness of mVIP and additional user expectations; intervention

The nine themes identified in the intervention group related to the usefulness of mVIP and additional user expectations. The nine themes are as follows: 1) mVIP is useful to meet users' information needs about how to ameliorate their HIV-related symptoms; 2) mVIP is useful to communicate/interact with healthcare providers by sharing information about their bothersome symptoms as well as any improvements or worsening of symptoms following the self-management; 3) mVIP is useful due to the convenience of using it at a place and time users preferred; 4) strategies provided using text and videos are good; adding sounds into the videos would be preferred; 5) mVIP being available in Spanish would facilitate its use; 6) intrinsic motivation of the frequency of mVIP use was often for individual enjoyment; however, using the app once a week is enough; 7) more symptoms and self-management strategies should be offered depending on years since the user's HIV diagnosis; 8) more individually-sensitive self-tailoring symptom management would improve the mVIP app; and 9) additional functionality of communication with social groups to share feelings with other PLWH would be good.

Participants in the interviews and focus groups perceived mVIP to be useful. They thought mVIP could help self-manage their HIV-related symptoms by using strategies. They also thought mVIP could help interact with their healthcare providers by sharing the information about their symptom status by using a review function within the app. Within the mVIP app, users are able to review all strategies previously provided related to their bothersome symptoms, which helps our participants communicate with their healthcare providers without forgetting their bothersome symptoms. One participant described that, *"Sometimes you go to the doctor and forget the symptoms you have been going through. If you bring this app to the doctor and go to the review part (in the app), this app could show the stuff, everything, you've been going through."*

Participants in the focus groups mentioned it would be important for the app to be tailored to different year of diagnosis groups and to be tailored to more sensitive individuals. As HIV is considered a chronic disease, PLWH have been living with the common symptoms in their daily lives and have already tried various self-care strategies. They highlighted their desire for mVIP to include more symptoms and self-management strategies. One participant elucidated that, *"If you just got diagnosed with HIV between 1-5 years, this (strategies) is perfect. I've been diagnosed since 1989. There were a lot of suggestions that did work, but we can't just stick with one. More helpful hints. More quantity of suggestions and strategies for us (who were diagnosed with HIV a long time ago)."* In addition, participants expressed their extended expectations about more individually sensitive self-tailoring symptom management stating that, *"You could have the HIV and Hepatitis. We are different individuals. I am women. I'm African American. I could be older. I'm obese. You're thinner."*

Regarding the intrinsic motivation of the frequency of mVIP use, one participant in the interviews reported that the reason of her frequent app use (e.g. sometimes three times per day) was for fun, even though she thought using the app once per week and trying the suggested self-management strategies for the week would be best.

Perceived ease of mVIP use to track symptoms but also acknowledged its deficits; control

The six themes identified in the control group related to the ease of mVIP use to track symptoms but also acknowledged its deficits. The six themes are as follows: 1) mVIP is an easy and simple app to facilitate self-awareness of symptoms; 2) there is a lack of information on how to manage the symptom reported; 3) in addition to asking about symptoms, providing a short summary would be helpful to share with healthcare providers; 4) mVIP is tedious due to the repeated questions; 5) extrinsic motivation of the frequency of app use was to get more opportunities to be invited to the future research study; and 6) some users preferred to save their password for the ease of use; others prioritized the security of the password (i.e. not to save their password).

Participants in the control group that participated in interviews and/or focus groups, perceived that mVIP is easy to use and facilitates self-awareness of their symptoms. They felt that they would be able to self-track their symptoms using the app. One participant stated that, *"My experience while using this easy app, it gave me the power to control and monitor what was really going on with my body. You should know what issues may occur. To be alert. To be aware."* Meanwhile, a few participants recommended the inclusion of a short symptom summary within the app to share with healthcare providers. They made specific recommendations about the symptom summary and suggested that it be easy to understand like line charts. Multiple participants also suggested that mVIP should provide with tips how to manage the bothersome symptoms in addition to asking about the symptoms and its intensity. One participant said that, *"I don't think the app itself helped me. It should say the way how to deal with my problems."*

During the focus groups, several participants expressed preferences for a function of saving a password related to the ease of use stating that, *"9 out of 10 times, I forgot the password. The app had a little button that says: remember me. Therefore, I didn't have to remember my password. It was very easy to use."* On the other hand, a few participants raised concerns about the security of the password. One participant highlighted his experience about the smartphone stolen and security issues stating that, *"For me, I never do that. Like, speaking to the gentleman who had his phone stolen – I have the experience. If you have that 'remember me' and somebody accesses your phone…let's say you have it on your bank account (because we usually use the same passwords). They can immediately see what your bank account level is, they have access to your HIV."*

Table 0-19. Themes and quotes of content analysis from the interviews and focus groups

	Interview	Focus groups
(Intervention Group) ***Usefulness of mVIP and additional user expectations***		

<table>
<tr><td>Similarity</td><td colspan="2"><u>Theme I-1. Usefulness for information needs – symptom problem solving</u>

“I don’t remember how many weeks I got horrible conditions. All of those (information) were helpful to me. I'm going through a lot of issues with that.”

“It was very helpful (for reducing my symptoms), for different situations. It (app) gave me a suggestion and I tried it and got better.”</td></tr>
<tr><td></td><td colspan="2"><u>Theme I-2. Usefulness for interaction needs with healthcare providers</u>

“I was discussing with my doctor about the app and she was very impressed about my situation (symptoms and self-care strategies I tried). They (doctors) can see (review) that it’s working (symptoms) improvements on me. I was so happy to have the app in my cell phone.”

“Sometimes you go to the doctor and forget the symptoms you have been going through. If you bring this app to the doctor and go to the review part (in the app), this app could show the stuff, everything, you’ve been going through.”</td></tr>
<tr><td></td><td colspan="2"><u>Theme I-3. Usefulness of mobile app format as a perceived facilitator</u>

“It’s very convenient because I can use it almost anywhere. While I’m in public transportation, on the buses, at the clinic, at home...everywhere.”

“I don’t disclose my status based on the violence perpetrated against me and people that I know in the industry. Stigma… because I’m HIV positive… I have a problem with it. I did my app at home or in the park, having a coffee when I stay only with myself because my phone is always with me.”</td></tr>
<tr><td>Difference</td><td><u>Theme I-4. Additional preference of strategy design (text & video with sounds)</u>

“I like both (text and video). The video is self-explanatory. It’s the same thing with what I read. It just that the video just made it easier.”

“I liked the video (more than just text). Very attractive.”

“What the video is saying can give you a little more insight on how to do things and how to go about them and whatever, but if you don’t have the audio it’s like, ‘Just let me read this, click and answer and just go on to the</td><td><u>Theme I-7. More symptoms and strategies needs according to years of diagnosis</u>

“I think it (strategies) will help people that are newly diagnosed that they are dealing with something new that they’re not familiar with, something that they didn’t expect to have and, as a newly diagnosed person, they go through a lot of confusion, a lot of questions in their mind. We need something geared towards where we are right now because we have much more issues than the app is talking about for us.”

“If you just got diagnosed with HIV between 1-5 years, this (strategies) is</td></tr>
</table>

	next one.' So, the audio would help." *"The video didn't have any sound. I never wanted to press play because I didn't hear anything. I wanted audio."*	*perfect. I've been diagnosed since 1989. There were a lot of suggestions that did work, but we can't just stick with one. More helpful hints. More quantity of suggestions and strategies for us (who diagnosed with HIV long time ago)."*
	Theme I-5. Additional preference of available language *"Because my community, the Latino community in NYC is very big and increasing in HIV. The Spanish community... It's very important the Latino community can comprehend the app. You can get two options, in English or in Spanish."*	Theme I-8. More individually-sensitive self-tailoring symptom management *"Everyone is different when it comes to their health. It (strategies) was less personal. We may not have the same status. We all should have our own things that we're dealing with in (personal) life..."* *"You could have the HIV and Hepatitis, we are different individuals. I am women. I'm African American. I could be older. I'm obese. You're thinner."*
	Theme I-6. Intrinsic motivation of the frequency of app use (for enjoyment) *"I use it (app) 3 times a day sometimes. Just playing around. Just to play a little game. I'm playing a game and I'm tired of the game, I just start to do the app instead. I don't have anything else to do. I don't think more (app use) would be helpful. Once a week is right on point."*	Theme I-9. More communication needs with social groups *"I think you should create a network where we can network among each other within the app. (So) you can respond to someone and you can say, 'I'm feeling the exactly same way today (like you).' Or, if someone is not feeling well you can send a message back like, '(tell me). Let me see how you're feeling. We can share the feelings (because we are all HIV+).'"*
(Control Group) ***Ease of mVIP use to track symptoms but also acknowledged its deficits***		
Similarity	Theme C-1. Easy app as a regular tool to facilitate self-awareness of symptoms *"I like to listen to my body and it made me more aware of what's going on with me. I like the app because it's simple and easy to use and there were something that were listed in the app that I had no idea that were related to my HIV. So, it caused me to listen more closely to what's going on with me."* *"My experience while using this easy app, it gave me the power to control and*	

