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FACTORS ASSOCIATED WITH ACCEPTANCE AND USE OF MOBILE TECHNOLOGY FOR HEALTH SELF-MONITORING AND DECISION SUPPORT IN LUNG TRANSPLANT RECIPIENTS

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Submitted to the Graduate Faculty of the

School of Nursing in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2015

UNIVERSITY OF PITTSBURGH

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University of Pittsburgh, 2015

Objectives. This cross-sectional study in lung transplant recipients (LTR) described acceptance and use of a smartphone application, Pocket PATH®, for health self-monitoring and decision support for reporting critical values in 12 months post-transplantation; and explored predictors of use and reporting.

Methods. This secondary analysis, guided by the Unified Theory of Acceptance and Use of Technology, included 96 LTR randomly assigned to the Pocket PATH group. Intention to use was measured at baseline. Due to skewness, use (percentage of days used) in 0 to 2, > 2 to ≤ 6, > 6 to ≤ 12, and 0 to 12 months was categorized as Low, Moderate, and High, using 25% and 75% as cutoffs. Reporting critical values was dichotomized as 100% and < 100% reporting. Descriptive statistics were used to summarize data and logistic regressions were employed to explore predictors of use and reporting.

Results. About 85% of LTR were very likely to use Pocket PATH. However, intention was not associated with use. Use decreased across four time intervals. Self-care agency interacted with gender (OR=0.94, *p*=0.04) and satisfaction with technology training (OR=0.93, *p*=0.02) in 0 to 2 months. Use from > 2 to ≤ 6 months was predicted by satisfaction with technology training (OR=3.00, *p*=0.03), and age interacted with psychological distress (OR=0.96, *p*=0.04). Use after 6 months was predicted by psychological distress (OR=0.42, *p*=0.04) and physical function (OR=1.07, *p*=0.04). Use from 0 to 12 months was predicted by age (OR=1.05, *p*=0.03), satisfaction with technology training (OR=2.78, *p*=0.05) and physical function (OR=1.09, *p*=0.03). Among 53 (55.2%) LTR with critical values detected, 62.3% (n=33) had 100% reporting. With increased technology experience, odds of 100% reporting decreased in men but increased in women (OR=0.21, *p*=0.03). LTR whose income met basic needs (OR=0.01, *p*=0.02), or with longer hospital stay (OR=0.94, *p*=0.01), were less likely to have 100% reporting. Moderate use group was less likely to report than High (OR=0.11, *p*=0.02) and Low (OR=0.04, *p*=0.02) use groups.

Conclusion. Use of mobile technology for health self-monitoring and for reporting critical values was predicted by different factors. Clinicians should assess LTR at risk for poor use and reporting.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

The study was supported through funding from the Greater Pittsburgh Nursing Research Conference Nursing Research Grant and the Pauline Thompson Clinical Nursing Research Award from the Nursing Foundation of Pennsylvania. I would like to recognize the funding source for the parent study, *Phase III Trial of Pocket PATH: A Computerized Intervention to Promote Self-Care* (NIH, NINR, R01NR010711, PI: A. DeVito Dabbs). I would like to thank my dissertation chair and committee members for sharing their time and expertise with me. Finally, I would like to express my gratitude to my family and friends for their patience and support.

1.0 DISSERTATION PROPOSAL

1.1 INTRODUCTION

Lung transplantation has been increasingly accepted as a standard treatment option for persons with end-stage lung diseases (Hartert et al., 2014). More than 40,000 lung transplant procedures have been performed worldwide (Yusen et al., 2013). In the United States, the number of people receiving lung transplants increased from 33 in 1988 to more than 1,900 in 2012 (International Society for Heart & Lung Transplantation., 2014). More than 9,000 Americans were living with a transplanted lung in 2011 (U.S. Department of Health and Human Services HRSA, 2012). However, lung transplant recipients (LTR) have a lower survival rate than other solid organ transplant recipients due to their higher risks for acute rejection and infection, especially during the first year after transplantation (Burguete, Maselli, Fernandez, & Levine, 2013; Orens & Garrity, 2009). Therefore, LTR are encouraged to perform daily health self-monitoring in order to detect and report critical condition changes early, which is important for facilitating early interventions and improving quality of life and survival (Avery, 2006; DeVito Dabbs et al., 2003; Knoop & Estenne, 2006).

Electronic devices and technology systems have been used by LTR for home self-monitoring (Finkelstein et al., 2013; Kugler et al., 2010) and shown to be valid and reliable for early detection of complications (Jaana, Pare, & Sicotte, 2009; Kugler et al., 2009; Wang, Finkelstein, & Hertz, 2013) as well as promotion of better health-related quality of life (DeVito Dabbs, Dew et al., 2009) and survival (Yoon, Guo, Hertz, & Finkelstein, 2008). However, LTR do not always accept and use these technologies (Kugler et al., 2009; Kugler et al., 2010; Yoon et al., 2008) and their use of electronic devices for home spirometry self-monitoring tends to decline over time (Karl, Finkelstein, & Robiner, 2006). Barriers to adoption of general consumer health information technology among the elderly, chronically ill, and underserved were reported to be lack of perceived benefit of use, inconvenient to use, or lack of support from clinicians (Jimison et al., 2008; Or et al., 2011). Individuals were also found to be more likely to accept health care delivered on technology devices with which they were familiar and used every day for other purposes, e.g. cell phones (Jimison et al., 2008). Previously reported reasons for non-adherence to home self-monitoring after lung transplantation were forgetfulness, lack of time, and poor health status (Kugler et al., 2010; Sabati, Snyder, Edin-Stibbe, Lindgren, & Finkelstein, 2001). Moreover, performance of home-monitoring by LTR may be influenced by their beliefs and perceived support from clinicians (Kugler et al., 2010).

Recent advancements of mobile technology, such as smartphones and their applications, have provided the capability of better support for the delivery of health self-monitoring (Marcano Belisario, Huckvale, Greenfield, Car, & Gunn, 2013). Currently, there are more than 40,000 health care-related smartphone applications ("app") available and more than half of their users have utilized the apps to gather health information (Slaper & Conkol, 2014). Pocket Personal Assistant for Tracking Health (Pocket PATH®) is a smartphone application with customized data recording, trending, and decision-support programs to promote health self-monitoring after lung transplantation (DeVito Dabbs, Dew et al., 2009). A preliminary study revealed that use of Pocket PATH in the first 6 months post-transplantation promoted self-care agency, self-care behaviors, and improved health-related quality of life in LTR (DeVito Dabbs, Dew et al., 2009). To date, no study has reported factors associated with use of mobile technology for health self-monitoring in LTR.

Previous studies examined patients' use of mobile technology for health self-monitoring in other populations and primarily explored technology acceptance determinants, such as perceived usefulness and perceived ease of use (Hung & Jen, 2012; Jen, 2010; Kirwan, Duncan, Vandelanotte, & Mummery, 2012; Lin & Yang, 2009). Other possible influencing factors related to patient health self-monitoring were not assessed concurrently, such as patient clinical characteristics, health status, health beliefs, and perceived self-care agency, which could be important to help interpret the variation in patients' use of technology for health self-monitoring (Attuquayefio & Addo, 2014; DeVito Dabbs, Terhorst et al., 2013; Dew et al., 2008; Or & Karsh, 2009). In addition, the patients' use of smartphone applications for health self-monitoring could change over time (Carter, Burley, Nykjaer, & Cade, 2013). It is important to understand factors that may influence both the short- and long-term use of mobile technology for patient self-monitoring after lung transplantation.

1.1.1 Purpose

This study used Pocket PATH as an exemplar of mobile technology, with the purposes to describe the use of mobile technology by LTR for health self-monitoring and decision support for reporting critical condition changes during the first 12 months after lung transplantation, and to explore correlates/predictors associated with (a) use of mobile technology in different time periods within the first 12 months and (b) reporting of recorded critical values of health indicators (pulse, blood pressure, and temperature) to clinicians over the first 12 months.

1.1.2 Specific Aims

The **primary specific aims** are to:

(1) describe the use of Pocket PATH for health self-monitoring (in terms of the percentage of days used) in the 0 to 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months after lung transplantation;

(2) identify predictor (perceived usefulness, perceived ease of use, intention to use, socio-demographics, clinical characteristics, health status, health control beliefs, self-care agency, and environmental factors) of use of Pocket PATH for health self-monitoring in each of the four time intervals;

(3) describe LTRs' reporting of recorded critical values for up to 12 months post-transplantation; and

(4) identify predictors (use of Pocket PATH for health self-monitoring, socio-demographics, clinical characteristics, health status, health control beliefs, self-care agency, and environmental factors) of reporting of recorded critical values for up to 12 months.

The **exploratory aims** are to:

(1) explore the intention to use Pocket PATH as a mediator of the relationship between

a. perceived usefulness and use of Pocket PATH in each time interval, and

b. perceived ease of use and use of Pocket PATH in each time interval;

(2) explore age and gender as moderators of the relationship between

a. perceived usefulness and intention to use Pocket PATH, and

b. perceived ease of use and intention to use Pocket PATH;

(3) explore experience with technology as a moderator of the relationship between perceived ease of use and intention to use Pocket PATH;

(4) explore age and experience with technology as moderators of the relationship between facilitating factors (clinical characteristics, health status, health control beliefs, self-care agency, and environmental factors) and use of Pocket PATH for health self-monitoring in each time interval; and

(5) explore whether use of Pocket PATH for health self-monitoring is a mediator or a moderator of the relationships between socio-demographic characteristics, or facilitating conditions (clinical characteristics, health status, health control beliefs, and environmental factors), and reporting of recorded critical values for up to 12 months.

1.2 BACKGROUND AND SIGNIFICANCE

1.2.1 Health Self-Monitoring after Lung Transplantation

Lung transplantation has become an accepted treatment option for persons with advanced lung disease. According to the International Society for Heart and Lung Transplantation (ISHLT), 42,069 adult recipients underwent lung transplantation before 2012 and the increase of lung transplantation in the past 5 years was estimated at 30% (Yusen et al., 2013). Although patients' quality of life and survival have been improved after lung transplantation (Singer & Singer, 2013; Yusen, 2011), one- and five-year survival rates (79% and 53%, respectively) of LTR are lower than those of other solid organ transplant recipients, such as heart (83% and 76%), liver (90% and 78%) and kidney (97% and 89%) transplants (National Health Service, 2013; Yusen et al., 2013). Infection makes a big impact on mortality within the first year after lung transplantation, accounting for 21% of deaths (Yusen et al., 2013). Up to 75% of LTR are affected by infection and 55% by acute rejection in the first year (Burguete et al., 2013; Martinu, Howell, & Palmer, 2010). Both are high risk factors for chronic rejection (bronchiolitis obliterans syndrome, BOS), which is the leading cause of death beyond the first year post-transplant (Burton et al., 2009; Valentine et al., 2009). Prompt recognition and control of risk factors is crucial for appropriate management of these complications. LTR are only required to return to the transplant center for bronchoalveolar lavage or transbronchial lung biopsy to detect critical condition changes at their regular follow-up visits. Therefore, LTR are encouraged to perform daily health self-monitoring at home in order to detect the earliest signs of complications (Kotsimbos, Williams, & Anderson, 2012).

Vital signs, respiratory symptoms, and pulmonary function need to be routinely monitored by LTR (Finkelstein et al., 1996; Laporta Hernandez, Lazaro Carrasco, Varela de Ugarte, & Ussetti Gil, 2014) because critical changes in these health indicators have been reported to be associated or potentially associated with complications post-transplant (DeVito Dabbs, Hoffman, Iacono et al., 2004; Diamond et al., 2013; Fang et al., 2011; Kuntz et al., 2009; Lederer et al., 2011; Liu, Liu, Su, & Jiang, 2014). Particularly, the development of reduced pulmonary function is often an early sign of infection and rejection (Suhling et al., 2012; Wang et al., 2013). LTR are instructed to perform pulmonary function testing every day through a portable spirometer and to contact their transplant coordinators when a 10% reduction in the forced expiratory volume in the first second (FEV_1) compared to their baseline FEV_1 is noticed (DeVito Dabbs, Myers et al., 2009). However, the baseline FEV_1 needs to be periodically recalculated since pulmonary function improves with time after transplantation (Laporta Hernandez et al., 2014). In addition, changes of other pulmonary function parameters, such as forced vital capacity (FVC), FEV_1/FVC, the mid-expiratory flow rate, and the peak expiratory flow rate, often need to be evaluated (Laporta Hernandez et al., 2014; Modrykamien, Gudavalli, McCarthy, Liu, & Stoller, 2009).

Self-monitoring of these health indicators and interpreting monitoring data can be challenging for LTR. With the perception of improvement after transplant, LTR might fail to monitor or deny or delay reporting symptoms (DeVito Dabbs, Hoffman, Swigart et al., 2004). It can be difficult for LTR to accurately record measures for all objective and subjective health indicators, to identify critical values when thresholds of indicators are reached, or to recognize changes from their own personal baselines (DeVito Dabbs, Myers et al., 2009). Moreover, LTR may not be sure about what and when to report to the transplant team (DeVito Dabbs, Myers et al., 2009). With the increase in number of recipients and amount of data collected, it will be time consuming for clinicians to review and screen all raw monitoring data from each LTR in order to identify critical values (Wang et al., 2013). On the other hand, LTR are encouraged to be engaged in their self-care, be aware of changes of their condition, and be involved in critical change detection. Therefore, LTR are in need of decision support for early detection and reporting of any signs of complications when they perform daily health self-monitoring. The advanced development of information technology may be able to help with such needs (DeVito Dabbs, Myers et al., 2009; Finkelstein et al., 2013; Wang et al., 2013).