	monitor what was really going on with my body. You should know what issues may occur. To be alert. To be aware.”	
	Theme C-2. Lack of action planning of symptom self-management *“It was easy (to use the app) but I thought there could be another portion that would deal with stress (symptoms).”* *“I don’t think the app itself helped me. It should say the way how to deal with my problems”*	
	Theme C-3. Lack of symptom summary to share with healthcare providers *“In regards to answering yes or no, and at the end. A short summary of what our symptoms were… when you see your doctor it just totals the graphs (charts) down and then he can see what’s going on me (symptoms)… We can build that kind of provider relationship (using symptom report summary).”*	
	Theme C-4. Tedious experience of the repeated questions *“The app, it kept repeating itself over and over again. It was like the same thing (questions) over and over, so it got kind of boring for me.”*	
Difference	Theme C-5. Extrinsic motivation of the frequency of app use (for rewards) *“Once a week is good. (But I used the app) At least twice a week because I want to build up my chances for being accepted for the research study next time. For the research study...”*	Theme C-6. Appraisal of ease of use vs. security of the password *“9 out of 10 times, I forgot the password. The app had a little button that says: remember me. Therefore, I didn’t have to remember my password. It was very easy to use.”* *“For me, I never do that. Like, speaking to the gentleman who had his phone stolen – I have the experience. If you have that ‘remember me’ and somebody accesses your phone…let’s say you have it on your bank account (because we usually use the same passwords). They can immediately see what your bank account level is, they have access to your HIV.”*

User-Perceived Satisfaction

Users-perceived satisfaction for participants in the in-depth interviews and focus groups rated using Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002) is presented in *Table 4-20*. Overall, participants in both intervention and control groups rated the usability of mVIP app as being high. The mean score of the overall Health-ITUES for participants in the interviews was 4.61 (*SD* = .54) in the intervention group and 4.19 (*SD* = .50) in the control group. The mean score of the overall Health-ITUES for participants in the focus groups was 4.46 (*SD* = .60) in the intervention group and 4.72 (*SD* = .33) in the control group. The mean score of the overall PSSUQ scores in the interviews was 1.76 (*SD* = .73) in the intervention group and 1.80 (*SD* = .98) in the control group. The mean score of the overall PSSUQ scores in the focus groups was 1.64 (*SD* = .82) in the intervention group and 1.32 (*SD* = .57) in the control group. All of the subscales were positively skewed in Health-ITUES and were negatively skewed in PSSUQ, which indicates more favorable usability scores on both instruments. While we compared the mean user satisfaction scores between study groups using a Kruskal-Wallis test, a non-parametric method, there was no significant difference between the intervention and control group scores on both subscales and overall Health-ITUES as well as PSSUQ scores. There was no significant association in a regression analysis adjusted for app use frequency, age, sex, race/ethnicity, education level, annual income status, and health literacy level.

Table 0-20. End-user's satisfaction: interviews (*N* = 10) and focus groups (*N* =36)

Health ITUES	Interview (*N* = 10)	Focus group (*N* =36)

Quality of Life	Intervention ($N = 29$)	4.80±.45	4.50±.56
	Control ($N = 17$)	4.07±.60	4.69±.52
	p-value	.07	.32
Perceived Usefulness	Intervention ($N = 29$)	4.38±.88	4.28±.81
	Control ($N = 17$)	4.16±.52	4.70±.39
	p-value	.34	.14
Perceived Ease of Use	Intervention ($N = 29$)	4.96±.09	4.77±.53
	Control ($N = 17$)	4.40±.55	4.88±.29
	p-value	.12	.45
User Control	Intervention ($N = 29$)	4.53±.45	4.46±.79
	Control ($N = 17$)	4.07±.72	4.50±.44
	p-value	.24	.50
Overall (all the items)	Intervention ($N = 29$)	4.61±.54	4.46±.60
	Control ($N = 17$)	4.19±.50	4.72±.33
	p-value	.29	.29

**p*-value from Kruskal-wallis

PSSUQ		Interview ($N = 10$)	Focus group ($N = 36$)
System Quality	Intervention ($N = 29$)	1.30±.51	1.39±.52
	Control ($N = 17$)	1.75±.96	1.25±.59
	p-value	.59	.22
Information Quality	Intervention ($N = 29$)	1.93±.91	1.75±1.00

	Control (N = 17)	1.88±1.03	1.43±.59
	p-value	.71	.67
Interface Quality	Intervention (N = 29)	2.20±1.26	1.81±1.22
	Control (N = 17)	1.75±.96	1.31±.63
p-value	*p*-value	.53	.20
Overall (all the items)	Intervention (N = 29)	1.76±.73	1.64±.82
	Control (N = 17)	1.80±.98	1.32±.57
	p-value	.80	.46

**p*-value from Kruskal-wallis

Chapter 5. Summary, Discussion, Conclusions, and Recommendations

This chapter summarizes the results of the study and provides a discussion of the results, including implications for nursing research and informatics, limitations, and recommendations for future research.

Summary of Study

The purpose of this study was to translate paper-based health information into an mHealth app, entitled mVIP, for symptom self-management in underserved PLWH and assess its usability. Based on the stratified view of health IT usability evaluation framework, a three-level usability evaluation was conducted. At level 1 (user-task), we applied a user-centered design method to guide the information architecture of mVIP. Using a reverse in-person card sorting technique, the rank order of the 13 symptoms and 151 self-management strategies from the paper-based HIV/AIDS symptom management manual was established. Incorporating the rank order of the symptoms and self-management strategies into the information architecture of a mobile app, we developed a prototype of mVIP. Higher-ranking symptoms and strategies appeared first in the mVIP prototype. At level 2 (user-task-system), we conducted a usability evaluation of the mVIP prototype in a laboratory setting. We examined task performance through end-user usability testing and assessed the user interface through heuristic evaluation with experts in informatics. Based on findings from the two usability evaluations, the prototype was iteratively refined. After excluding and rewording some of the original self-management strategies per the usability results, 143 self-management strategies for 13 symptoms were incorporated into the refined mVIP prototype. 143 animated videos presenting the finalized 143 symptom self-management strategies were created and added into the refined mVIP prototype. At level 3 (user-task-system-environment), usability of the mVIP prototype was evaluated in a real-world setting. We explored in-depth understandings of users' experiences, perceptions, and satisfaction through interviews and focus groups in a three-month RCT. Of the 15 themes identified from the interviews and focus groups, nine themes related to *Perceived usefulness of mVIP and additional user expectations* were identified from the interviews and focus groups with intervention group participants. Six themes related to *Perceived ease of mVIP use to track symptoms but also acknowledged its deficits* were identified during the interviews and focus groups with control group participants. Findings from the study showed that first, mVIP is useful for HIV-related symptom self-management and has the potential for being used as a communication tool with healthcare providers; and second, mVIP is easy to use to monitor symptom experience over time. At the same time, participants suggested mVIP be more sensitively tailored based on years from initial diagnosis of HIV, an individuals' age, and conditions. The overall usability was rated high by Health-ITUES and PSSUQ, which reflects high user satisfaction of mVIP.

Discussion of Results

Level 1 (User-Task): User-Centered Design

Inclusion of intended end-users in mVIP design

Poor design that does not meet the needs of the intended end-users is one of primary reasons why many technologies ultimately fail to accomplish their objectives (Maguire, 2001;

Meuter, Ostrom, Roundtree, & Bitner, 2000). To develop an effective mHealth app, it is critical to start by incorporating users' requirements into the app's design so that the users can be more engaged in the use of the app (R. Schnall, S. Bakken, et al., 2015). However, many mHealth apps are designed without or with minimal end-user feedback, and the continued proliferation of mHealth apps without input of users in the design process is inherently flawed (Schnall et al., 2016). In the mVIP design process, we explored the needs of our intended end-users, underserved PLWH. Inclusion of the end-users in the design process was intended to lead to greater usefulness and ease of use of mVIP for PLWH, which doubtlessly resulted in a more useful mVIP prototype as well as higher user satisfaction of the app than if the design process happened with limited or without end-user participation.

Robustness of mVIP content using evidence-based strategies for symptom self-management

mVIP was designed employing earlier evidence from patient-centered outcomes research studies (Wantland et al., 2008). A paper-based HIV/AIDS symptom management manual with self-care strategies was shown to be effective in PLWH (Wantland et al., 2008), and evidence-based interventions have been well-validated for behavior change in the context of health care (Fishbein, Triandis, Kanfer, Becker, & Middlestadt, 2000). Thus, employing evidence-based strategies for HIV symptom self-management is a strength of the content of the mVIP app.