1.2.2 Use of Technology for Health Self-Monitoring and Decision Support in LTR

Electronic spirometry systems for home self-monitoring in LTR have been widely reported in previous studies and shown to be valid and reliable for early detection of complications (Ewert, Wensel, Muller, & Hetzer, 2000; Finkelstein et al., 1996; Kugler et al., 2009; Morlion, Knoop, Paiva, & Estenne, 2002; Wagner et al., 1999; Wang et al., 2013). Most electronic spirometry systems collect daily pulmonary function data, vital signs, and respiratory symptoms (Finkelstein et al., 1996; Karl et al., 2006; Morlion et al., 2002; Sengpiel et al., 2010; Wagner et al., 1999). But some systems only collect pulmonary function data (Ewert et al., 2000; Kugler et al., 2009) or collect symptom data weekly (Sengpiel et al., 2010). Frequent collection of data may increase the workload for data interpretation (Wang et al., 2013); however, it provides more information for early detection of any signs of complications. Not all systems can transmit data daily to the research center or the hospital. For those systems that transmit data weekly (Finkelstein et al., 1996; Karl et al., 2006) or have data downloaded during regular clinical visits (Kugler et al., 2009), there is potential delay in data interpretation if the patient is not involved in critical value detection. Most systems send data to clinicians for data interpretation and do not provide decision support functions for LTR (Ewert et al., 2000; Finkelstein & Ratner, 2006; Karl et al., 2006; Morlion et al., 2002; Wagner et al., 1999). Some systems provide reminders or alerts to interact with LTR (Karl et al., 2006; Morlion et al., 2002; Sengpiel et al., 2010). In one internet-based home monitoring system, after the data are transmitted to a home computer terminal, the computer will show a request for up to two additional spirometric measures whenever the first FEV_1 is below 100% of the reference value, which is regularly updated over time (Morlion et al., 2002). In another system, the predefined alarm symptoms (fever, sputum discoloration, dyspnea, nausea, emesis, etc.) generate instructions for LTR to contact the transplant center immediately when new symptom data are entered and matched (Sengpiel et al., 2010). Lastly, an electronic spirometry system, described by Kugler et al. (2010), compares the actual FEV_1 value with individually defined and stored predicted FEV_1 (best FEV_1), informs the individual about potential increases or declines of the current value, and provides specific traffic light colors to instruct patients on how to interpret and respond to the actual FEV_1 value. These basic decision-support function designs allow LTR to participate in the detection and report of condition changes.

With the rapid development of mobile technology, smartphone applications have been increasingly used in the health care field and have been reported to be convenient to use for health self-monitoring and provision of supportive real-time interventions (Bender, Yue, To, Deacken, & Jadad, 2013; Carter et al., 2013; Free et al., 2010; Slaper & Conkol, 2014; Wac, 2012). Pocket Personal Assistant for Tracking Health (Pocket PATH®) is a smartphone application developed by a multidisciplinary research team from the University of Pittsburgh and Carnegie Mellon University. This application has customized programs for recording pulmonary function, vital signs, symptoms, weight and values from laboratory assays. It supports both log and graphical displays of changes in those values over time and automatically generates feedback messages when critical values of health indicators are entered into the device, providing decision support for LTR about when and what to report to their transplant coordinators (DeVito Dabbs, Song et al., 2013). Self-monitoring data in Pocket PATH are automatically transmitted to the research site daily through a secure cellular connection. Preliminary study results confirmed that the use of Pocket PATH for health self-monitoring by LTR promoted early self-care agency, self-care behaviors, and health-related quality of life (DeVito Dabbs, Dew et al., 2009).

1.2.3 Acceptance and Use of Technology for Health Self-Monitoring

After transplantation, LTR begin to engage in a lifelong commitment to self-care and medical follow-up (Xu et al., 2012). Electronic devices and health-enabling technologies provide a convenient and reliable way for them to perform health self-monitoring and hold promise for early detection of complications and potential improvement of quality of life (DeVito Dabbs, Dew et al., 2009; Finkelstein et al., 1993; Kugler et al., 2010; Wang et al., 2013). Moreover, a cost-analysis study indicated that a 52.4% reduction of total cost can be predicted if LTR have 100% usage of the home self-monitoring system (Adam, Finkelstein, Parente, & Hertz, 2007). However, LTR may not always accept and use these devices or systems (Karl et al., 2006; Morlion et al., 2002; Sengpiel et al., 2010). In fact, use of electronic spirometry systems for health self-monitoring tends to decrease over time in LTR (Finkelstein et al., 1996; Morlion et al., 2002). Previous studies reported that approximately 82% of LTR transmitted electronic spirometric data each week (Finkelstein et al., 1996) and average weekly home monitoring adherence ranged from 74% to 88% during the first year (Adam et al., 2007; Finkelstein et al., 2013). Adherence rates to daily spirometry monitoring systems have been reported to be 85% in the first year and 63% in the second year; 84% for one measurement a day and 55% for two measurements a day (Morlion et al., 2002). Kugler et al. (2010) reported that 59.4% of subjects did not perform electronic monitoring of their lung function in the last two weeks and only 40.6% monitored at least once daily over a three-month period. Researchers had tried to update the systems and add new components, such as interactive communication, automatic data transmission via Bluetooth connection, feedback messages, and newsletters, to promote routine use of the systems for self-monitoring (Goldstein, Snyder, Edin, Lindgren, & Finkelstein, 1996; Karl et al., 2006; Lavelle et al., 2010; Pangarakis, Harrington, Lindquist, Peden-McAlpine, &

Finkelstein, 2008; Pieczkiewicz, Finkelstein, & Hertz, 2007; Sengpiel et al., 2010). However, the effects on improved use of the systems in LTR were not statistically significant (Lavelle et al., 2010; Sengpiel et al., 2010) or have not been evaluated in the long term (Goldstein et al., 1996; Karl et al., 2006). Challenges may also exist for the use of smartphone-based health self-monitoring services. Individuals' use of a smartphone application for self-monitoring weight management was found to decline over time (Carter et al., 2013). User acceptance associated with credibility and reliability of smartphone applications for self-care needs to be further evaluated with evidence-based approaches (Wac, 2012). In particular, more studies are expected to be conducted to explore facilitators and barriers to short- and long-term use of mobile technology systems for health self-monitoring in LTR (Kugler et al., 2010).

1.2.4 Factors Associated with Acceptance and Use of Technology for Health Self-Monitoring

1.2.4.1 Theoretical Foundation.

Previous studies have reported challenges for LTR to adhere with treatment regimens and home spirometry monitoring with or without the use of technology (De Geest, Dobbels, Fluri, Paris, & Troosters, 2005; Dew et al., 2008; Kugler et al., 2010; Sabati et al., 2001; Teichman, Burker, Weiner, & Egan, 2000; Yoon et al., 2008). Few studies have examined factors associated with acceptance of technology systems for health self-monitoring by LTR (Karl et al., 2006; Sengpiel et al., 2010), especially based on a theoretical model. As for a technology-based service, patients' acceptance and intention to use technology may affect their actual use (Jian et al., 2012; Jimison et al., 2008). A widely used conceptual model for assessing users' acceptance and actual usage of a variety of technologies is the Unified Theory of Acceptance and Use of Technology

(UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003), developed by integrating the constructs common to eight previous theories, including Theory of Reason Action (TRA), Technology Acceptance Model (TAM), Motivational Model (MM), Theory of Planned Behavior (TPB), combined TAM and TPB, Model of PC Utilization (MPCU), Innovation Diffusion Theory (IDT), and Social Cognitive Theory (SCT). The UTAUT posits that the behavior of people using information technology systems is predicted by their behavioral intention to use and facilitating conditions, while behavioral intention is determined by their performance expectancy and effort expectancy of using the technology systems, as well as their perception of important others' opinions for using the technology systems (social influences). Gender, age, technology experience, and voluntariness of use are considered as moderators of the key relationships in the UTAUT model (Figure 1).

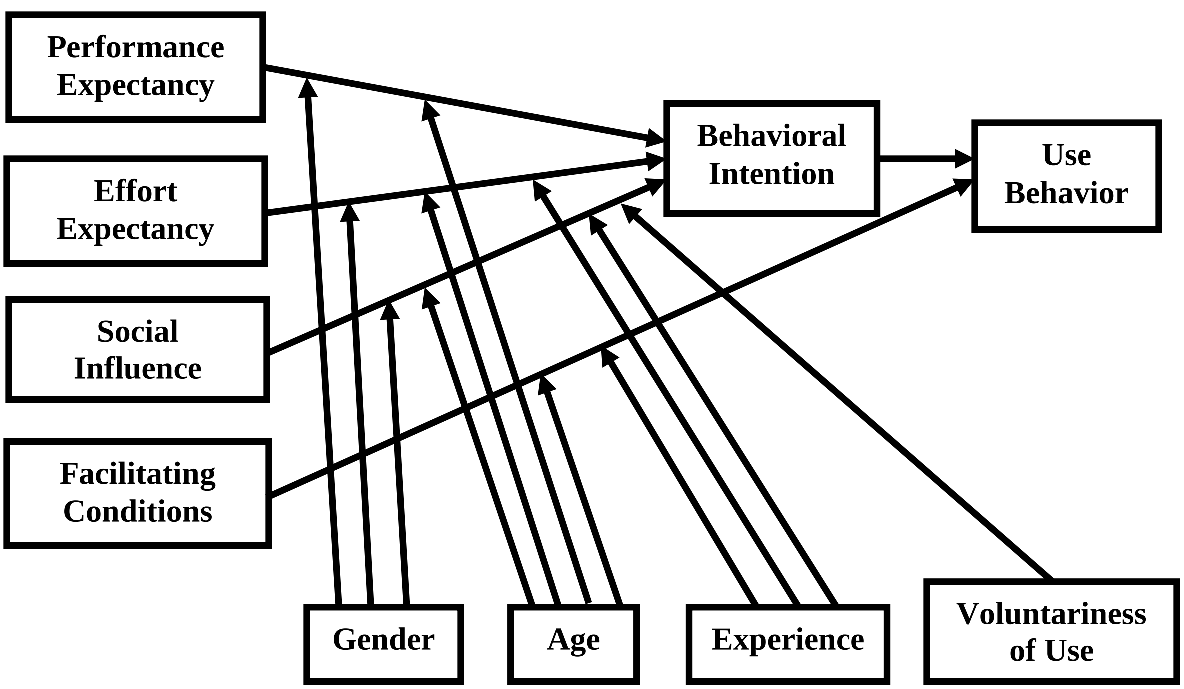


Figure 1. Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003)

Performance expectancy and effort expectancy are the same as perceived usefulness and perceived ease of use in TAM (Davis et al., 1989). Facilitating conditions are similar to the concept of perceived behavioral control in TPB. According to TPB, perceived behavioral control is derived from two sources: the external and the internal control (Ajzen, 1991). As a behavioral model, the UTAUT aims to explain the behavior of people using information technology systems and has been validated with large real world data (Attuquayefio & Addo, 2014; Venkatesh et al., 2003), including the use of self-monitoring technology by home care patients (Lee & Rho, 2013; Or et al., 2011; Tseng et al., 2013). Although Venkatesh et al. (2012) extended the UTAUT to the UTAUT2 by adding three new constructs, Hedonic Motivation, Price Value, and Habit, to fit the consumer technology use context, the UTAUT2 is less tested in the health self-care arena. In addition, the newly added construct, Price Value, is not applicable for the proposed study in which all participants were provided the Pocket PATH application for health self-monitoring at no cost. In fact, the common components between UTAUT and UTAUT2 can satisfy the needs of the proposed study with its aims to examine the impact of technology acceptance (perceived usefulness, perceived ease of use, and intention to use) and facilitating conditions (clinical characteristics and health status, health control beliefs, self-care agency, and environmental factors) on use of mobile technology for health self-monitoring. Therefore, the UTAUT will be used as a theoretical framework to guide this study, which will identify potential factors associated with the use of Pocket PATH for health self-monitoring (Figure 2). No previous conceptual framework has been found to identify potential factors associated with reporting of recorded critical values with the decision support of mobile technology in LTR. Therefore, two exploratory models (Figure 3 and Figure 4), based on the UTAUT model and the literature, are proposed for this purpose. Previous studies reported that patient demographics may be associated

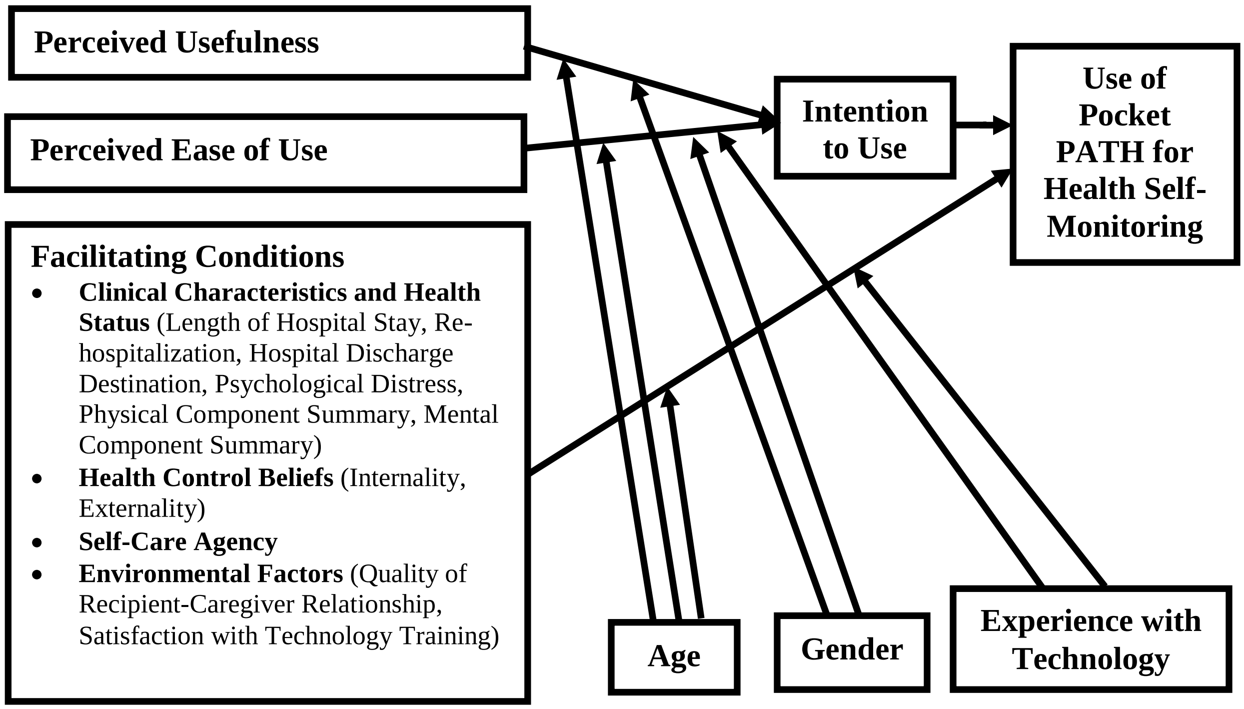


Figure 2. Conceptual Model for Acceptance and Use of Pocket PATH for Health Self-Monitoring in Lung Transplant Recipients (adapted from the UTAUT)

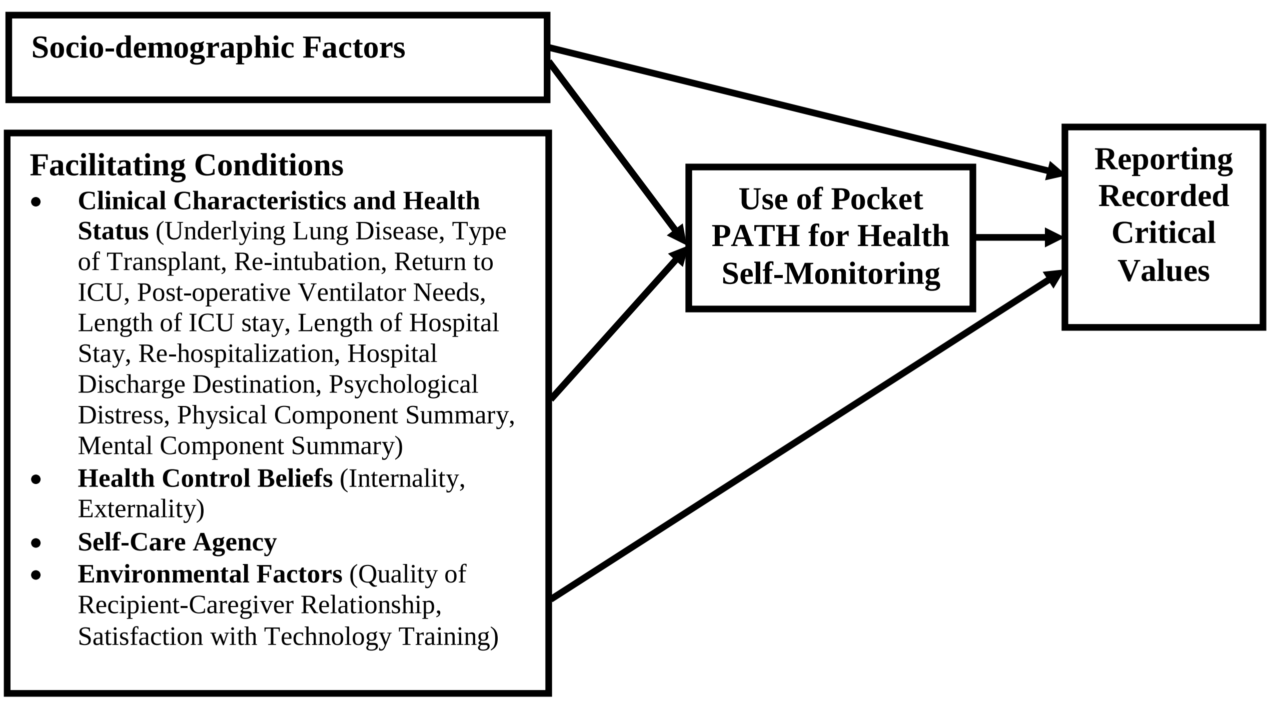


Figure 3. Exploratory Research Model 1: Reporting Recorded Critical Values during Health Self-Monitoring in Lung Transplant Recipients (Use of Pocket PATH as a Mediator)

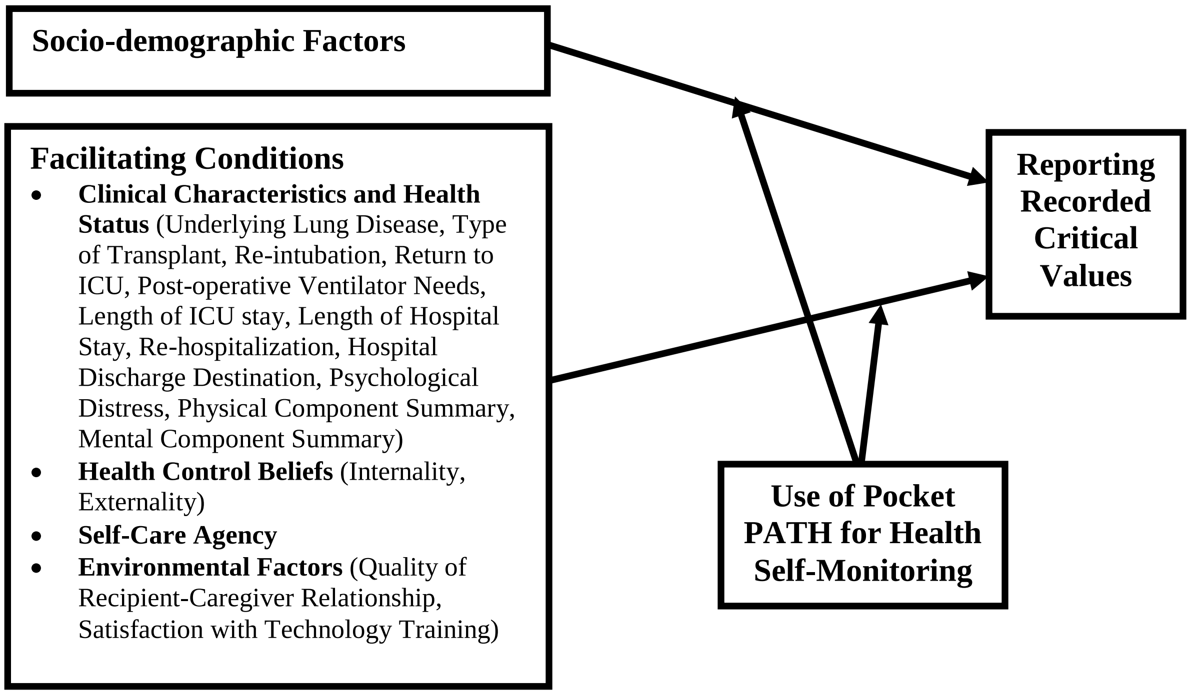


Figure 4. Exploratory Research Model 2: Reporting Recorded Critical Values during Health Self-Monitoring in Lung Transplant Recipients (Use of Pocket PATH as a Moderator)

with their adherence to medical recommendations (DiMatteo, 2004; Sherbourne, Hays, Ordway, DiMatteo, & Kravitz, 1992). Gender difference has been reported in individual symptom reporting and technology adoption (Kroenke & Spitzer, 1998; Venkatesh, Morries, & Ackerman, 2000; Zhang, Guo, Lai, & Li, 2014). Therefore, socio-demographic factors are considered as the direct predictors instead of potential moderators in the two proposed models. These two models posit that socio-demographic factors and facilitating conditions potentially affect reporting of recorded critical values by LTR. In addition, the use of Pocket PATH for health self-monitoring may potentially moderate or mediate the relationships between predictors and reposting of recorded critical values.

1.2.4.2 Perceived Usefulness

Perceived usefulness (PU), referring to the degree to which the individual believes that using the system is beneficial, is consistently found to be a significant predictor of consumers' behavioral intentions toward the use of health information technology in previous studies (Jian et al., 2012; Jimison et al., 2008; Or & Karsh, 2009; Or et al., 2011). However, inconsistent results were reported regarding individuals' perception of the use of mobile health technology services for their own use (Hung & Jen, 2012; Kirwan et al., 2012; Lee & Rho, 2013; Lin & Yang, 2009). PU was reported as a significant predictor of healthy persons' intention to use mobile health services in a few studies (Deng, Mo, & Liu, 2014; Hung & Jen, 2012; Jen, 2010; Lim et al., 2011). However, in a study with small sample size (*n*=50), the use of a smartphone application for self-monitoring and self-reported physical activity was not found to be significantly predicted by healthy persons' perceived usefulness of the application (Kirwan et al., 2012). In another study conducted in Taiwan that examined 229 asthma patients' acceptance of an asthma care mobile service in which patients used the mobile phone to record data and recognize condition changes, PU was not found to directly predict behavioral intentions. Instead, their relationship was mediated by attitude toward use (Lin & Yang, 2009). One study in South Korea did not directly explore the relationship of PU with intention to use (IU) (Lee & Rho, 2013). Instead, this study compared acceptance of a mobile health monitoring service between the users and non-users and reported a significantly higher mean score of PU in the user group. However, the magnitude of difference in means (±*SD*) was small (5.8±1.2 in users, 5.2±1.1 in non-users). In addition, although the majority of participants had hypertension (34.7%) and diabetes (30.6%), persons without any diagnosed disease accounted for 13.2% of the sample (Lee & Rho, 2013). In summary, the relationship between patients' PU and intention to use self-monitoring technology systems may vary in the context of the study, potentially influenced by patient population, country where the study is conducted, and technology platform that is assessed (Griebel, Sedlmayr, Prokosch, Criegee-Rieck, & Sedlmayr, 2013; Or & Karsh, 2009; Peek et al., 2014). In addition, a limited number of studies have examined the relationship of PU with actual use of mobile technology. To the best of our knowledge, the proposed study will be the first to examine the impact of PU on both IU and actual use of mobile technology for health self-monitoring in LTR.

1.2.4.3 Perceived Ease of Use

Perceived ease of use (PEU) is usually assessed at the same time as PU and has been consistently reported to be a significant predictor of acceptance of consumer health information technology (Kim & Garrison, 2009; Lai, Larson, Rockoff, & Bakken, 2008; Wilson & Lankton, 2004; Yu, Li, & Gagnon, 2009). More often, it is reported to indirectly impact intention to use through PU or through PU and attitude toward use (Hung & Jen, 2012; Jian et al., 2012; Lin & Yang, 2009; Liu, Tsai, & Jang, 2013; Or et al., 2011). The direct and indirect positive effects of healthy people's and patients' PEU on their intention to use mobile health technology services have been previously reported (Hung & Jen, 2012; Jen, 2010; Lee & Rho, 2013; Lin & Yang, 2009). However, the relationship between PEU and the use of mobile technology for health self-monitoring is unclear and needs to be further studied in LTR.

1.2.4.4 Intention to Use

Intention to use (IU), or behavioral intention in the UTAUT, is the most common measure of acceptance of technology. Previous studies have indicated that IU can predict use of a technology system (Chiu & Eysenbach, 2010; Davis et al., 1989; Jian et al., 2012; Venkatesh et al., 2003). Typically, the effect of PU and PEU on the use of the technologies is mediated by IU (Davis et al., 1989; Venkatesh et al., 2003). Individuals' intention to use consumer health information technology has been previously reported (Or & Karsh, 2009), indicating patients' high intention to use a home telecare system (Rahimpour, Lovell, Celler, & McCormick, 2008). However, it is unknown if LTR have intention to use the mobile technology for health self-monitoring and whether LTR who have intention to use will actually use mobile technology for health self-monitoring.

1.2.4.5 Facilitating Conditions

As mentioned above, variables that need to be applied to determine patients' intention to use and actual use of health information technology may vary in the context of the study (Attuquayefio & Addo, 2014). Specifically, such variables that should be considered include facilitating conditions, which refer to organizational and technical support in the UTAUT (Venkatesh et al., 2003) and perceived internal and external control in TPB (Ajzen, 1991). Internal control and external control represent the extent to which individuals have the internal ability and external resources to perform a behavior (Pavlou & Fygenson, 2006). Therefore, facilitating conditions can be generally described as the potential conditions that facilitate performing the behaviors (Sun, Wang, Guo, & Peng, 2013). Previous studies have referred to some factors as facilitating conditions, such as satisfaction with training, health control beliefs, and environment for using the technology (Or & Karsh, 2009), as well as patients' self-efficacy (Rahimpour et al., 2008; Sun et al., 2013). Patients' perceived self-care agency, referring to their capability to engage in self-care (Gast et al., 1989), can be considered as an internal control factor for patients' use of technology for self-monitoring. In addition, patients' clinical characteristics and health status will affect their performance of self-care and acceptance of technology (Goetzmann et al., 2007;

Mann, Marchant, Tomita, Fraas, & Stanton, 2001; Or & Karsh, 2009; Peek et al., 2014). Therefore, facilitating conditions of use of mobile technology for health self-monitoring by LTR will be operationalized as (1) clinical characteristics and health status (physical and psychological health), (2) health control beliefs (internality and externality), (3) self-care agency, and (4) environment factors (quality of recipient-caregiver relationship and satisfaction with technology training).