Innovative user-centered design method in the app development; card sorting activities

We used card sorting activities, a user-centered design method (Nielsen, 1995), in the first level of our usability evaluation as we planned to translate health information of HIV-related symptoms and self-management strategies from a paper-based HIV/AIDS symptom management manual to an mHealth app. Card sorting is particularly effective during the design phase since it generates an overall information structure and suggestions for navigation, menus, and possible taxonomies of the system (Spencer, 2004). It is instrumental in capturing and organizing helpful information during the information design phase, ultimately making the app easier to use. Card sorting has been used in a number of usability studies for the development of software interfaces (Fuccella, 1997; Whang, 2008; Zimmerman & Akerelrea, 2002). A study using card sorting for developing informational websites demonstrated that card sorting provided a formative evaluation methodology to enhance the overall structure and potential information for the websites. The labeling and organization based on the results of card sorting facilitated navigation and searching the website and made the content more understandable (Zimmerman & Akerelrea, 2002). In another study using card sorting during website development, authors stated that it was useful to minimize discrepancies among the developers' and intended end-users' frames of reference (Fuccella, 1997). Card sorting can be useful to any design team developing or modifying their own system by helping to build a more compelling, insightful system (Whang, 2008). Despite the benefits of card sorting for website development, there have been no usability studies using card sorting activities for mobile app development. Thus, our rigorous user-centered design approach applying the card sorting technique to the app design process is an innovation and should be considered in future development of mobile apps.

Information architecture of symptoms and self-management strategies

Findings from the card sorting exercise established a ranked order of symptoms and self-management strategies from the HIV/AIDS symptom management manual. Of the 13 symptoms included in the mVIP prototype, fatigue was found to be the most prevalent symptom, similar to findings from a study of symptom experience among PLWH in the Eastern Cape, South Africa (Peltzer & Phaswana-Mafuya, 2008). Insomnia (rank 2), depression (rank 4), and anxiety (rank 5) were also highly prevalent symptoms among our participants, similar to what was found in a review of symptom management in HIV-infected patients (Hughes, 2004).

The information collected through the card sorting exercise informed app navigation and the hierarchical order of symptoms and self-management strategies within the mVIP prototype, as higher-ranked symptoms and self-management strategies appear first. In other words, this level of the usability evaluation identified needs (e.g. priorities) for our intended end-users to inform the app's design and establish its components before prototyping took place. Good information architecture is key to creating engaging, easy to use, and intuitive technology. Thus, the level 1 study supported the needs of our end-users by building the mVIP prototype which was created based on the information architecture specified by them.

Level 2 (User-Task-System): Usability Evaluation in a Laboratory Setting

Comprehensive examination of usability in a laboratory setting

Usability evaluations in a laboratory setting are foundational to the success of achieving systems that meet human-computer interaction principles. Usability evaluations have been widely used, and in many cases have improved the system to which they are applied in a real-world setting (Norgaard & Hornb, 2006). In end-user usability testing, we examined task performance by 20 PLWH using an eye-tracking and retrospective think-aloud method. By integrating data from task performance time, eye movements, and contents from the think-aloud protocol, usability problems with the mVIP prototype were identified, and its user-perceived satisfaction was rated. Through heuristic evaluation, usability issues primarily related to the user interface were found by five usability experts in informatics, and the expert-perceived satisfaction was rated. Based on the findings from the two usability evaluations, we identified a number of usability issues with the mVIP prototype and iteratively refined its content, functionality, and interface.

In many cases, heuristic evaluations are conducted prior to end-user usability testing (Jaspers, 2009). For example, heuristic evaluations are frequently used in the early stages of system design (Allen, Currie, Bakken, Patel, & Cimino, 2006; Bright et al., 2006; Zhang, Johnson, Patel, Paige, & Kubose, 2003), and end-user usability testing is used in system design/implementation stage (Chiu & Lottridge, 2005; Kushniruk, Triola, Borycki, Stein, & Kannry, 2005; Ostergren & Karras, 2007; Peute & Jaspers, 2007). In this dissertation, end-user usability testing preceded the heuristic evaluation due to the timeframe related to the development process (i.e. a web version of the prototype was implemented for the heuristic evaluation after the mVIP prototype had been designed based on the findings from the level 1 study). The two evaluation methods used to identify usability problems in this level of the dissertation represented different perspectives of the app's usability problems, obtaining both the end-users' task performance interacting with the mVIP prototype and the experts' examination of the user interface. While both end-users and usability experts are effective in revealing usability problems, they capture different usability perspectives (Lai, Larson, Rockor, & Bakken, 2008). Usability issues identified by experts but not by end-users are more likely to be interface features but are generally less relevant to impact on task performance (Jaspers, 2009). Therefore, a combination of usability evaluation methods from both end-user and usability expert perspectives in our study provides the most effective and thorough usability evaluation results before the mVIP prototype was used in a real-world setting (Yen & Bakken, 2009).

Level 2-1. End-User Usability Testing

End-user usability testing was conducted with 20 PLWH, including 10 Android and 10 iPhone users who self-identified as heavy smartphone users. The inclusion of participants with familiarity with smartphone apps was important in the level 1 study, since otherwise it would have been impossible to ensure that usability issues identified from this study would occur not from participants' lack of technology skills, but from problems with the app. A heavy smartphone user might interact more intensely with an app and apply a more closed-system perspective when thinking about events in a laboratory setting (Yee, 2006), yielding a deeper understanding of user, task, and system interaction.

The impact of health literacy on health outcomes among PLWH continues to be a growing area of HIV research (Wawrzyniak, Ownby, McCoy, & Waldrop-Valverde, 2013). Low health literacy is significantly associated with ethnicity, socioeconomic status, and level of education (Paasche-Orlow, Parker, Gazmararian, Nielsen-Bohlman, & Rudd, 2005; Wawrzyniak et al., 2013). As our target population is underserved PLWH, we collected health literacy data from our participants to assess their ability to read and understand the HIV-related health information within the mVIP prototype. 70% of the participants in our study self-identified as African American, 60% of participants reported an annual income of less than $19,999, and more than one third of participants reported an education level of high school or less. Health literacy levels of the 20 PLWH, however, differed by measurement with S-TOFHLA (Baker et al., 1999) compared with NVS (Weiss et al., 2005). The S-TOFHLA mainly focuses on reading comprehension and does not include numeracy testing, while the NVS weighs heavily toward numeracy. While 95% of the participants (*N* = 19) were rated as having ‘adequate’ health literacy using S-TOFHLA, 85% (*N* = 17) were rated as having ‘low’ health literacy using NVS. In this dissertation, the two most widely used instruments for health literacy measures were selected, and these differences are consistent with prior studies. For example, significant inconsistencies were observed between the S-TOFHLA and NVS in their identification of individuals with limited health literacy among African Americans (Patel et al., 2011). Existing studies have demonstrated patients’ deficits in understanding and applying nutritional label information required to follow dietary recommendations (Kirk et al., 2012; Patel et al., 2011; Rothman, Housam, Weiss, & Davis, 2006). These deficits may explain our participants achieving higher health literacy levels as measured by the S-TOFHLA compared to the NVS testing numeracy skills. Moreover, these differences illustrate that our mobile technology may be usable as an effective delivery mode of HIV-related information for end-users with limited health literacy as the mVIP app requires literacy (i.e. reading comprehension) but not numeracy skills. Since low health literacy is associated with poor health outcomes (Patel et al., 2011), understanding intended end-users' health literacy level may help researchers deliver health information in the format that the end-users can easily understand. Given the inconsistent results of the S-TOFHLA and NVS, researchers should carefully select health literacy assessments depending on the features/contents within mHealth technologies they are developing.

Combination of eye-tracking and think-aloud methods

Our end-user usability testing results showed significant differences in task performance duration between participants who experienced difficulties and those that did not. Differences primarily resulted from incorrect/unclear error messages or from participants' mistakes related to items on the smartphone screen being too small for their fingers; however, a particular time difference within task 1 was found to be due to the placement of the 'Continue' button. This usability problem was identified by eye movements collected during the participant's app testing process and verbalizations collected during the retrospective think-aloud protocol. Since the 'Continue' button was placed under the response options, participants were required to scroll down to find the button. When the participant had trouble finding the button, a large red circle resulting from the long eye fixation or long red lines resulting from distractive eye movements were identified upon replay of the screen-recordings of their task performance. Using the retrospective think-aloud protocol, we learned the reason for their unusual eye movements. The majority of participants with the problem reported that they thought answering a question would trigger the next app page, as the 'Continue' button was not immediately visible. A similar problem was identified on the login page, where the 'Log-in' button was obscured behind the keyboard used to input the login information. These severe usability problems were identified as a result of using both the eye-tracking method and think-aloud protocols. A combination of eye-tracking and think-aloud methods provides more information on what the users are thinking and doing since the think-aloud protocol alone cannot provide complete information, and self-reported usability problems without a cue are often considered to be biased (Manhartsberger & Zellhofer, 2005; Schiessl, Duda, Thölke, & Fischer, 2003). As demonstrated in a study using eye-tracking to address limitations in a think-aloud protocol, adding eye-tracking in the think-aloud method not only helped to gain more valuable information, but also minimized biased responses. The study findings suggest that a think-aloud protocol may fail to identify additional objective cues that provide insight into participants' expectations about where information should be located and their level of confidence about information found (Cooke & Cuddihy, 2005), supporting the usefulness of incorporating both of these methods.