Clinical Characteristics and Health Status. The literature is unclear about the relationships between specific clinical characteristics and use of technology for health self-monitoring in LTR. However, post-transplant complications, long-term quality of life, and survival are reported to be associated with underlying lung disease (Burguete et al., 2013), type of transplant (Gerbase, Spiliopoulos, Rochat, Archinard, & Nicod, 2005; Hartert et al., 2014), length of hospital stay (LOS), and length of ICU stay (Armstrong et al., 2013), indicating that clinical characteristics impact post-transplant health outcomes and likely the presence of critical values of health indicators during health self-monitoring in LTR. Previous studies suggested that patient health status is a potential predictor of patients' acceptance of consumer health information technology (Or & Karsh, 2009). Both better health and poorer health have been reported to be associated with increased acceptance of or adherence with technology use (Chae, Park, Cho, Hong, & Cheon, 2000; Jeannot et al., 2004; Kugler et al., 2010; Millard & Fintak, 2002). Specifically, Sabati et al. (2001) found poor health status was a barrier to adherence with home monitoring in LTR. The inconsistent findings imply that the relationship between health status and technology acceptance may need to be further explored using specific domains of health status, such as physical function and mental function, related to the person's specific health care needs (Mann et al., 2001; Peek et al., 2014). Psychological distress is a common measure of psychological health and it has been reported to affect performance of self-care by LTR (Barbour, Blumenthal, & Palmer, 2006; DeVito Dabbs, Terhorst et al., 2013). Initial hospital length of stay and re-hospitalization after transplantation were often used as indicators of health outcomes in LTR (Armstrong et al., 2013; Mullan, Snyder, Lindgren, Finkelstein, & Hertz, 2003). Additionally, when LTR were discharged from the hospital, discharge destination indicates whether the individual's health status is stable enough to return home (or to a local residence) or go to an inpatient or rehabilitation facility. Therefore, these factors can be considered as proxies of health status and included as potential factors to predict use of mobile technology for health self-monitoring by LTR in each time interval.

Health Control Beliefs. Health control beliefs refer to the extent to which LTR believe that their health outcomes are primarily their own responsibility (internality), the responsibility of their health professionals (externality), or primarily due to chance (chance). Teichman et al. (2000) reported LTR with higher externality significantly more quickly contacted the transplant coordinator when they had a temperature that reached or exceeded the critical value. However, the association between adherence with a home spirometry monitoring system and health control beliefs was not found to be significant in another study of LTR (Lindgren et al., 2002). More recently, Dew et al. (2008) reported that lower internality was a significant predictor of non-adherence to home self-care and specifically spirometry use in LTR. Inconsistent findings imply that health control beliefs need to be further investigated when examining use of mobile technology for health self-monitoring by LTR.

Self-Care Agency. Self-care agency refers to the perception of one's abilities to engage in self-care activities. Previous studies have found that greater self-care agency predicted better anti-hypertensive medication adherence (Wang, Lau, Loo, Chow, & Thompson, 2014) and better timing adherence to immunosuppressants in LTR (Bosma, Vermeulen, Verschuuren, Erasmus, & van der Bij, 2011). A moderate and positive correlation was found between self-care agency and adherence to pharmacological and non-pharmacological treatment among people with cardiovascular risks (Velandia-Arias & Rivera-Alvarez, 2009). Few studies explored the relationship between technology use and self-care agency. One study did report that the person's knowledge of how to use technology for self-care contributed positively to self-care agency (Fex, Flensner, Ek, & Soderhamn, 2012). Moreover, a preliminary study to evaluate the effect of Pocket PATH on health self-monitoring in LTR showed that use of mobile technology potentially increased self-care agency (DeVito Dabbs, Dew et al., 2009). Conversely, the effect of self-care agency on use of mobile technology for health self-monitoring by LTR needs to be further studied.

Environmental Factors. Environmental factors usually refer to the physical aspects of the environment, such as the residential living space where patients use the technology. In this study, environmental factors refer to environmental situations that may influence social or technical support that LTR are able to obtain when they use mobile technology for health self-monitoring, such as their satisfaction with the caregiver relationship and satisfaction with technology training (Or & Karsh, 2009). These factors are important because they may impede or facilitate patients' abilities to use technology effectively and efficiently (DeVito Dabbs, Terhorst et al., 2013; Nijland, van Gemert-Pijnen, Boer, Steehouder, & Seydel, 2008; Peek et al., 2014). In addition, non-adherence to home spirometry self-monitoring in LTR was found to be associated with lack of family caregiver support (Dew et al., 2008; Teichman et al., 2000). Technology training was provided to facilitate the future use of the technology, as well as decreasing users' technology anxiety and improving their technology use self-efficacy

(Rahimpour et al., 2008). The individual's interest in the use of technology for health self-monitoring can be reinforced by appropriate training programs (Nahm et al., 2008). Therefore, environmental factors, such as the quality of the recipient-caregiver relationship and satisfactions with technology training, will be included in this study to investigate their impact on use of mobile technology for health self-monitoring by LTR.

1.2.4.6 Socio-demographic Factors and Experience with Technology

Socio-demographic factors, especially age and gender, have been frequently assessed for their relationships with patients' acceptance of health information technology. However, inconsistent results about the relationships have been reported (Or & Karsh, 2009). Significant relationships suggested that younger age may be associated with increased acceptance (Or & Karsh, 2009); however, one study showed that health-related internet offers were more likely to be accepted by older internet users (Birkmann, Dumitru, & Prokosch, 2006). Many other studies reported nonlinear relationship or no association between age and health technology acceptance (Or & Karsh, 2009). Gender difference may exist in the use of a new technology (Venkatesh, Morris, & Ackerman, 2000). However, most studies did not find an association between gender and health technology acceptance (Or & Karsh, 2009). Only a few studies revealed that females are more likely to have positive perceptions of health technology (Carrell & Ralston, 2006; Lee & Rho, 2013; Millard & Fintak, 2002).

Higher education and prior experience with technology were found to be associated with increased acceptance of health technology in the majority of studies (Or & Karsh, 2009). However, inconsistent findings have also been reported for the relationship between education and adherence to self-care. Studies indicate that higher education is an independent predictor of post-transplant non-adherence with immunosuppressants (Dobbels et al., 2009) and a correlate of better adherence to self-monitoring of blood glucose in type 2 diabetic patients (Yuan et al., 2014), but is a non-significant predictor of online self-monitoring for weight control (Krukowski, Harvey-Berino, Bursac, Ashikaga, & West, 2013). Therefore, relationships of education with health self-monitoring and reporting of recorded critical values of health indicators need to be further explored in this study.

The UTAUT suggests that age, gender, and experience with technology moderate the relationships between PU and IU, PEU and IU, and facilitating factors and use of technology systems (Venkatesh et al., 2003). However, interactions among these variables have been tested less often in studies of patients' acceptance and use of health information technology. As reported, older adults are less likely to accept health technology, which may be due to lack of technology familiarity and technology literacy or their poor health status (Cimperman, Brencic, Trkman, & De Leonni Stanonik, 2013; Mann et al., 2001; Peek et al., 2014). Gender has been reported as a significant moderator of computer anxiety and perceived behavioral control in previous studies (Venkatesh et al., 2000). Yu et al. (2009) found that computer skills had indirect impact on IU through PEU. Considering these research findings, age, gender, and prior technology experience will be examined as potential moderators when exploring factors associated with use of mobile technology for health self-monitoring by LTR.

1.2.5 Summary

In summary, LTR are encouraged to perform intensive health self-monitoring for early detection and reporting of any signs of complications, such as acute infection and rejection, especially in the first year after transplantation. The use of electronic spirometry systems for self-monitoring in LTR has been demonstrated to be convenient, reliable, and valid to identify critical condition changes. However, the use of spirometry systems for self-monitoring tends to decline over time. The advance of mobile technology has the potential to improve self-care behavior in LTR and identify critical condition changes. Little is known about use of mobile health technology for self-monitoring in LTR in the short- and long-term and factors associated with use of mobile technology. It is crucial to identify facilitators and barriers to use of mobile technology for health self-monitoring in LTR. Findings from this study may help to develop effective interventions to improve performance of health self-monitoring in LTR with the support of mobile health technology systems, which may in turn lead to better patient-related outcomes.

1.3 PRELIMINARY STUDIES

The principal investigator conducted two preliminary studies using the baseline measures and a subset of data from the parent study (R01 NR010711), "*Phase III Trial of Pocket PATH: A Computerized Intervention to Promote Self-Care*" to examine prior technology experiences and the relationships between technology acceptance and training satisfaction with adoption of Pocket PATH in LTR. The first abstract was presented at the Greater Pittsburgh 23rd Annual Nursing Research Conference (October, 2011) and the second abstract was presented at the International Transplant Nurses Society 21st Annual Symposium and General Assembly (October, 2012) (Appendix A). Findings from these two preliminary studies provided a better understanding of the pattern of previous technology use among LTR and further support for including specific predictor variables (i.e., PU, PEU, and satisfaction with technology training) into the dissertation conceptual model.

1.4 RESEARCH DESIGN AND METHODS

1.4.1 Study Design

The proposed study will employ a descriptive correlational design using existing data from the parent study "*Phase III Trial of Pocket PATH: A Computerized Intervention to Promote Self-Care*" (NIH, NINR, R01 NR010711, PI: Annette DeVito Dabbs). Only data from the technology intervention, Pocket PATH, group will be utilized in this proposed study to address the primary and exploratory aims.

1.4.2 Conceptual Models

A conceptual model (Figure 2) is used to determine factors that are associated with use of Pocket PATH for health self-monitoring in LTR. This model is adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). The UTAUT posits that technology use is predicted by behavioral intention (intention to use) and facilitating conditions, while behavioral intention is directly influenced by performance expectancy (perceived usefulness), effort expectancy (perceived ease of use), and social influences. Age, gender, experience with technology, and voluntariness of use are four factors thought to moderate the relationships between constructs (Figure 1). For this proposed study, the relationship between social factors and behavioral intention will not be assessed because the data were not available. Also, voluntariness of use will not be included as a potential moderator since it was not measured in the parent study.

Two proposed exploratory models are used for the exploration of factors that are thought to be associated with the reporting of recorded critical values (Figure 3 and Figure 4). These two models are an extension of the conceptual model discussed above (Figure 2), positing that socio-demographic factors, clinical characteristics and health status, health control beliefs, self-care agency, and environmental factors (quality of recipient-caregiver relationship and satisfaction with technology training) affect reporting of recorded critical values, and their relationships will be mediated or moderated by use of Pocket PATH for health self-monitoring in LTR. Given the small sample size, the initial multivariate exploratory model (multiple predictors) will be estimated including those predictor variable identified through the preliminary univariate (single predictor) analyses (using $p \leq 0.25$ as the screening criterion) (Bendel & Afifi, 1977; Mickey & Greenland, 1989). Significant predictors and possible interactions between predictor variables will be identified in the final model ($p<0.05$).

1.4.3 Parent Study

The parent study was a randomized controlled trial to test the efficacy of the Pocket PATH intervention versus usual care for promoting self-care agency, self-care behaviors, and transplant-related health at 2, 6, and 12 months after discharge following lung transplantation. The study was conducted in collaboration with the Adult Pulmonary Transplant Program of the University of Pittsburgh Medical Center (UPMC). All subjects were recruited from the acute cardiothoracic unit of UPMC from December 2008 to December 2012. They received pre-discharge education for usual self-care, including instruction for performing self-monitoring (e.g. using a microspirometer daily to monitor their breathing and recording their daily health indicators of pulse, blood pressure, temperature, spirometry, weight, and symptoms). When hospital discharge was imminent, 99 participants were randomly assigned to the Pocket PATH intervention group. Eighty-eight (88.9%) LTR received intervention training before discharge. The remaining 11 (11.1%) Pocket PATH participants had the training session at their second or sixth month home visit due to their poor health status. However, there were no statistically significant differences in socio-demographic and clinical characteristics between those 88 and 11 participants. The training session lasted about 30-45 minutes and was delivered by one of two trained nurse interventionists. Participants were given the Pocket PATH application on a study smartphone and trained to use its features and customized programs for health self-monitoring. They were required to perform return demonstrations of competency using the device for self-monitoring at the end of the training. A Pocket PATH User Support Manual and a toll-free number for participants to call for help with technical problems were also provided. After training, participants were encouraged to perform daily health self-monitoring and record their health indicators using the customized features of Pocket PATH. Data recorded on the device could be viewed in either log or graphical format for any selected date ranges. In addition, the application was programmed to generate automatic feedback messages when critical values of health indicators were entered into the device, reminding LTR to report the critical values to transplant clinicians (DeVito Dabbs, Song et al., 2013). It was explained to participants that the transplant team, not the research team, managed their clinical conditions.