The Health-ITUEM theoretical framework

The theoretical framework plays an important role in guiding the study activities and selection of measures; however, there continues to be a dearth of theoretical frameworks and models in research studies of evaluation of health systems (Brown et al., 2013; Schnall, Rojas, Travers, Brown, & Bakken, 2014; Yen & Bakken, 2012). In the level 2 and 3 study of this dissertation, we used the Health-ITUEM (Yen, 2010), widely used in mobile technology studies since its validation with mobile technologies (Brown et al., 2013). By using this rigorous theoretical framework for mHealth apps, we were able to identify usability problems of the mVIP prototype during end-user usability testing.

Based on nine concepts of the Health-ITUEM framework (i.e. error prevention, completeness, memorability, information needs, flexibility/customizability, learnability, performance speed, competency, and other outcomes), 27 codes broken the nine concept codes into positive, negative, and neutral were used to identify usability issues from the transcripts of participants' verbalizations. Of the nine Health-ITUEM concepts, *Error prevention* was the most frequent usability issue. Although an app should offer appropriate error management, error correction through an undo function, or error prevention to assist users performing tasks, our results showed several usability problems caused by unclear error messages, contradictory information in error messages, an inconspicuous back button, difficulty understanding the term 'dashboard', and a lack of instructions for how the app works. Previous studies suggest the best results in usability evaluations come from carrying out as many small tests as possible, and that correcting most of the problems before the end of the usability evaluations might result in a more effective experience for the later usability evaluators (Schneider, Bolger, Eschman, Neff, & Zuccolotto, 2005). Therefore, the unclear error messages and contradictory information in error messages were corrected immediately after the end-user usability testing without waiting for the completion of the heuristic evaluation. Integral to the recommendations from heuristic evaluators, the color red was used to highlight the error message to help users more easily recognize the error.

Learnability was the next most frequently used code. While usability issues associated with *Learnability* were mostly related to difficulties finding a specific button, confusion related to the use of checkmarks in response options was a problem making it harder for participants to understand how to operate the mVIP prototype. However, *Learnability* was coded positively as participants mentioned that difficulties related to the button or checkmarks were a problem for the first app use but not in subsequent uses. This was demonstrated in the task performance results as the mean time of the task to reach the first continue button was 160.75 seconds for participants with trouble and 29.56 seconds for those without trouble in the first app session, but 15.10 seconds on average in the second app session, with no participants reporting trouble. In a study assessing usability of an Android app for locating individuals while indoors, *Learnability* was measured by how much the task execution time was decreased between the first and the second execution, and it was found that the second execution needed only 80.7% of the time needed in the first try (Closs, Da Costa, & Da Rosa Righi, 2014). In regards to *Learnability* related to the first continue button in our study, the second execution required only 89.4% of the time needed in the first try.

Regarding the usability factor *Flexibility/Customizability* as coded negatively, several participants preferred to be able to save their username and password on their own smartphones. As forgetfulness was identified as one of the most common symptoms in PLWH in the level 1 study, forgetfulness may affect participants' desire for having an additional function allowing them to save the login information within the app despite the risk in the security protections. Adding the function of saving the user ID and password into the mVIP prototype could help our end-users log into the app with less trouble.

Multiplatform solution; mobile web-app

To resolve usability issues, in particular those related to the buttons not standing out, we transitioned the mVIP prototype from a native app to a mobile web-app. Most developers prefer native apps that are specific to an environment in order to take full advantage of their particular features, since native apps provide a richer experience with a more responsive interface and users can open them faster after installing the apps onto their mobile devices (Serrano, Hernantes, & Gallardo, 2013). There are many different Android versions and browsers, however, and some of these versions have poor support for standardized cross-platform solutions (Joorabchi, Mesbah, & Kruchten, 2013). Considering the limitations of the different capabilities between Android and iOS platforms, changing mVIP to a mobile web-app was the best solution. To improve the user experience and make the web-app prototype look and feel like a native app, we suggested individuals participating in the usability evaluation in a real-world setting navigate to and bookmark the mVIP page to their smartphone home screen.

User-perceived satisfaction

Despite the identified usability problems, our participants indicated high satisfaction with the mVIP prototype as rated by Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002). They may have perceived the usability issues of the mVIP prototype to be easily resolvable. Considering the results of *Learnability* as discussed above, our participants may have perceived that it was easy to learn how to overcome the usability issues during the testing. Since several issues had been largely resolved during the app testing, participants had fewer issues at completion of the testing app sessions than at the beginning. Learnability is one of the key factors for the acceptance of the system, which affects user-perceived satisfaction (Davis & Connolly, 2007; Tsakonas & Papatheodorou, 2008).

Level 2-2. Heuristic Evaluation

Previous research on heuristic evaluation demonstrates that this evaluation can identify minor usability problems that are often not detected in actual end-user usability testing (Nielsen, 1992). While our heuristic evaluators identified similar usability issues to those identified by our end-users, they were more likely to focus on 'making things work' or what is referred to as 'functionality', while the end users were more interested in task performance or their ability to use the app (Lai, 2007; Lathan, Sebrechts, Newman, & Doarn, 1999). For example, the usability factor *Match between System and the Real World* was identified by usability experts regarding the helpfulness assessment question for each of the strategies suggested in the previous session. They recommended that an additional response option for end-users who did not try that particular strategy be included and that no strategies be provided for symptoms reported as not bothersome by end-users. These changes would make the mVIP prototype follow real-world conventions, making information appear in a natural and logical order (Nielsen, 1994a).

Level 3 (User-Task-System-Environment): Usability Evaluation in a Real-World Setting

Real-world usability testing

Usability of a system is closely linked to the interaction of users performing tasks in the system within a specified environment. Change in any of the components of user, task, system, and environment may change the entire interaction and influence the usability of the system (Yen, 2010). It is imperative to take usability problems into consideration throughout the process of system development. Nonetheless, many studies on the development of an mHealth app evaluate its usability only in a laboratory setting or assess its usability in a laboratory setting and its feasibility (i.e. impact on health outcomes) in a real-world setting. This approach may overlook usability issues related to the actual interaction between user, task, system, and environment. In this dissertation, usability testing in a real-world setting after refining the mVIP prototype followed by usability evaluations in a laboratory setting enabled us to measure users' actual experience when interacting with the mVIP app, an important strength of our study.

User acceptance of mVIP

User acceptance of mobile technology is about how users accept and adopt the technology for use, which is strongly linked to the success or failure of the technology (Louho, Kallioja, & Oittinen, 2006). Of several critical factors that may influence technology use, previous research suggests two key constructs are especially important (Davis, 1989). First, people tend to use or not use the technology to the extent they believe it will help them perform their tasks better; this construct is called perceived usefulness. Second, potential users may believe that the technology is useful, but perceive that it is too hard to use and that the performance benefits of usage are outweighed by the effort of technology use; this construct is referred to as perceived ease of use. Findings from 10 in-depth interviews and four focus group sessions, to explore in-depth understandings of users' experiences, perceptions, and satisfaction at the conclusion of a three-month RCT, related perceived usefulness of mVIP in the intervention group, and related perceived ease of use of mVIP in the control group. Findings from the study in both intervention and control groups showed high user-perceived satisfaction rated by Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002).

Perceived usefulness of mVIP

Findings from the study in the intervention group showed that our participants perceived mVIP as useful for HIV-related symptom self-management and as having the potential for being used as a communication tool with healthcare providers. mVIP was intended to provide evidence-based self-management strategies to help PLWH ameliorate their symptoms; therefore, this study supports this intention. In addition, this study adds to the literature on mHealth apps as a potentially effective tool for both symptom problem-solving as well as a deeper interaction with healthcare providers for PLWH, which might help to improve their health outcomes. At the same time, focus groups findings indicated that the symptom self-management strategies presented in mVIP are likely more useful for PLWH within five years of diagnosis than for people who have been living with HIV for more than five years. Our participants who had been living with HIV for many years expressed that they have long-standing experiences in trying various self-care strategies. In addition, they expressed a preference to connect not only their initial HIV-related symptoms experienced at the beginning of an HIV diagnosis but also many symptoms they experienced due to ‘just getting older’ with the app. The Joint United Nations Program on HIV/AIDS (UNAIDS) estimates that in 2006, 2.8 million people aged 50 and over were living with HIV, meaning aging and health is becoming an urgent issue due to the increasing number of people over age 50 with HIV (Chambers et al., 2014; World Health Organization, 2016). PLWH over age 50 face more challenges from HIV-associated non-AIDS conditions such as cardiovascular disease, osteoporosis, COPD, liver disease, and diabetes (Deeks & Phillips, 2009). Therefore, mVIP should be tailored based on years from initial diagnosis of HIV, an individuals' age, and conditions.

Findings from the interviews showed that participants had positive perceptions of the mVIP prototype providing self-management strategies with text and short animated videos, however they preferred that the videos have sounds in regards to flexibility/customizability. In a study testing the impact of a video supplementing informed consent about preventive HIV vaccine trials, providing both a pamphlet with written information as well as a videotape to supplement the written information significantly increased knowledge immediately after presentation of the information; however, only the video-supplemented group retained the information a month later (Fureman, Meyers, McLellan, Metzger, & Woody, 1997). Thus, a health information intervention with both text and videos with sounds would be more useful for underserved PLWH to understand and retain the health information provided, potentially leading to better health outcomes.