Pocket PATH programs were first built on the HTC Tilt Window Phone (AT&T) and then switched to the HTC Pure Windows Phone (AT&T) when the Tilt models were no longer available for purchase. The operating system was also upgraded from Window Mobile 6 to Window Mobile 6.5. After changing platforms, consistency with the original intervention was maintained and training manuals and educational materials were updated to match the new model (DeVito Dabbs, Song et al., 2013). The HTC Pure device has 3G data connectivity via AT&T's HSDPA/UMTS network, with a 3.2-inch touchscreen, full onscreen QWERTY keyboard, and an extra stylus for data entry. Self-monitoring data recorded in Pocket PATH were uploaded automatically to the research site server through the cellular network. If the network coverage in the area was limited, the synchronization function of the application allowed the participant to manually upload or send data when the network coverage was better.

1.4.4 Subjects

There were 99 LTR randomly assigned to the Pocket PATH group in the parent study. However, 2 LTR died and 1 recipient refused before they started the intervention. The sample in the proposed study will include the 96 LTR who actually received the Pocket PATH for health self-monitoring. Inclusion criteria were the same as those in the parent study with one addition: (1) ≥ 18 years of age, (2) stable enough to be transferred from the cardiothoracic ICU to the acute cardiothoracic unit, and (3) able to read and speak English. In addition, the participant was assigned to the intervention group and received the Pocket PATH for health self-monitoring. LTR were excluded if they: (1) were recipients of any prior type of transplant, (2) had a condition that precluded discharge from the hospital, or (3) had limited involvement in their own post-transplant care.

1.4.5 Variables, Measurement, and Level of Measurement

1.4.5.1 Use of Pocket PATH for Health Self-Monitoring

Use of Pocket PATH for Health Self-Monitoring is defined as percentage of days that LTR actually entered data in the Pocket PATH programs for health self-monitoring (data transmission daily to the research site). The use of Pocket PATH in each time interval (0 to 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months post-transplantation) is calculated by the number of days LTR recorded data using Pocket PATH in the time interval divided by the number of participation days in the same time interval and then multiplied by 100. Participation days are possible self-monitoring days, which are calculated based on the dates when data were collected, such as the start date, 2-month date, 6-month date, and 12-month date, excluding the person's re-hospitalization days in the same time interval. The use of Pocket PATH is measured as a continuous variable (continuous version of data), ranged from 0% to 100%. The data will be categorized (categorized version of data) if the data distribution cannot satisfy the analysis assumptions even after data transformation.

1.4.5.2 Reporting of Recorded Critical Values

Reporting of Recorded Critical Values refers to the total number of reports of critical values to the clinicians out of the total number of recorded critical values in Pocket PATH. This variable can be operationalized as the number of feedback messages appropriately handled by LTR out of the number of feedback messages generated by the Pocket PATH. The Pocket PATH programs were designed to automatically generate feedback messages whenever reportable or critical values of health indicators were entered into the device. Specific values considered as critical included: a temperature > 101° Fahrenheit (or 38.3° Celsius), a blood pressure of systolic > 160 or < 88 or diastolic >100 mmHg, and a pulse < 60 or > 120 beats/min (Kovach, Aubrecht, Dew, Myers, & Dabbs, 2011). In addition, reportable feedback messages were generated when FEV1 declined for more than 10% compared to the individual's personal best value recorded in 7 days, weight gain of 2 pounds in 24 hours, and an increase of 4 points in a symptom rating in 24 hours (DeVito Dabbs, Myers et al., 2009). These feedback messages provide decision support for LTR, reminding them to take action, such as, when to contact the clinicians for their potential critical condition changes. For example, when the recipient entered a BP value of 161/75 mmHg, the following feedback message automatically popped up on the device: "You reported a high blood pressure. Wait 5 minutes, then recheck and enter your blood pressure again. If it is still elevated, report your blood pressure to the coordinator immediately" (Kovach et al., 2011, p. 576). For values considered reportable, LTR were instructed to report to clinicians during next regular business hours. Pocket PATH's decision support function was considered as accepted and followed if the LTR appropriately handling the critical feedback messages. The feedback messages were summarized on a website and the data were coded according to a data monitoring algorithm (Appendix B) (Kovach et al., 2011). Project staff reviewed the website for feedback messages every 72 hours. Also, they obtained information from the transplant coordinators' progress notes to identify if the critical values were reported to the clinicians or if the clinicians were already aware of the critical values. If data fit with three codes in the algorithm -- Value returned to acceptable level; Participant reported critical value; or Clinician already aware of critical value -- LTR were considered as "yes" for appropriately handling critical feedback messages. *Report of Recorded Critical Values* is calculated by the total count of "yes" for appropriately handling critical feedback messages divided by the total number critical values generated by Pocket PATH. *Report of Recorded Critical Values* is the continuous version of data. However, if the data are highly skewed and cannot be normalized, they will be categorized to appropriate levels (categorized version of data).

1.4.5.3 Intention to Use, Perceived Usefulness, and Perceived Ease of Use

Intention to Use (IU) was used as a measure of acceptance of Pocket PATH for health self-monitoring by LTR after transplantation. *Perceived Usefulness (PU)* and *Perceived Ease of Use (PEU)* refer to two potential determinants of intention to use Pocket PATH according to the UTAUT (Venkatesh et al., 2003). IU (1 item), PU (4 items), and PEU (4 items) are continuous variables measured by Technology Acceptance Subscales, a 7-point Likert scale (1=very likely to 7=very unlikely), adapted from previous studies that assessed people's acceptance of computer technology. After reverse coding all items, the possible scores of IU are from 1 to 7, with higher scores indicating higher intention. IU will be categorized if the data are highly skewed and cannot be normalized. The scores of PU and PEU are calculated as the sum of 4 items respectively, ranging from 4 to 28, with higher scores indicating higher perceptions. Internal consistency reliability of the original technology acceptance subscales for measuring IU, PU, and PEU was excellent with a Cronbach's alpha of 0.96 for IU, 0.90 for PU, and 0.92 for PEU (Venkatesh et al., 2003).

1.4.5.4 Facilitating Conditions

Facilitating conditions refers to potential conditions that facilitate performance of health self-monitoring by LTR. Specifically, these conditions include clinical characteristics and health status, health control beliefs, self-care agency, and environmental factors, which are described below.

Clinical Characteristics and Health Status. Clinical characteristics at baseline were obtained from medical record review, including *Underlying Lung Disease* (obstructive vs. non-obstructive), *Type of Transplant* (single vs. double), *Re-intubation* (yes vs. no), *Return to ICU* (yes vs. no), *Post-operative Ventilator Needs* ($<$ 48 hours vs. $\geq$ 48 hours), *Length of ICU Stay* (days), and *Length of Hospital Stay* (LOS, days). In addition, *Re-hospitalization* (days) at each time interval during 12 months post-discharge was also obtained from the patient's medical record. If non-normally distributed, *Re-hospitalization* will be categorized into two levels as "yes" for being re-hospitalized and "no" for not being re-hospitalized during the time interval. All clinical characteristics will be used to describe the sample. LOS (baseline) and re-hospitalization (in each time interval), as two general clinical characteristics, will be included in the model to identify predictors of the use of Pocket PATH for health self-monitoring (Armstrong et al., 2013; Mullan et al., 2003). When exploring predictors of reporting of recorded critical values, model building is of interest. Although patients' health conditions have been reported to be associated with their adherence to medical recommendations (DiMatteo, 2004; Sherbourne et al., 1992), it is unclear which clinical characteristic may be associated with following recommendations made by technology for reporting critical condition changes in LTR. All clinical characteristics will be evaluated in univariate (single predictor) analysis. The cutoff *p*-value 0.25 will be used for screening candidate predictor variables that can be included in the final multivariate (multiple predictor) analysis model (Bendel & Afifi, 1977; Mickey & Greenland, 1989).

Health status refers to perceived physical and psychological health post-transplantation. H*ospital Discharge Destination* was obtained from medical record review, indicating health status at the time when LTR were leaving the hospital. They might be stable enough to go back home (own home or local residence) or not stable enough so that they need to stay in an inpatient or rehabilitation facility. Therefore, *Hospital Discharge Destination* is dichotomized into two levels, “Home” vs. “Facility”.

Psychological Distress is assessed by the Anxiety and Depression subscales of the Symptom Checklist 90-Revised (SCL-90-R) (Derogatis, 1994). This checklist measured the severity of the psychological distress symptoms of anxiety (10 items) and depression (13 items) at baseline, and 2 months, 6 months, and 12 months post-transplantation. Items are rated on a 5-point Likert scale (from “Not at all” to “Extremely”). Subscale scores are computed by averaging items. The test-retest reliability for the checklist ranges from 0.80 to 0.90 (Derogatis, 1994), and Cronbach’s alpha for the two subscales ranges from 0.80 to 0.88 (DeVito Dabbs, Hoffman, Swigart et al., 2004). Both anxiety and depression are continuous variables ranging from 0 to 4, with higher scores indicating higher anxiety and depression. If the two variables are found to be highly correlated, a new variable, psychological distress, will be computed by summing the anxiety and depression scores. In addition, the mean psychological distress score for each time interval will be computed.

Physical Component Summary (PCS) and *Mental Component Summary* (MCS) are two summary measures of Health-Related Quality of Life (HRQoL) from the Medical Outcomes Study Short Form (SF-36) v2 (McHorney & Ware, 1995). Specifically, PCS is a summary score of positive weights for subscales of Physical Functioning, Role Physical, Bodily Pain, General Health, and Vitality, and negative weights for Social Functioning, Role-Emotional, and Emotional Well-being; MCS is a summary score of positive weights for subscales of Vitality, Social Functioning, Role-Emotional, and Emotional Well-being and negative weights for Physical Functioning, Role-Physical, Bodily Pain, and General Health (Ware, Kosinski, &

Keller, 1994). PCS and MCS are frequently used as measures of health status in different population (Kessler & Alverson, 2013; Wilke et al., 2012). HRQoL was measured in LTR at 2 months, 6 months, and 12 months post-transplantation, reflecting recall of their health status in the previous four weeks. Both PCS and MCS are continuous variables ranging from 0 to 100; higher scores indicate better HRQoL. The mean of PCS and MCS from 2 to 6 months, from 6 to 12 months, and from 2 to 12 months will be computed.

Health Control Beliefs. *Health Control Beliefs* was measured at baseline by the Multi-dimensional Health Locus of Control (MHLC) scale. Internal consistency (Cronbach's alpha) has been reported to range from 0.83 to 0.86 for the instrument and its subscales (Wallston & Wallston, 1978; Wallston, Wallston, & DeVellis, 1978). A previous study reveals that it is important for LTR to have both high internal and external health control beliefs for optimal health management (DeVito Dabbs, Kim, Hamdan-Mansour, Thibodeau, & McCurry, 2006). Therefore, the subscales of internality (6 items) and externality (6 items) will be included in this proposed study, assessing the extent to which LTR believe that their health outcomes are primarily their own responsibility or depend on following their health professionals' recommendations. Items are rated on a 6-point Likert scale (from "strongly disagree" to "strongly agree"). The score on each subscale is the sum of six items, with possible scores ranging from 6 to 36. A higher score indicates higher internality/externality. Both internality and externality are treated as continuous variables.

Self-Care Agency. The Perception of Self-Care Agency (PSCA) scale, a 53-item, 5-point Likert scale (1=never like me to 5=always like me), was used to measure LTRs' perceived abilities to engage in self-care at baseline, the 2^{nd} month, 6^{th} month, and 12^{th} month after transplantation (Gast et al., 1989). A previous study reported its Cronbach's alpha was .93, and

1-week test-retest reliability was .85 (Hanson & Bickel, 1985). The PSCA scale has been used on a small group of LTR (*n*=34) and demonstrated to be sensitive to change in self-care agency between baseline and 2 months (Cronbach's alpha was .94) (DeVito Dabbs, Dew et al., 2009). The score of this scale is the sum of all items, with the total score ranging from 53 to 265. A higher score indicates higher self-care agency. Self-care agency is treated as a continuous variable. The mean score in each time interval, from baseline to the 2nd month, the 2nd month to 6th month, the 6th month to the 12th month, and baseline to the 12th month, will be computed for data analysis.

Environmental Factors. Environmental Factors in this proposed study refer to *Quality of Recipient-Caregiver Relationship* and *Satisfaction with Technology Training*.

Quality of Recipient-Caregiver Relationship was measured at baseline using an adaptation of the Dyadic Adjustment Scale (Spanier, 1976), an 18-item self-report measure of the quality of the relationship between the LTR and their primary caregivers. The scale has been found to be applicable for assessing quality of recipient-caregiver relationships between spouses or non-spouses (DeVito Dabbs, Terhorst et al., 2013). Previous studies of LTR reported Cronbach's alpha of .86 (DeVito Dabbs, Terhorst et al., 2013) and .94 (DeVito Dabbs, Dew et al., 2009). For the proposed study, only the sum score of the first 15 items will be used for analysis because the first 15 items apply to any type of recipient-caregiver relationship. *Quality of Recipient-Caregiver Relationship* is treated as a continuous variable, ranging from 15 to 75, with higher scores indicating less distress in the relationship.

Satisfaction with Technology Training was measured by After-Scenario Questionnaire (ASQ) (Lewis, 1995), a 3-item, 7-point Likert scale (1=strong agree to 7=strongly disagree), with Cronbach's alpha ranging from .90 to .96. This questionnaire is scored by averaging three items, with possible scores ranging from 1 to 7. After reversely coding the items, higher average scores will represent greater satisfaction. If the satisfaction score is highly skewed even after data transformation, this continuous variable may be categorized.

1.4.5.5 Socio-demographic Factors

Socio-demographic factors were measured at baseline including *age* (years), *gender* (male vs. female), *race* (white vs. non-white), *marital status* (currently married or living with partner/significant other vs. not currently married), *education* (≤ high school vs. > high school), *employment* (employed vs. non-employed), and *income* (yes vs. no for basic needs met by income). This questionnaire included items about previous experience in using some common technologies, such as a cell phone, Personal Digital Assistant (PDA), other hand-held device (e.g., MP3, Digital Camera, etc.), and computer. For each technology, LTR reported the frequency of use on a Likert-type scale, as 0=Never, 1=Once, twice, or a few times, and 2=Multiple times. A new variable, *experience with technology*, will be generated to represent their general prior technology-use experience by summing scores of all technology use (cell phone, PDA, other hand-held devices, and computer). This new variable will be treated as a continuous variable ranging from 0 to 8, with higher scores indicating greater experience.

All socio-demographic factors will be used to describe the sample. Based on the conceptual model (Figure 2), age, gender, and experience with technology will be assessed as potential moderators of relationships of predictor variables with IU and actual use of Pocket PATH for health self-monitoring. As the relationships between socio-demographics and the reporting of critical values are unclear in the literature, all socio-demographic factors will be evaluated as potential predictors of the reporting of recorded critical values in univariate (single predictor) analysis. Only predictors meeting the pre-established screening criterion (the cutoff p-value ≤ 0.25) will be considered in the final multivariate (multiple predictors) analysis (Bendel & Afifi, 1977; Mickey & Greenland, 1989).

1.4.6 Data Collection and Management

Data were collected in the parent study at five time points: prior to discharge, and 1 week, 2 months, 6 months, and 12 months post-discharge. Table 1 provides the variables and timing of data collection over 12 months. Data collected prior to discharge and at 1 week post-discharge are called baseline data in general. Hospital discharge destination, health control beliefs, self-care agency, quality of recipient-caregiver relationship, and socio-demographic factors were collected during hospitalization prior to discharge instruction and randomization. Baseline psychological distress was collected at the first clinic follow-up visit within the first week post-discharge. Data for technology acceptance and satisfaction with technology training were collected immediately following delivery of the Pocket PATH intervention. Data on psychological distress and self-care agency were additionally collected at 2 months, 6 months, and 12 months post-hospital discharge, while physical component summary and mental component summary from the SF-36 were collected initially at 2 months and repeated at 6 months and 12 months post-hospital discharge. Data for re-hospitalizations during each time interval (0 to 2 months, > 2 to $\leq$ 6 months, > 6 to $\leq$ 12 months, and 0 to 12 months post-transplantation) were abstracted from medical records after discharge. Data for the use of Pocket PATH for health self-monitoring and critical feedback messages generated for health indicator were collected from the devices. Data for the reports of critical values (appropriately handling critical feedback messages) were collected by research assistants according to information obtained from the clinicians' progress notes and codes from the data monitoring algorithm. All

Table 1. Variables and Timing of Data Collection Over 12 Months

Variables	0 to 2	>2 to ≤6	>6 to ≤12	0 to 12
Use of Mobile Technology (Pocket PATH)	X	X	X	X
Report of Recorded Critical Values				X
Re-hospitalizations (Yes/No)	X	X	X	X
Variables	**Baseline**	**2nd Month**	**6th Month**	**12th Month**
Technology Acceptance (IU, PU, and PEU)	X			
Clinical Characteristics and Health Status at baseline (lung disease, type of transplant, re-intubation, return to ICU, ventilator needs, length of hospital stay, length of ICU stay)	X			
Psychological Distress	X	X	X	X
Physical Component Summary (PCS)		X	X	X
Mental Component Summary (MCS)		X	X	X
Health Control Beliefs: Internality	X			
Health Control Beliefs: Externality	X			
Perceived Self-Care Agency	X	X	X	X
Hospital Discharge Destination	X			
Quality of Recipient-Caregiver Relationship	X			
Satisfaction with Technology Training	X			
Socio-demographic factors (age, gender, race, marital status, education, employment, income, experience with technology)	X			

data collectors received specific data collection training and had a series of three practice data collection sessions that were video-recorded and reviewed for their competence and adherence to protocols. The project director observed and audiotaped randomly selected recruitment and data collection sessions to detect any problems in data collection and provided feedback to data collectors for improvement, if necessary.

Microsoft Access for Windows was used for data management. All data collection forms (questionnaires) were reviewed and scanned for missing data by the individual who collected the data. Attempts were made to gather the missing information and document it on the questionnaires. After the data were entered into the appropriate Access form, the form was initialized, dated, and placed in the “TO BE VERIFIED” bin for verification. Any mistakes identified and the changes made during verification were documented on the data collection form, with the person’s initials and the verification date. The Data Entry Log Sheet was filled out and updated over time. Health self-monitoring data recorded in the Pocket PATH device were automatically uploaded to the research site computer. Research staff assessed data for critical feedback messages every 72 hours and managed data feedback messages according to the data monitoring algorithm (Appendix B).

1.5 STATISTICAL ANALYSIS PLAN

Statistical analyses will be conducted using SPSS (version 22.0, IBM, Inc., Chicago, IL). Sample size justification (effect size estimation) and preliminary analysis procedures (exploratory data analysis) will be conducted before the final data analysis for all specific aims.

1.5.1 Sample Size Justification

As the proposed study is a secondary analysis of data from a completed study, the sample size for this study is fixed (*N*=96). Therefore, the sample size justification will be presented in terms of precision (i.e., margin of error) when estimating point estimates with a confidence coefficient of 0.95 (Primary Aims 1 and 3), and the minimum effect sizes detectable at the desired level of statistical power of 80% at a significance level of 0.05 when testing two-sided hypotheses (Primary Aims 2 and 4) (Hulley, Cummings, Browner, Grady, & Newman, 2013).

Specifically, for Primary Aim 1 and Primary Aim 3, with a sample size of 96 LTR that were assigned to use Pocket PATH for health self-monitoring, a margin of error (in terms of the half-width of the confidence interval) of no more than $0.2\sigma_{use}$ will be obtained when estimating mean use of Pocket PATH for 0 to 2 months, > 2 to ≤ 6 months, > 6 and ≤ 12 months, and 0 to 12 months after lung transplantation with a confidence coefficient of 0.95, where σ_{use} is the population standard deviation for use of Pocket PATH. When estimating the mean reports of critical values recorded, the margin of error should be no more than $0.2\sigma_{reports}$, with a confidence coefficient of 0.95, where $\sigma_{reports}$ is the population standard deviation for reporting of recorded critical values.

For Aim 2 and Aim 4, with a sample size of 96 LTR, a population R^2 as small as 0.06 for a single adjusted predictor could be detected with 80% power using multiple linear regression at a significance level of 0.05 for the use of Pocket PATH for self-monitoring in each time interval and for the report of recorded critical values for up to 12 months, with models containing 15 additional predictors explaining at most 20% of the variance in use of Pocket PATH and in reporting of recorded critical values.

1.5.2 Preliminary Analysis Procedures

To ensure the validity of the primary analysis of data, exploratory data analysis will be first conducted, including assessment of data accuracy, outliers, missing data, and the underlying statistical assumptions. Data accuracy will be assessed by proofreading and computation of descriptive statistics for range checking. Questionable values will be verified with original data collection sheets. Univariate and multivariate outliers will be assessed by graphical methods, such as histograms and scatterplots, and statistical procedures, such as frequencies and Mahalanobis distance. Data transformation or score alteration (i.e., Winsorization) will be conducted to reduce the impact of outliers when it is necessary. Also, the amount and pattern of missing data will be evaluated. Little's test will be conducted to assess whether data are missing completely at random (MCAR). Single imputation (< 5% missing) or multiple imputation (≥ 5% and < 50% missing) will be applied when data are not MCAR but missing at random (MAR). If data are neither MCAR nor MAR, they are missing not at random (MNAR). MNAR sensitivity analyses will be conducted by comparing results with missing data and results without missing data (Resseguier, Giorgi, & Paoletti, 2011). Finally, for multiple linear regression analyses, underlying assumptions, such as independence, normality, and linearity, will be assessed by scatterplots, histograms, normal probability plots, and residual plots by graphing the studentized residuals (y-axis) with the standardized predicted values (x-axis). Homoscedasticity can also be assessed by studentized residual plots, inspecting whether the vertical scatter (i.e., variability in the dependent variables) is the same across all x values. Multicollinearity will be assessed by bivariate correlations, tolerance indices, and variance inflation factors, as well as variance-decomposition proportions and the associated condition indices (Belsley, 1991). If the underlying assumptions for multiple linear regressions cannot be met after data transformations (such as log base 10 or square root), the categorization of dependent variables will be considered, and binary logistic regression (two categories) or proportional odds model for ordinal logistic regression (more than two categories) will be conducted. Linearity in the logit between the dependent variable and each continuous type of predictor variable will be further assessed by the addition of an interaction term of the predictor with the natural logarithm of the predictor in the model. Furthermore, the proportional odds assumption will be tested if ordinal logistic regression is employed.

1.5.3 Data Analysis Procedures for Primary Aims

1.5.3.1 Data Analysis Plan for Primary Aim 1

Descriptive statistics will be used to characterize the use of Pocket PATH (measured in terms of percentage of days used) for health self-monitoring by LTR during 0 to 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months after lung transplantation. For normally distributed data, the mean and standard deviation of the use of Pocket PATH in each time interval will be calculated as the measure of central tendency and dispersion, respectively. The 95% confidence interval for the mean use of Pocket PATH will be computed to estimate the range of mean use of Pocket PATH in the population. If data are not normally distributed, data transformation (e.g., log base 10 or square root) will be considered. If data cannot be normalized, non-parametric descriptive statistics (e.g., median and inter-quartile range) will be applied for description of use. If categorization of the use of Pocket PATH is required (categorized version of data), frequencies and percentages will be used to describe the use of Pocket PATH, mode will be obtained to reflect the most common use category in the dataset, and range will be used to summarize the variability. Given the variable's level of measurement, appropriate graphical methods, such as histograms and bar charts, will be also used to display the distribution of the use of Pocket PATH in each time interval and over the 12 month period.

1.5.3.2 Data Analysis Plan for Primary Aim 2

Relationships between potential predictors (PU, PEU, IU, socio-demographic factors, clinical characteristics and health status, health control beliefs, self-care agency, and environmental factors) and the use of Pocket PATH in each time interval will be examined by univariate (single predictor) and multivariate (multiple predictor) regression analyses. If the continuous version of data for the use of Pocket PATH meets the underlying standard assumptions (i.e., linearity, normality, independence, etc.), simple and multiple linear regression will be applied. Otherwise, the categorized version of data for the use of Pocket PATH will be modeled using binary or ordinal logistic regression (Hosmer, Lemeshow, & Sturdivant, 2013). Regression coefficients with confidence intervals and *t*-statistics or Wald-statistics will be computed to summarize and test hypotheses regarding the associations between predictors of use of Pocket PATH in each time interval. Specifically, for the linear regression models, the R-squared of the fitted regression model will be obtained to summarize the variation explained in use of Pocket PATH for each time interval by the predictors. For the binary or ordinal logistic regression models, the odds ratio of each predictor can be derived by exponentiating the estimated regression coefficient. The *F*-statistic test for linear regression and the model Likelihood Ratio Chi-Square test for binary or ordinal logistic regression will be used to test the significance of the overall model.

Table 2 lists potential predictors for four multivariate regression models. Variables that were only measured or obtained at baseline, such as PU, PEU, IU, socio-demographic factors (age, gender, and experience with technology), and some facilitating conditions (length of hospital stay, hospital discharge destination, internality, externality, quality of recipient-caregiver

Table 2. Potential Predictors Associated with Use of Pocket PATH for Health Self-Monitoring

Model	Dependent Variable	Predictor
All Models	Percentage of days using Pocket PATH for self-monitoring in: 0 to 2 months post-transplant (Model 1), > 2 to ≤ 6 months (Model 2), > 6 to ≤ 12 months (Model 3), and 0 to 12 months post-transplant (Model 4)	PU
		PEU
		IU
		Length of hospital stay
		Hospital discharge destination
		Internality
		Externality
		Quality of recipient-caregiver relationship
		Satisfaction with technology training
		Age
		Gender
		Experience with technology
1	Percentage of days using Pocket PATH for self-monitoring in: 0 to 2 months post-transplant	Re-hospitalization during the first two months
		Mean self-care agency from baseline to the 2nd month
		Mean psychological distress from baseline to the 2nd month
2	Percentage of days using Pocket PATH for self-monitoring in: > 2 to ≤ 6 months post-transplant	Re-hospitalization from the beginning of the 3rd month to the end of the 6th month
		Mean self-care agency from the 2nd month to the 6th month

Table 2. Potential Predictors Associated with Use of Pocket PATH for Health Self-Monitoring (continued)

		Mean physical component summary from the 2nd month to the 6th month
		Mean mental component summary from the 2nd month to the 6th month
3	Percentage of days using Pocket PATH for self-monitoring in: > 6 to ≤ 12 months post-transplant	Re-hospitalization from the beginning of the 7th month to the end of the 12th month
		Mean self-care agency from the 6th month to the 12th month
		Mean physical component summary from the 6th month to the 12th month
		Mean mental component summary change from the 6th month to the 12th month
4	Percentage of days using Pocket PATH for self-monitoring in: 0 to 12 months post-transplant	Re-hospitalization from the start date to the end of the 12th month
		Mean self-care agency from the baseline to the 12th month
		Mean physical component summary from the 2nd month to the 12th month
		Mean mental component summary from the 2nd month to the 12th month

relationship, and satisfaction with technology training), will be included in each multivariate model. However, for variables those were measured over time, such as psychological distress, physical component summary, mental component summary, and self-care agency, the mean score during each time interval (calculated by the subtraction of the start-point measure from the end-point measure divided by the start-point measure and then multiplied by 100) will be used as the potential predictor for the model of that time interval. It is anticipated that multicollinearity will exist between psychological distress and mental component score. Therefore, mean psychological distress will be used instead of mean mental component summary in models 2 and 4. Re-hospitalization was measured in each time interval. Therefore, the re-hospitalization variable coinciding with the specified time interval will be entered into each of the four models.