Perceived ease of Use of mVIP

Both study groups were asked a series of questions about their experience with one of 13 symptoms and how much the reported symptom bothered them in the prior week, however, only the intervention group participants received the self-management strategies tailored to the reported symptoms. While we did not anticipate either perceived usefulness or ease of use to increase in the control group, control group participants highlighted that mVIP is easy to use to track their symptom experience over time as a simple and regular tool to facilitate self-awareness of symptoms. An additional desire of a summary of self-reported symptoms such as visualization using graphs or charts was highlighted, particularly to share with healthcare providers for enhanced communication between patients and providers. Moreover, participants in the control group pointed out the lack of health information of action planning for symptom management, which may indicate the identification of information needs for self-management related to symptoms in PLWH.

During focus group sessions, participants discussed a trade-off between ease of mVIP use and security of personal information regarding their preference of a function to save passwords. As forgetfulness is a common symptom among PLWH, it was not surprising that an option of saving passwords could increase ease of use to simplify returning to the app; however, concerns of using the option were related to HIV disclosure and stigma.

Dosing:

Findings from the interviews showed that using the mVIP app at a frequency of once per week would be sufficient for participants' needs. Regarding the app use patterns, our heavy users (i.e. >14 uses over three months) revealed that they had used the app more frequently due to the belief that more frequent use might give researchers better impressions of them as participants, leading to more opportunities for participation in the future studies. They did not expect that their very frequent app use would result in more effective symptom management. All interviewees regardless of their use frequency agreed that weekly app use was appropriate for their HIV-related symptoms as we requested per the study protocol. These may be related to social desirability bias. Our participants might tend to choose responses they believed were more socially desirable or acceptable rather than choosing responses that reflected their true thoughts or feelings. This tendency can result in over-reporting of responses that are socially desirable and under-reporting of those responses that are deemed to be socially undesirable or less desirable (Grimm, 2010).

User-perceived satisfaction between study groups

User satisfaction of the mVIP prototype use at the baseline and follow-up visit was highly rated by both Health-ITUES (Yen et al., 2010) and PSSUQ (Lewis, 2002). Overall, participants in both intervention and control groups rated the usability of mVIP app as being high. The mean score of the overall Health-ITUES for participants in both interviews and focus groups was more than 4.19 (*SD* = .50) of 5.00 (i.e. where the higher the response, the higher the subject's usability satisfaction with the system) in both study groups, indicating a high user satisfaction of the mVIP app. The mean score of the overall PSSUQ scores in both interviews and focus groups was less than 1.80 (*SD* = .98) of 7.00 (i.e. where the lower the response, the higher the subject's usability satisfaction with the system) in both study groups, reflecting strong user acceptance of the app. There were no significant differences between the intervention and control groups, and/or between baseline and follow-up time points. Participants in both study groups, however, did indicate verbally that they found the app to be useful in monitoring their symptom experience over time. The mVIP app was initially developed through rigorous user-centred design processes; therefore, the overall user satisfaction scores were already high at baseline, which reflects strong usability of mVIP. Given these findings and that both groups perceived the app as highly usable at baseline, it is not surprising that there was no significant difference in perceptions of usability between groups over time. In a study, a website very high in aesthetic appeal but low in usability scored high on user satisfaction when first encountered, whereas users' overall level of satisfaction dropped considerably as use continued (Lindgaard & Dudek, 2003). Our results of user-perceived satisfaction rated high consistently at different measurement points; this may reflect that mVIP can be considered to be both high in appeal and high in usability.

Implications

Implementation and dissemination of evidence-based symptom self-management strategies

HIV has evolved from a fatal disease into a chronic illness. The burden of HIV disease continues to grow globally (Hamine et al., 2015); therefore, mVIP for HIV-related symptom self-management can be useful across the world. Improving PLWH's ability to self-manage their symptoms is key to achieving the aims of the National HIV/AIDS Strategy for the US by reducing HIV-related disparities, and improving health outcomes and health-related quality of life in PLWH. Approximately two-thirds (66%) of Americans use mHealth apps to manage their health (Makovsky, 2015). Interventions delivered via mHealth technology can reduce costs associated with providing face-to-face interventions, and mHealth interventions can provide new and potentially transformative opportunities to improve health outcomes (Hall, Fottrell, Wilkinson, & Byass, 2014). Thus, findings from this dissertation using an mHealth intervention to translate paper-based health information would contribute to a reduction of HIV-related disparities and improvement of health outcomes, which would lead to a reduction of the burden of HIV disease in the US.

mVIP was developed by incorporating a paper-based HIV/AIDS manual with self-management strategies and patient-centered research findings from the web-based symptom self-management tool, which was a strength of the app's content. Although the manual was found to be efficacious in reducing symptom frequency and intensity for PLWH, subsequent use of the strategies has been low. Since mHealth technology permeates consumers' everyday lives, mobile technology offers the opportunity for integrating mVIP use into the routines of the daily lives of PLWH given its high acceptability, usability and use during our study period. Ensuring PLWH's continuous use of mVIP will require the app's release to an app marketplace. Thus, findings from this dissertation will facilitate the implementation and dissemination of evidence-based strategies for HIV symptom self-management in underserved PLWH in the US, and ultimately improve their capacity for symptom self-management.

Guidelines for future mobile app development through robust theoretical framework and rigorous usability evaluation

Despite the increase in mobile technology use as a platform for health information interventions, few mHealth apps have undergone systematic and rigorous usability evaluation prior to their dissemination. Usability factors are a major obstacle to technology adoption; therefore, usability must be considered before and after prototyping takes place in order to support the quality of the technology and end product in use (Holzinger, 2005; Shackel, 1991). Despite the importance of usability for the development of mHealth apps, more than 95% of mHealth apps have not been tested (Furlow, 2012). Although it is essential to ensure mHealth apps' quality in use through usability evaluations throughout the development process, existing studies have evaluated apps' usability at certain stages of development, or without using a solid theoretical framework (Park, 2011; Ping, Small, Dran, & Barcellos, 1999). Moreover, there have been no clear guidelines or recommendations for the utilization of a theoretical framework in apps' usability studies (Yen & Bakken, 2012).

In this dissertation, a stratified three-level usability evaluation of mVIP utilizing a theoretical framework was conducted, ensuring the app's quality in use through the rigorous usability evaluation methods at each stage of the entire development process. Card sorting activities were an innovative approach used in the app design process. The technique is cost-effective and the data collected through this method is easy to analyze. In addition, eye-tracking was also an innovative approach in that it reduced the limitations of think-aloud protocols by providing a cue to improve the validity of usability data. Although a concurrent think-aloud protocol is predominantly used in usability testing, a retrospective think-aloud protocol was utilized to address limitations of the concurrent think-aloud protocol when used in conjunction with eye-tracking as mentioned earlier. In spite of this, a retrospective think-aloud protocol presented a particular challenge for our study, as it was time-consuming and tedious. For example, upon completing the tasks employing a use case scenario, participants were encouraged to think aloud retrospectively and asked to verbalize their thoughts about the tasks while watching a recording of their use of the app that depicted their eye movements overlaid on the app screen. The process took a significant amount of time and as a result, the participants felt fatigued. Nevertheless, the retrospective think-aloud protocol would be most appropriate when combined with eye-tracking, and our eye-tracking and retrospective think-aloud method can produce valuable insights for usability evaluation as opposed to a stand-alone method (i.e.

concurrent think-aloud protocols only). In addition to end-user usability testing, heuristic evaluation added value to this study by producing reliable results of a user interface. While interviews and focus group discussions are commonly used for gaining an in-depth understanding of users' experiences, perceptions and satisfaction, focus groups are of particular effectiveness and convenience in circumstances where time and resources are limited. This distinct advantage was evidenced in this study as most of the major themes identified from the interviews were also detected in the focus group discussions. These rigorous usability evaluations throughout the development process of mVIP make it possible to improve efficacy, efficiency, and satisfaction of the app use, and eventually may facilitate the implementation and dissemination of evidence-based strategies for HIV symptom self-management in underserved PLWH in the US. This scientific and systematic approach to usability evaluations may encourage other researchers to use a conceptual framework when planning and designing their usability studies for the development of mHealth apps and to choose the most appropriate evaluation methods that best meet the goals of the system.

Consideration of structural barriers in PLWH

Understanding the factors associated with the use of mVIP in our study may help to inform system development as well as implementation and promotion of HIV symptom self-management for PLWH. Housing instability and low income status are relevant issues that may keep many study participants from completing study activities as planned. These issues may also interfere with the effectiveness of app use as well as achievement of better health outcomes, specifically symptom management in PLWH. For example, several light users who could not be reached for the interviews but contacted us after completion of the interviews (i.e. after completion of data collection) disclosed housing instability as a barrier related to the app use. Poverty-related barriers, such as lack of transport infrastructure or food insecurity, collectively have been shown to influence the extent to which PLWH adhere to their HIV medication regimens (Kagee et al., 2011). Because housing instability and other structural obstacles have been cited as barriers to health-related outcomes in PLWH (Leaver, Bargh, Dunn, & Hwang, 2007), these obstacles may be a factor related to some participants' low app use. Considering the real-life issues faced during the usability evaluation of our app in a real-world setting, it may be important to know how these barriers impact underserved individuals with HIV in regards to their symptom self-management. This study has important implications, which can inform programs, policy development, and future nursing research. Implications for social service providers and policy makers may be to improve or increase referral resources (e.g. to housing, food, or transportation assistance). Additional implications urge researchers to acknowledge their population's needs, specifically to accommodate structural barriers in the design of the study protocol by allowing flexibility in scheduling, providing nutritious snacks, and offering appropriate social referral information when needed or requested.

Limitations

The generalizability of the results may be limited by the study sample, settings, and inclusion/exclusion criteria. Our targeted population was underserved PLWH, specifically racial and ethnic minorities and those from low-socioeconomic groups who have low annual income, low level of education, and limited health literacy. Results may differ in other groups who have higher annual income, higher education, and adequate health literacy. The studies in this dissertation focused on a single geographic area, NYC. While our sample was demographically representative of the HIV/AIDS epidemic in the US (Centers for Disease Control and Prevention, 2015b), there might be unique aspects of HIV management in this setting that limits the generalizability of our findings. Our population of underserved PLWH includes a substantial number of primary-Spanish speakers who are not able to speak English; however, we included only English speakers as the contents of mVIP are currently only available in English. In the end-user usability testing at level 2, we recruited only heavy smartphone users, so usability issues that would be identified by novice smartphone users might have been missed. Moreover, the exclusion criteria of participants who already participated in the previous level of the study prevent understanding participants' insights into the entire development process.

Although the limitations of a think-aloud protocol can be addressed by using eye-tracking, we faced several challenges when collecting eye-tracking data. Certain type of glasses could interfere with the eye tracker capturing participants' eye movements (Tobii Technology); therefore participants who wore bifocal or progressive glasses were excluded, which led to the exclusion of otherwise eligible participants, and might further limit the generalizability of the results. Even so, it was difficult to calibrate several participants' eyes, resulting in repeated recalibrations, or restarting the eye tracker and the computer. To avoid losing participants' eye movements, we dimmed the lights, asked the participants to reposition their head and maintain the same position. These specifications might be tiring to participants, and be time-consuming for the researchers. Since there has been no rigorous standard of measuring what is considered a good eye pattern, it was hard to set standards for a given interface (Cowen, Ball, &

Delin, 2002). Despite these limitations, eye-tracking proved to be a valuable tool to explore usability issues in conjunction with a think-aloud protocol.

Recommendations for Future Research

We propose several recommendations for future research. First, this dissertation focused on the development and usability evaluation of mVIP prior to exploring the feasibility of using mVIP among underserved PLWH in a three-month RCT. Thus, the feasibility of using mVIP should be demonstrated by assessing the app's impact on symptom frequency and intensity, as well as health-related quality of life. Additionally, outcomes should be compared to detect any differences depending on use patterns or among participants in the different study groups. Second, as several factors might affect the use of mHealth apps and their acceptance in underserved PLWH, a study examining the available empirical evidence on the relationship between structural barriers in PLWH (i.e. poverty-related barriers) and the use of mHealth interventions aimed at improving health-related outcomes in PLWH is recommended. As Health-ITUES has not yet been validated for use with mobile technologies in HIV-positive populations, a validation study of the Health-ITUES as an instrument for assessing the usability of mHealth technology is suggested. Finally, the increasing likelihood that PLWH will be confronted with more symptoms related to aging presents an urgent challenge that researchers should seek to understand (Chambers et al., 2014; High et al., 2012); specifically, what conditions older PLWH are experiencing, what self-management strategies they have been using to mitigate their symptoms, and of those, which strategies were more or less helpful in their everyday lives. Thus, future research identifying the experience of symptom conditions and self-management strategies in PLWH with HIV-associated non-AIDS conditions is strongly recommended. This will facilitate the development of additional empirical and evidence-based health information that can be used to inform interventions for underserved PLWH with multiple chronic conditions related to aging. These studies should seek to recruit on a national level to ensure a more representative sample of underserved PLWH in the US by age, geography, and engagement in healthcare services.

Conclusions

We conducted a three-level usability evaluation of all potential interactions between the user, task, system, and environment. Methods used included a card sorting technique, an eye-tracking and retrospective think-aloud method, heuristic evaluations, in-depth interviews, and focus groups. Integral to the findings from the three-level usability evaluation, we assessed the usability of the mVIP prototype and found the prototype was highly accepted by PLWH, indicating high user satisfaction. This study will add to the body of literature on translation of evidence-based health information into an mHealth app and its usability assessment, which highlights the importance of the use of mobile technology for PLWH, specifically racial and ethnic minorities as well as those from low-socioeconomic groups who have limited health literacy and low level of education.

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APPENDICES

Appendix A. Use Case Scenario

FOR THE PURPOSES OF THIS STUDY,

PLEASE IMAGINE YOURSELF IN THE FOLLOWING 2 SCENARIOS

SCENARIO #1

Our app includes 13 HIV-related symptoms.

When you select a symptom, our app (VIP) will recommend that you try some strategies to self-manage the symptom. If you say 'no', VIP will not recommend you any strategies.

When completing our app session, you can review the strategies recommended to you (your history).

Imagine that you experienced 2 out of 13 HIV-related symptoms in the past 7 days.

The 2 symptoms were: 1) Tiredness, and 2) Trouble Sleeping

You want to get information on how to reduce those 2 symptoms using our app.

You have just created a new account.

Your ID is: **vip1@gmail.com**

Your password is: **vip1@gmail.com**

Once you login, you will be required to update your password.

You feel like your password is too long, so you want to change your password into vip1.

You are asked to complete the following tasks,

1) Please login the VIP

2) Please update your password to vip1

3) Please start the app session to get some strategies on how to self-manage the 2 symptoms of **Feel tired**, and **Difficulty falling or staying asleep**

4) Please review your strategies (your history) when completing the app session.

For the second task:

Please click the home icon (upper left corner) to go back to the main page.

SCENARIO #2

As you are now aware, our app includes 13 HIV-related symptoms.

When you select a symptom, our app (VIP) will recommend that you try some strategies to self-manage the symptom. If you say 'no', VIP will not recommend you any strategies.

At this time, our app will ask you if the strategies recommended before were helpful to you.

Before and after using our app, you can review the strategies recommended to you (your history).

During the last week, you tried the strategies as our app had recommended you to self-manage the 2 symptoms of Tiredness and Difficulty falling or staying asleep.

You do not have **Tiredness** any more.

However**, you still have Trouble Sleeping**.

For the symptom of **Trouble Sleeping**, you tried the following 3 strategies during the last week:

1) Develop a routine of going to bed in the evening and getting up each morning at the same time. Naps are okay, but keep them short and early in the day.
2) Read before going to sleep.
3) Take a warm bath before going to bed.

Out of 3 strategies, you think **Only the first strategy was helpful**.

You are asked to complete the following tasks,

1) Please review your previous strategies (your history)

2) Please start session to get more strategies on how to self-manage the symptom of **Trouble Sleeping**

---- When you see 'Great Work', you are done.

Appendix B. Health-ITUES (customized for this study)

Quality of Life	
1	I think mVIP would be a positive addition for persons living with HIV.
2	I think mVIP would improve the quality of life of persons living with HIV.
3	mVIP is an important part of meeting my information needs related to symptom self-management.
Perceived Usefulness	
4	Using mVIP makes it easier to self-manage my HIV-related symptoms.
5	Using mVIP enables me to self-manage my HIV-related symptoms more quickly.
6	Using mVIP makes it more likely that I can self-manage my HIV-related symptoms.
7	Using mVIP is useful for self-management of HIV-related symptoms.
8	I think mVIP presents a more equitable process for self-management of HIV-related symptoms.
9	I am satisfied with mVIP for self-management of HIV-related symptoms.
10	I self-manage my HIV-related symptoms in a timely manner because of mVIP.
11	Using mVIP increases my ability to self-manage my HIV-related symptoms.
12	I am able to self-manage my HIV-related symptoms whenever I use mVIP.
Perceived Ease of Use	
13	I am comfortable with my ability to use mVIP.
14	Learning to operate mVIP is easy for me.
15	It is easy for me to become skillful at using mVIP.
16	I find mVIP easy to use.

17	I can always remember how to log on to and use mVIP.
User Control	
18	mVIP gives error messages that clearly tell me how to fix problems.
19	Whenever I make a mistake using mVIP, I recover easily and quickly.
20	The information (such as on-line help, on-screen messages and other documentation) provided with mVIP is clear.

Appendix C. PSSUQ

System Quality	
1	Overall, I am satisfied with how easy it is to use this app (mVIP).
2	It was simple to use this app (mVIP).
3	I was able to complete the tasks and scenarioss quickly using this app (mVIP).
4	I felt comfortable using this app (mVIP).
5	It was easy to learn to use this app (mVIP).
6	I believe I could become productive quickly using this app (mVIP).
Information Quality	
7	The app (mVIP) gave error messages that clearly told me how to fix problems.
8	Whenever I made a mistake using the app (mVIP), I could recover easily and quickly.
9	The information (such as on-line help, on-screen messages, and other documentation) provided with this app (mVIP) was clear.
10	It was easy to find the information I needed.
11	The information provided for the app (mVIP) was easy to understand.
12	The organization of information on the app (mVIP) screens was clear.
Interface Quality	
13	The interface of this app (mVIP) was pleasant.
14	I liked using the interface of this app (mVIP).
15	This app (mVIP) has all the functions and capabilities I expect it to have.
Overall	
16	Overall, I am satisfied with this app (mVIP).