1.5.3.3 Data Analysis Plan for Primary Aim 3

A similar descriptive statistics strategy as outlined for Primary Aim 1 will be used to characterize reporting of recorded critical values (in term of percentage of feedback messages appropriately handled from all feedback messaged generated) for up to 12 months post-transplantation. Specifically, means and standard deviations (or medians and inter-quartile ranges, if data are not normally distributed) will be used to describe central tendency and dispersion, respectively. If categorization of reporting of recorded critical values is required, frequencies and percentages will be used to describe the report of recorded critical values and the mode will be obtained to reflect the most common report category in the dataset. Appropriate graphical methods (e.g., histogram and bar charts) will be used to display the distribution of the report of recorded critical values.

1.5.3.4 Data Analysis Plan for Primary Aim 4

Two proposed exploratory models (Figure 3 and Figure 4) will be used to guide data analysis for Aim 4. The dependent variable of interest is reporting of recorded critical values for up to 12 months post-transplantation. A similar regression analysis strategy as outlined for Aim 2 will be used for assessing and evaluating the relationships of socio-demographic factors, facilitating conditions (clinical characteristics and health status, health control beliefs, self-care agency, and environmental factors), and the use of Pocket PATH for health self-monitoring with reporting of recorded critical values up to 12 months. For Primary Aim 4, only one multivariate (multiple predictors) regression model will be conducted. For those predictors that were measured over the 12 months, such as self-care agency, PCS, and MCS, their mean measures at all time points will be computed and examined in the univariate and multivariate models.

1.5.4 Data Analysis Plan for Exploratory Aims

1.5.4.1 Data Analysis Plan for Exploratory Aim 1

Based on the conceptual model (Figure 2), simple mediation models will be used to assess IU as a mediator of the relationship between PU and use of Pocket PATH in each time interval. A four-step approach including several regression analyses will be conducted (Baron & Kenny, 1986). In Step 1, a simple regression analysis will be conducted with PU predicting the use of Pocket PATH. Step 2 involves conducting a simple regression analysis with PU predicting IU. For Step 3, a simple regression analysis will be performed with IU predicting the use of Pocket PATH. Lastly, in Step 4 a multiple regression analysis will be used with PU and IU predicting the use of Pocket PATH. Significance of the coefficients at each step will be examined. If a non-significant relationship is identified at Steps 1-3, it implies that mediation may not be possible or likely. In

Step 4, if the effect of IU on the use of Pocket PATH remains significant after controlling PU, some form of mediation is still supported. If PU is no longer significant when IU is controlled, full mediation is supported. If PU and IU both significantly predict the use of Pocket PATH, partial mediation is supported. The indirect effects of PU will be calculated using the Judd and Kenny difference of coefficients approach (Judd & Kenny, 1981), subtracting the partial regression coefficient of PU obtained from Step 4 from the simple regression coefficient obtained from Step 1.

The same mediation analysis steps and indirect effect calculation approach will be conducted to explore the role of IU in the relationship between perceived ease to use and the use of Pocket PATH in each time interval. The type of regression analysis to be used will be based on the form of the dependent variable, the use of Pocket PATH. Linear regression will be used if the use of Pocket PATH is the continuous type variable with approximate normal error, whereas, ordinal logistic regression models will be used if the normality assumption for the continuous version of the use of Pocket PATH variable cannot be reasonably satisfied and the categorical version of the variable must be used for analysis.

1.5.4.2 Data Analysis Plan for Exploratory Aim 2

Based on the conceptual model (Figure 2), age and gender will be assessed as potential moderators for the relationships of IU with (a) PU and (b) PEU. The moderator effect of age on the relationship between PU and IU is indicated by the interaction of PU and age in explaining IU. A multiple regression analysis will be conducted with PU, age, and the interaction of PU and age (created as the product of the two variables) predicting IU. The coefficient of the interaction of two variables measures the moderation effect, with a no-significant coefficient indicating no moderation effect. The same approach will be used to explore the moderator effect of age on the relationship between PEU and IU, the moderator effect of gender on the relationship between PU and IU, and the moderator effect of gender on the relationship between PEU and IU.

The type of regression to be used will be determined by the type of data of IU. Linear regression will be used for the continuous version of IU, whereas logistic regression (binary or ordinal) will be applied for the categorized version of IU.

1.5.4.3 Data Analysis Plan for Exploratory Aim 3

A similar multiple regression analysis strategy as outlined for Exploratory Aim 2 will be used to explore the possible moderator effect of experience with technology on the relationship between PEU and IU. The type of regression model to be used will again be determined by whether the continuous type or categorical version of IU is the most appropriate for analysis.

1.5.4.4 Data Analysis Plan for Exploratory Aim 4

A similar multiple regression analyses strategy as outlined for Exploratory Aim 2 will also be applied to explore the possible moderator effect of age and experience with technology on the relationship between facilitating conditions (clinical characteristics and health status, health control beliefs, self-care agency, and environmental factors) and the use of Pocket PATH, respectively. The regression analysis to be employed will be determined by the data version of use of Pocket PATH variable that is the most appropriate for analysis.

1.5.4.5 Data Analysis Plan for Exploratory Aim 5

Based on a proposed exploratory research model (Figure 3 and Figure 4), the use of Pocket PATH for health self-monitoring (percentage of days Pocket PATH was used) will be assessed to determine whether it is a mediator or a moderator of the relationships between socio-demographic factors and facilitating conditions with the report of recorded critical values up to 12 months post-transplantation. First, a similar 4-step simple mediation analysis approach as outlined for Exploratory Aim 1 will be used to explore the use of Pocket PATH for health self-monitoring as a potential mediator of the relationships between socio-demographic factors and facilitating conditions with the report of recorded critical values. Second, a similar multiple regression analysis strategy as outlined for Exploratory Aim 2 will be used to explore the use of Pocket PATH for health self-monitoring as a possible moderator of relationships between socio-demographic factors and facilitating conditions with the report of recorded critical values up to 12 months post-transplantation.

1.6 POTENTIAL LIMITATIONS & ALTERNATIVE APPROACHES

As a secondary analysis, this proposed study used existing data that were collected for answering different research questions. Therefore, the proposed study lacks control over data quality and the completeness of data. According to the UTAUT (Venkatesh et al., 2003), social influence, defined as the degree to which an individual perceives that important others believe he or she should use the new system, is a determinant of technology acceptance. However, this variable was not measured in the parent study. Also, voluntariness of use as a potential moderator for the relationship between social influence and IU will not be able to be assessed due to lack of available data. Therefore, the conceptual model for the proposed study will only partially test the UTAUT. This strategy is acceptable because social influence was not included in the original Technology Acceptance Model (TAM) (Davis et al., 1989), which is one of the important sources used to develop the UTAUT. In addition, many previous studies did not test the effect of social influence on intention to use mobile health technology services (Hung & Jen, 2012; Jen, 2010; Wu, Wang, & Lin, 2007). When applying the UTAUT specifically for the use of health information technology, it is possible to adjust the model to fit the context of research (Griebel et al., 2013).

Another potential limitation in the proposed study is the amount of missing data. Technology acceptance measures (IU, PU, and PEU) were added to the battery of instruments in the Pocket PATH group after the study had been underway for a period of time and were only measured at baseline. Therefore, about one third of the Pocket PATH participants (*n*=33) did not complete the technology acceptance measures. After checking the pattern of missing data, multiple imputation may be able to be performed to fill in those missing data based on those correlated variables in the dataset and appropriate imputation models. Potentially, the study results could be influenced by the proposed procedures to address these missing data.

In addition, a few predictor variables were only measured at baseline, such as health control beliefs and quality of recipient-caregiver relationship. In fact, health beliefs and relationships with family caregivers may change over time in LTR. When modeling the use of Pocket PATH in a later time interval in the 12-month period, the impact of health control beliefs and quality of recipient-caregiver relationship during that time interval on the use of Pocket PATH in the same time interval will not be able to be explored. However, the baseline measures of these variables will still be included in the models to examine their effects at baseline on use of the Pocket PATH in each time interval.

Finally, considering the number of potential predictors (12-16) that will be included in the regression models, the sample size for this proposed study is relatively small (*n*=96). If multiple imputation is not able to be performed to impute the missed measures of technology acceptance, the sample size would drop to 66. Therefore, the level of statistical significance will be evaluated and reported with caution. Adjustment of the testwise level of significance may be considered. The effect size with confidence interval will also be calculated to reflect the strength of the relationships and the precision. Moreover, the proposed exploratory models used to assess predictors for the report of recorded critical values will be refined after the initial univariate (single predictor) analysis, and the number of predictors in the final models may be decreased by the careful screening of the univariate findings to identify candidate predictors for the multivariate analysis.

1.7 TIMELINE

- Overview will be planned for September 12, 2014
- Data analysis for Aims 1 and 2 will be completed by the end of November, 2014
- The draft of a manuscript-format report of Aims 1 and 2 will be prepared by the end of December, 2014
- Data analysis for Aims 3 and 4 will be completed by the end of January, 2015
- The draft of a manuscript-format report of Aims 3 and 4 will be prepared by the end of February, 2015
- Dissertation documents will be submitted to the committee members in March, 2015
- Dissertation defense will be planned for May, 2015.

Adjustments will be made to the timeline as needed in the event of unforeseen data management and analysis issues or other circumstances.

1.8 RESEARCH PARTICIPANT RISK AND PROTECTION

A protocol application was submitted to the University of Pittsburgh Institutional Review Board (IRB) for exempt review of the proposed study (Appendix C). The IRB approval for the parent study has been renewed. See Appendix D for a copy of the parent study IRB approval letter.

1.8.1 Involvement of Human Participants

The proposed study will include 96 subjects 18 years of age or older who had lung transplantation surgery, were able to read and write English, were stable enough to be transferred from Cardiothoracic ICU to the acute cardiothoracic unit, where they were recruited before they were discharged from the hospital, and were randomly assigned to the technology intervention group and received the Pocket PATH for health self-monitoring. Subjects were excluded from the study if they had received any prior transplant, had a condition that precluded discharge from the hospital, and were anticipated to have limited involvement in post-transplant care. Children under the age of 18 years were not included because they have dissimilar underlying conditions and response patterns as a result of their developmental stage and dependency on adult guardians. There was also no involvement of other vulnerable participants such as fetuses, pregnant women, or institutionalized individuals in this study.

1.8.2 Sources of Data

Annette DeVito Dabbs, PhD, RN, FAAN, principal investigator of the parent study (the clinical trial # NCT0081825), granted permission for Yun Jiang, MS, BSN, RN and PhD student at the

University of Pittsburgh School of Nursing to have access to the dataset to conduct the proposed study. The data are all de-identified.

1.8.3 Recruitment and Retention

The proposed study is a secondary analysis of de-identified existing data. No participant screening, recruitment, or follow-up will occur in the proposed study.

1.8.4 Potential Risks

There is minimal risk to the participants. The data are already de-identified. The likelihood of occurrence and seriousness of risk is null.

1.8.5 Procedures to Minimize Potential Risks

No protected health information from participants will be accessed for this proposed study or placed into the medical record. No strategies to prevent breach of confidentiality are needed.

1.8.6 Cost-to-Benefit

As a secondary analysis of de-identified existing data, the proposed study will not provide any compensation for subjects for participation. Subjects will not receive a direct benefit from this proposed study. The knowledge gained may help identify those factors that predict use of mobile technology for health self-monitoring, and factors associated with the report of recorded critical values, which in term may help researchers develop programs to improve performance of health self-monitoring and health outcomes.

1.8.7 Vertebrate Animals (not applicable)

2.0 MANUSCRIPT #1: CORRELATES OF ACCEPTANCE AND USE OF MOBILE TECHNOLOGY FOR HEALTH SELF-MONITORING IN LUNG TRANSPLANT RECIPIENTS DURING THE FIRST YEAR POST-TRANSPLANTATION

2.1 ABSTRACT

Objective. To describe acceptance and use of a smartphone application, Pocket PATH®, by lung transplant recipients (LTR) for health self-monitoring during the first 12 months post-transplantation, and explore independent correlates of acceptance and use of Pocket PATH for different time intervals over 12 months.

Materials and Methods. Secondary analysis of data from 96 LTR who were randomly assigned to use Pocket PATH for daily health self-monitoring in a randomized controlled trial. Intention to use Pocket PATH was measured at baseline. Use of Pocket PATH (percentage of days used) in 0 to 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months post-transplant was categorized as Low, Moderate, and High levels. Ordinal logistic regression was employed to explore predictors related to use of technology in each time interval, based on a conceptual model adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT).