Appendix D. mVIP Contents

<u>Final 143 Self-Management Strategies for 13 symptoms:</u>

1) Fatigue / Tiredness

During the past 7 days, did you feel fatigued or have a loss of energy? How much does your fatigue or loss of energy bother you?	
1_Fatigue_1	Stick to your medication(s) as prescribed. Talk to your doctor/nurse about any side effects or reactions that are not normal for you.
1_Fatigue_2	Try relaxing or activities that reduce stress, such as: deep-breathing exercises; meditation (personal "quiet time"); massage; listening to music; taking a warm bath.
1_Fatigue_3	Go for a walk every day, or do your favorite exercise. It can reduce anxiety, depression, and fatigue.
1_Fatigue_4	Limit the following foods: sugary foods, fast foods and other high fat foods.
1_Fatigue_5	Avoid alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed), as these tend to make you sluggish later.
1_Fatigue_6	Take breaks at work, mid-morning and mid-afternoon.
1_Fatigue_7	Eat more of the following foods: oatmeal and other whole grain cereals, fruit and vegetables, whole grain baked goods and yogurt.
1_Fatigue_8	Develop a routine sleeping schedule – go to sleep at the same time every night and wake up at the same time each morning. Naps are okay, but keep them short (45 minutes or less).
1_Fatigue_9	Vegetables are a good source of vitamins, which can help you gain energy. Do not overcook vegetables since this makes them lose vitamins.

2) Difficulty sleeping

During the past 7 days, did you have difficulty falling or staying asleep? How much does your difficulty falling or staying asleep bother you?	
2_Insomnia_1	Develop a routine sleeping schedule – go to sleep at the same time every night and wake up at the same time each morning. Naps are okay, but keep them short (45 minutes or less).
2_Insomnia_2	Read before going to sleep.
2_Insomnia_3	Take a warm bath before going to bed.
2_Insomnia_4	Get a massage.
2_Insomnia_5	Avoid over-the-counter sleep aids because you could become dependent on them (such as Unisom™, Kirkland™ Sleep-Aid).
2_Insomnia_6	Turn on a fan or soft music to block out street noise.
2_Insomnia_7	Do not exercise too close to bedtime – exercise at least 4-6 hours before going to bed.
2_Insomnia_8	Listen to music or books on tape.
2_Insomnia_9	Use several pillows to make yourself comfortable.
2_Insomnia_10	Drink a cup of warm milk or herbal chamomile tea before going to bed, but do not drink so much fluid that you have to get up to go to the bathroom during the night.
2_Insomnia_11	Wear earplugs.

3) Difficulty remembering

During the past 7 days, did you have difficulty remembering? How much does your difficulty remembering bother you?	
3_Forgetfulness_1	Ask your health care provider to call you before your appointments to remind you of the date and time of the appointment.
3_Forgetfulness_2	Organize your medications in an easy way (e.g. pillbox) to help you

	remember to take them.
3_Forgetfulness_3	Write-up a daily/weekly schedule and try to stick to it.
3_Forgetfulness_4	Use a date book to write down your appointments or schedule right away so you don't forget them later.
3_Forgetfulness_5	Keep your stuff in the same place every day.
3_Forgetfulness_6	Develop a routine sleeping schedule – go to sleep at the same time every night and wake up at the same time each morning. Naps are okay, but keep them short (45 minutes or less).
3_Forgetfulness_7	Avoid alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed), as these tend to make you sluggish later.
3_Forgetfulness_8	Ask friends or family members to help you remember things and keep your appointments or schedule.

4) Depression

During the past 7 days, did you feel sad, down or depressed?

How much does your feeling sad, down or depressed bother you?

4_Depression_1	Stick to your medication(s) as prescribed. Talk to your doctor/nurse about any side effects or reactions that are not normal for you.
4_Depression_2	Try relaxing or activities that reduce stress, such as: deep-breathing exercises; meditation (personal "quiet time"); listening to music; taking a warm bath.
4_Depression_3	Attend a free support group offered in your community. Check if the group has a specific focus that interests you.
4_Depression_4	Go for a walk every day, or do your favorite exercise. It can reduce anxiety, depression, and fatigue.
4_Depression_5	Do things such as wash and get dressed at the same time each day.
4_Depression_6	Develop a routine sleeping schedule – go to sleep at the same time every night and wake up at the same time each morning. Naps are okay, but keep

	them short (45 minutes or less).
4_Depression_7	Read about depression.
4_Depression_8	Get involved in activities such as volunteer work, church groups, social clubs or sports activities.
4_Depression_9	Avoid alcohol and other mood-altering non-prescription drugs (e.g. cocaine, speed) as these tend to make you sluggish later.

5) Anxiety

During the past 7 days, did you feel nervous or anxious? How much does your feeling nervous or anxious bother you?	
5_Anxiety_1	Try relaxing or activities that reduce stress, such as: deep-breathing exercises; meditation (personal "quiet time"); listening to music; taking a warm bath.
5_Anxiety_2	Go for a walk every day, or do your favorite exercise. It can reduce anxiety, depression, and fatigue.
5_Anxiety_3	Stick to your medication(s) as prescribed. Talk to your doctor/nurse about any side effects or reactions that are not normal for you.
5_Anxiety_4	Keep a diary to record your thoughts and feelings.
5_Anxiety_5	Attend a free support group offered in your community. Check if the group has a specific focus that interests you.
5_Anxiety_6	Drink a cup of warm milk or herbal chamomile tea before going to bed, but do not drink so much fluid that you have to get up to go to the bathroom during the night.
5_Anxiety_7	Eat fewer products containing sugar (including sodas).
5_Anxiety_8	Drink less caffeine (coffee and tea).

6) Neuropathy

During the past 7 days, did you have pain, numbness or tingling in your hands or feet? How much does your pain, numbness or tingling in your hands or feet bother you?	
6_Neuropathy_1	Massage your hands/arms/legs/feet.
6_Neuropathy_2	Keep your hands/feet warm, but not so warm that they sweat.
6_Neuropathy_3	Try relaxing or activities that reduce stress, such as: deep-breathing exercises; meditation (personal “quiet time”); listening to music; taking a warm bath.
6_Neuropathy_4	Get checked by a health professional for diabetes as the cause of the pain.
6_Neuropathy_5	Do passive exercises with your hands/arms/legs/feet, or ask family members or friends to assist.
6_Neuropathy_6	Wear loose-fitting comfortable shoes with padded soles.
6_Neuropathy_7	Elevate your hands/feet above your head.
6_Neuropathy_8	Avoid long periods of standing or walking.
6_Neuropathy_9	Wear cotton socks to reduce wetness due to sweating.
6_Neuropathy_10	Apply hot compresses for cold-related pain.

7) Cough / Shortness of breath

During the past 7 days, did you have a cough or trouble catching your breath? How much does your cough or trouble catching your breath bother you?	
7_Cough/Shortness of Breath_1	Sit up straight to expand the chest as much as possible.
7_Cough/Shortness of Breath_2	Try relaxing or activities that reduce stress, such as: meditation (personal “quiet time”); listening to music; taking a warm bath.
7_Cough/Shortness of Breath_3	Drink sips of hot water or warm fluids. If you like, add

	lemon juice.
7_Cough/Shortness of Breath_4	Inhale steam, using hot water with Vicks.
7_Cough/Shortness of Breath_5	Pursed Lips Breathing: Breathe in normally through the nose while counting s-l-o-w-l-y to two; purse lips, as if about to whistle; breathe out slowly through your pursed lips (take twice as long to breathe out as you did to breathe in – count slowly to 4).
7_Cough/Shortness of Breath_6	Try controlled or Paced Breathing: The key is to inhale slowly and exhale through pursed lips while performing the work. Focus on breathing out slowly and evenly.
7_Cough/Shortness of Breath_7	Contact your doctor/nurse for additional suggestions or other breathing strategies.
7_Cough/Shortness of Breath_8	Take a walk every day at your own pace, in your home or outside. Muscles that are weak from lack of activity or exercise can make you feel short of breath with any movement.
7_Cough/Shortness of Breath_9	Drink tea or coffee.
7_Cough/Shortness of Breath_10	Avoid foods that irritate your throat.

8) Dizziness

During the past 7 days, did you feel dizzy or lightheaded?

How much does your dizziness or lightheadedness bother you?

8_Dizziness_1	Rise slowly when waking up – sit up first, then stand.
8_Dizziness_2	Drink plenty of fluids (water, non-caffeinated beverages) – at least six 8-ounce glasses per day.
8_Dizziness_3	Ensure enough ventilation and air flow.
8_Dizziness_4	Lie down and raise your feet above your head.
8_Dizziness_5	Sit down and lower your head below your knees to encourage circulation to

	the brain.
8_Dizziness_6	Eat a balanced diet.
8_Dizziness_7	Eat high-energy foods.
8_Dizziness_8	Wear loose-fitting clothing.
8_Dizziness_9	Eat green leafy vegetables (e.g. kale, spinach) in order to increase iron intake.

9) Skin problems

During the past 7 days, did you have skin problems such as rash, dryness or itching? How much does your skin problem such as rash, dryness or itching bother you?	
9_Skin Problems_1	Bathe or shower with a mild, non-perfumed soap (such as Cetaphil™, Dove™, Sunlight™ bath soap/bar soap) and lukewarm water. Avoid hot baths/showers; they dry your skin.
9_Skin Problems_2	Use a warm mist humidifier – dry air can irritate the skin.
9_Skin Problems_3	Report any skin changes to your doctor/nurse.
9_Skin Problems_4	Use lukewarm water – avoid very cold and very hot water.
9_Skin Problems_5	Drink plenty of fluids (water, non-caffeinated beverages) – at least six 8-ounce glasses per day.
9_Skin Problems_6	Check in your drugstore for anti-irritants or use an oatmeal and water mixture on affected areas of body to reduce the itch.
9_Skin Problems_7	Do not share linens.
9_Skin Problems_8	Bathe with antiseptics diluted with water.
9_Skin Problems_9	Wash your hands frequently.
9_Skin Problems_10	Use unscented moisturizing lotions or creams that do not contain alcohol. Lotions or creams containing aloe vera/natural plant extracts may help.

9_Skin Problems_11	Keep your fingernails short and clean. Try not to scratch.
9_Skin Problems_12	Keep sheets and blankets off sensitive skin. For example, use a pillow at the foot of the bed to hold sheets off your feet.
9_Skin Problems_13	Use bandages or a clean cloth for any bleeding discharges or drainage to prevent the spread of the infection to other parts of your body or to other people.
9_Skin Problems_14	Air dry or pat dry your skin after bathing.
9_Skin Problems_15	Wear light, non-irritating clothing and a hat when in the sun.
9_Skin Problems_16	Use oils, such as sweet almond, to nourish dry skin.

10) Fever

During the past 7 days, did you have fever, chills or sweats?

How much does your fever, chills or sweats bother you?

10_Fever_1	Take your temperature when you feel sick. If it is more than 99ºF (38ºC), take it again in 3 to 4 hours. If your fever is above 101ºF (39ºC) call your doctor/nurse within 24 hours.
10_Fever_2	Take fever reducing medicine (e.g. Tylenol™, Advil™) as directed by your doctor/nurse.
10_Fever_3	Drink plenty of fluids (water, non-caffeinated beverages) – at least six 8-ounce glasses per day.
10_Fever_4	Get plenty of rest to conserve energy and avoid fatigue.
10_Fever_5	If you are taking antibiotics, be sure to take all of the medication.
10_Fever_6	Wrap each arm and each leg (including the toes) with towels or blankets. It is better not to cover your entire body as this may cause your fever to rise.
10_Fever_7	Avoid sponge baths or using fans as these may cause you to have chills and shivering. Shivering causes the temperature to rise even higher and should be avoided when possible.

10_Fever_8	Avoid drinking chilled or cold liquids. Drink warm liquids.
10_Fever_9	Change clothes if they become soaked with sweat.
10_Fever_10	Wear socks or shoes when walking on cold floors.

11) Diarrhea

During the past 7 days, did you have diarrhea or a loose bowel movement?
How much does your diarrhea or loose bowel movement bother you?

11_Diarrhea_1	Avoid these foods/drinks: caffeine, fast foods, fried foods, luncheon meats, hot dogs, bacon, chips, dairy products (except for yogurt), whole grains, cornmeal, bran, granola, wheat germ, nuts, seeds, alcoholic and carbonated beverages.
11_Diarrhea_2	Try these Supplements: Acidophilus or Metamucil™ (You can purchase these nutritional supplements at a health food or drug store). Share your plan to take nutritional supplements with your doctor/nurse before starting.
11_Diarrhea_3	Try eating/drinking: oatmeal, strawberries, potatoes, apples (peeled and allowed to brown), pears, bananas, yogurt, or porridge.
11_Diarrhea_4	Try to drink 10 glasses of water per day, oral rehydration solution, energy drinks (e.g. Gatorade™), ginger ale, diluted fruit juice, or ginger tea.
11_Diarrhea_5	Keep your skin clean by washing with warm water after each bowel movement if you can. Dry the skin thoroughly.
11_Diarrhea_6	When planning activities away from home, consider the availability of bathrooms.
11_Diarrhea_7	Consider taking an extra change of underpants and an extra roll of toilet paper with you if you will be away from your home for extended long period of time. Bring along (hand wipes) to clean your hands.
11_Diarrhea_8	Use absorbent shields to prevent the leakage of diarrhea onto clothing.
11_Diarrhea_9	Eat frequent, small meals.

11_Diarrhea_10	If the skin is intact (no open cut), apply a cream containing petroleum (such as Vaseline or A&D ointment™) to protect the skin (If the skin is open, contact your health care provider).
11_Diarrhea_11	Consider carrying a squeeze bottle filled with warm water and a spray cleaner with you when you go out, for personal hygiene.

12) Nausea / Vomiting

During the past 7 days, did you have nausea or vomiting?

How much does your nausea or vomiting bother you?

12_Nausea/Vomiting_1	Do not lie down for at least 30 minutes after eating.
12_Nausea/Vomiting_2	Stick to your medication(s) as prescribed. Talk to your doctor/nurse about any side effects or reactions that are not normal for you.
12_Nausea/Vomiting_3	Take frequent sips of water or suck on ice chips.
12_Nausea/Vomiting_4	Try eating dry foods such as toast and crackers.
12_Nausea/Vomiting_5	Avoid greasy foods, fried foods, and alcohol.
12_Nausea/Vomiting_6	Breathe in fresh air.
12_Nausea/Vomiting_7	Breathe in pleasant smells such as lemon or lime peels, and ginger.
12_Nausea/Vomiting_8	Use oral rehydration solution.
12_Nausea/Vomiting_9	Eat small portions of food when least sick.
12_Nausea/Vomiting_10	Save your favorite foods for when you are feeling well.
12_Nausea/Vomiting_11	Try to focus your mind on something pleasant.
12_Nausea/Vomiting_12	Try relaxing or activities that reduce stress, such as: deep-breathing exercises; meditation (personal "quiet time"); massage; listening to music; taking a warm bath.

12_Nausea/Vomiting_13	Avoid odors, sights or sounds that trigger nausea or vomiting.
12_Nausea/Vomiting_14	Use aromatherapy, such as wild strawberry or ginger extracts.
12_Nausea/Vomiting_15	Try to eat and drink when you are not feeling nauseous.

13) Weight loss

During the past 7 days, did you have problems with weight loss or wasting? How much does your problem with weight loss or wasting bother you?	
13_Weight loss_1	Keep track of your weight by weighing yourself or by looking for changes in the way your clothes fit.
13_Weight loss_2	Do some light exercise to boost your appetite.
13_Weight loss_3	Take a multivitamin with at least 100% Recommended Daily Allowance (RDA) every day.
13_Weight loss_4	If you are having difficulty chewing/swallowing due to mouth sores: Eat cold foods (e.g. popsicles and ice cream) and soft/liquid foods (e.g. mashed potatoes, applesauce, pasta and soups).
13_Weight loss_5	Eat frequent, small meals.
13_Weight loss_6	If food doesn't taste good to you: Add spices (e.g. basil, oregano, garlic) or other flavor enhancers such as lemon juice, lime juice, or vinegar. Marinate meats in sweet wine, fruit juices, beer, Italian dressing or soy sauce.
13_Weight loss_7	Add instant breakfast drinks, milk shakes or other supplements to your diet and drink them any time of the day.
13_Weight loss_8	Eat high-protein, high-calorie foods and snacks such as peanut butter and jelly sandwiches, crackers and cheese, pudding and yogurt.
13_Weight loss_9	Add garlic to your food.
13_Weight loss_10	Eat fresh fruits and vegetables.

13_Weight loss_11	When traveling, take high-calorie snack bars or powdered calorie supplements along.
13_Weight loss_12	Keep foods that are easy to prepare on hand (e.g. frozen and canned foods).
13_Weight loss_13	If you are having difficulty chewing/swallowing due to mouth sores: See your health care provider (including your dentist) for treatment.
13_Weight loss_14	If you are having difficulty chewing/swallowing due to mouth sores: Drink liquids through a straw to bypass the sores.
13_Weight loss_15	If you are having difficulty chewing/swallowing due to mouth sores: Avoid spicy, salty, or crunchy foods, and acidic drinks (e.g. orange juice, tomato juice).
13_Weight loss_16	If you are having difficulty chewing/swallowing due to mouth sores: Soften foods by soaking them in milk or soup, or by putting them in a blender.
13_Weight loss_17	Cook and eat with friends or family to make meals enjoyable.