Results. LTR reported high intention to use Pocket PATH for health self-monitoring. However, IU did not predict actual use (p=0.67). Use of Pocket PATH for health self-monitoring decreased across three time intervals in 12 months. Self-care agency significantly interacted with both gender (p=0.04) and satisfaction with technology training (p=0.02) in the first 2 months; higher use in > 2 to ≤ 6 months was predicted by high satisfaction with technology training (OR=3.00, p=0.03), and age significantly interacted with psychological distress (p=0.04); use after the first 6 months was significantly predicted by psychological distress (OR=0.42, p=0.04) and physical component summary (OR=1.07, p=0.04); and use in 0 to 12 months was predicted by age (OR=1.05, p=0.03), satisfaction with technology training (OR=2.78, p=0.05) and physical component summary (OR=1.09, p=0.03).

Conclusion. Use of mobile technology for health self-monitoring was predicted by different factors, including age, gender, self-care agency, satisfaction with technology training, psychological distress, and physical health function in different time interval during the first year post-transplantation. It is important to monitor LTR with poor health status to improve use of technology for health self-monitoring. In addition, follow-up education can be conducted by nurses to reinforce long-term use of technology for health self-monitoring.

KEYWORDS: Mobile technology, Health self-monitoring, Lung transplantation, Health status, Technology training

2.2 BACKGROUND AND SIGNIFICANCE

Lung transplantation is accepted as a standard treatment procedure for persons with end-stage lung diseases to improve their survival and quality of life (Hartert et al., 2014; Singer & Singer, 2013; Yusen, 2011). More than 42,000 adult recipients underwent lung transplantation worldwide before 2012 and the increase of lung transplant is estimated at 30% in the past 5 years (Hartert et al., 2014; Yusen et al., 2013). However, lung transplant recipients (LTR) have lower

1- and 5-year survival compared to other solid organ transplant recipients (National Health Service., 2013; Yusen et al., 2013), which may be due to their high risks for infection and rejection, especially during the first year post-transplantation (Burguete, Maselli, Fernandez, & Levine, 2013; Martinu, Howell, & Palmer, 2010; Yusen et al., 2013). Therefore, LTR are highly encouraged to perform daily health self-monitoring at home in order to detect early signs of complications (Kotsimbos, Williams, & Anderson, 2012), which is important for conducting effective interventions with a potential to increase survival rate (Yoon, Guo, Hertz, & Finkelstein, 2008).

Use of electronic spirometry systems for LTR to self-monitor pulmonary function, vital signs, and respiratory symptoms (Finkelstein et al., 1996; Karl, Finkelstein, & Robiner, 2006; Morlion, Knoop, Paiva, & Estenne, 2002; Sengpiel et al., 2010; Wagner et al., 1999) has been reported in the literature and shown to be valid and reliable for early detection of complications (Finkelstein et al., 1996; Kugler et al., 2009; Morlion et al., 2002; Wagner et al., 1999), and therefore, have the potential to reduce the overall cost of post-transplant medical care (Adam, Finkelstein, Parente, & Hertz, 2007). However, most of these systems do not involve patients for data interpretation. LTRs' use of these systems tends to decrease over time (Adam et al., 2007; Finkelstein et al., 1996; Karl et al., 2006; Kugler et al., 2010; Morlion et al., 2002). Recently, mobile technology has been increasingly adopted in the health care field and shown to be convenient for patient health self-monitoring (Bender, Yue, To, Deacken, & Jadad, 2013; Carter, Burley, Nykjaer, & Cade, 2013; Free et al., 2010; Wac, 2012). Pocket Personal Assistant for Tracking Health (Pocket PATH®) is a smartphone application developed with customized data recording, trending, and decision-support programs for LTR to perform health self-monitoring. Preliminary findings in a pilot trial revealed that Pocket PATH promoted early self-care agency, self-care behaviors, and health-related quality of life (DeVito Dabbs, Dew et al., 2009). A full scale trial of Pocket PATH compared to usual care found that Pocket PATH was superior in promoting self-management (DeVito Dabbs et al., 2014). LTR tended to accept and use Pocket PATH for their health self-monitoring during the first year post-transplant. However, it is unclear what factors will affect their acceptance and use of this technology.

Previous barriers to performance of home self-monitoring by LTR were reported as forgetfulness, lack of time, and poor health status (Kugler et al., 2010; Sabati, Snyder, Edin-Stibbe, Lindgren, & Finkelstein, 2001). In addition, health beliefs and perceived support from clinicians influenced their performance (Dew et al., 2008; Teichman, Burker, Weiner, & Egan, 2000). Few studies have applied technology acceptance theories to examine the relationship between acceptance of technology systems and actual use of technology for health self-monitoring by LTR or predictors of acceptance and use (Karl et al., 2006; Sengpiel et al., 2010). Although it is known that patient's use behavior can change over time, no study has explored whether there are different factors that predict short- and long-term use of technology by LTR for health self-monitoring. This information is important for clinicians to identify subgroups of LTR who may be at high risk for lower use of technology for health self-monitoring, and develop tailored interventions to assist them to engage in health self-monitoring.

2.3 OBJECTIVES AND THEORETICAL BACKGROUND

This study used existing data from a parent RCT "*Phase III Trial of Pocket PATH: A Computerized Intervention to Promote Self-Care*" (NIH, NINR, R01 NR010711, PI: Annette DeVito Dabbs) with aims to test the efficacy of Pocket PATH technology intervention versus usual care for promoting self-care agency, self-care behavior, and transplant-related health following lung transplantation. Using Pocket PATH as an exemplar of mobile technology, the purposes of this study were to (1) describe acceptance and use of mobile technology for health self-monitoring during the first 12 months after lung transplantation and (2) explore possible correlates of use of mobile technology in the time intervals of 0 to 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months post-transplant.

A conceptual model (Figure 2) adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT) guided this study (Venkatesh, Morris, Davis, & Davis, 2003). The UTAUT was developed by integrating the constructs common to previous theories (Venkatesh et al., 2003). As a behavioral model, it aims to explain the behavior of people using information technology systems and has been validated with large real world data (Attuquayefio & Addo, 2014; Venkatesh et al., 2003), including customers' acceptance and use of mobile health self-monitoring systems (Lee & Rho, 2013; Or et al., 2011; Tseng, Hsu, & Chuang, 2013). The modified UTAUT used in this study posits that use of technology systems is predicted by behavioral intention (intention to use) and facilitating conditions; while behavioral intention is directly influenced by performance expectancy (perceived usefulness) and effort expectancy (perceived ease of use); age, gender, and experience with technology are purported to moderate the relationships between predictors and use of technology for health self-monitoring.

Facilitating conditions were based on the concepts of perceived internal and external control in Theory of Planned Behavior (Ajzen, 1991; Kraft, Rise, Sutton, & Roysamb, 2005), which refers to the extent to which individuals have the internal ability and external resources to perform a behavior (Pavlou & Fygenson, 2006). Therefore, facilitating conditions can be generally described as the potential conditions that facilitate performance of the behaviors (Sun, Wang, Guo, & Peng, 2013). Facilitating conditions such as health control beliefs, self-efficacy, satisfaction with technology training, and other environment factors have been examined as potential promoters of technology use (Or & Karsh, 2009; Rahimpour, Lovell, Celler, & McCormick, 2008; Sun et al., 2013). Literature supports that patients' clinical characteristics and health status (physical and psychological health) can potentially affect their performance of self-care and acceptance of technology (Goetzmann et al., 2007; Mann, Marchant, Tomita, Fraas, & Stanton, 2001; Or & Karsh, 2009; Peek et al., 2014). Therefore, in this study, facilitating conditions were operationalized as (1) clinical characteristics and health status (length of hospital stay, re-hospitalization, hospital discharge destination, psychological distress, and HRQoL physical component summary), (2) health control beliefs, (3) self-care agency, and (4) environmental factors (quality of recipient-caregiver relationship and satisfaction with technology training).

Perceived usefulness (PU) and perceived ease of use (PEU) have been consistently reported as two significant predictors of intention to use consumer health information technology (Jian et al., 2012; Jimison et al., 2008; Or & Karsh, 2009; Or et al., 2011). However, inconsistent results were found regarding individuals' perception of use of mobile health technology for their own use (Hung & Jen, 2012; Kirwan, Duncan, Vandelanotte, & Mummery, 2012; Lee & Rho, 2013; Lin & Yang, 2009). A limited number of studies have examined their relationships with the actual use of mobile technology (Kirwan et al., 2012). Therefore, consistent with the modified UTAUT, this study explored the mediation effects of intention to use (IU) on relationships of PU and PEU with actual use of mobile technology, and the moderation effects of age, gender, and experience with technology on relationships between PU or PEU and IU, or between facilitating conditions and use of mobile technology in each time interval.

2.4 METHODS

2.4.1 Study Design and Sample

A cross-sectional correlational design was used with existing data from 96 subjects in the Pocket PATH intervention group of a randomized controlled trial. All subjects were recruited from the acute cardiothoracic unit of the University of Pittsburgh Medical Center from December 2008 to December 2012. LTR were included if they were at least 18 years of age, stable enough to be transferred to the acute cardiothoracic unit, and able to read and speak English. LTR were excluded if they had a prior transplant, were not able to be discharged from the hospital, or were likely to have limited involvement in their own post-transplant care. Since two participants died before receiving the Pocket PATH training, and one participant refused to be in the intervention group, data from 96 participants in the Pocket PATH group were included in this secondary analysis.

2.4.2 Procedures

All subjects in the parent study received pre-discharge education, including instructions for using a microspirometer daily to monitor their breathing and recording daily pulse, blood pressure, temperature, spirometry, weight, and symptoms. Patients randomized to the Pocket PATH group received additional training about using the device for health self-monitoring by one of two trained nurse interventionists before discharge. LTR were informed that self-monitoring data would be automatically transmitted to the research site every night. Data recorded on the device can be viewed in either logged or graphical format for any selected date ranges. In addition, the application is programmed to generate automatic feedback messages when critical values of health indicators are entered into the device, reminding LTR to take action, including reporting the critical values to transplant clinicians (DeVito Dabbs, Song, et al., 2013; Kovach, Aubrecht, Dew, Myers, & Dabbs,, 2011).

2.4.3 Measures

Measures were assessed at five time points: baseline (prior to discharge and at 1 week), 2 months, 6 months, and 12 months post-discharge. All blinded data collectors received specific data collection training and had a series of three practice data collection sessions that were video-recorded and randomly selected for review by the project director to ensure competence and adherence to protocols.

Use of Pocket PATH for health self-monitoring. Use of Pocket PATH during each time interval (0 to 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months post-transplant) was calculated by the number of days using Pocket PATH in the time interval divided by the number of participation days in the same time interval (re-hospitalization days were excluded). The variable was coded as missing if the individual did not start to use Pocket PATH or did not use Pocket PATH due to re-hospitalization. If the person missed using Pocket PATH in any two intervals through 0 to 12 months, the total use in 12 months was coded as missing. Since the data were highly skewed and could not be normalized by data transformation, use of Pocket PATH for health self-monitoring was categorized using 25% and 75% as the cutoff points, based on the literature reports that (1) when LTR had about 25% adherence to the electronic spirometry system, the net medical savings covered the cost of home monitoring (Adam et al., 2007); and (2) LTR with high adherence rate (> 75%) to an electronic home-monitoring program had a tendency toward better survival (Yoon et al., 2008). Therefore, in this study, use of Pocket PATH was divided into three groups: Low Use (0% ≤ percentage of days used ≤ 25%), Moderate Use (25% < percentage of days used ≤ 75%), and High Use (75% < percentage of days used ≤ 100%).

Intention to Use (IU), Perceived Usefulness (PU), and Perceived Ease of Use (PEU). Three variables were measured by the Technology Acceptance Subscales, which were based on the instruments used in previous studies that assessed people's acceptance of computer technology systems and modified for the Pocket PATH technology. Internal consistency reliability of the original scales was reported with a Cronbach's alpha of 0.96 for IU, 0.90 for PU, and 0.92 for PEU (Venkatesh et al., 2003). Scores for PU (4 items) and PEU (4 items) range from 4 to 28, with each item response ranging from 1=very unlikely to 7=very likely; and scores for IU (1 item) range from 1=strongly disagree to 7=strongly agree, after reversely coding. Higher scores indicate higher perception and higher intention. Since data were highly skewed, PU and PEU were dichotomized as Low perception (≤24, rating each of 4 items less than or equal 6) vs. High perception (>24, rating each of 4 items greater than 6). IU was dichotomized as Low intention (<7) vs. High intention (=7).

Clinical characteristics and health status. Data for *Length of Hospital Stay (LOS)*, *Re-hospitalization,* and *Hospital Discharge Destination* were obtained from medical record review with the consensus of two abstractors. LOS was measured by days, re-hospitalization was coded as "yes" and "no" indicating whether the person was ever re-hospitalized during the indicated time interval, and discharge destination is dichotomized into two levels, "Home" vs. "Facility".

Psychological Distress was assessed by the Anxiety and Depression subscales of the Symptom Checklist 90-Revised (Derogatis, 1994). The test-retest reliability for the checklist ranged from 0.80 to 0.90 (Derogatis, 1994), and Cronbach's alpha for the two subscales ranged from 0.80 to 0.88 in LTR (DeVito Dabbs, Hoffman, Swigart et al., 2004). The severity of anxiety and depression was measured at baseline, and 2, 6, and 12 months post-transplant. Since the two subscales were highly correlated (r=0.684 to 0.740, p<0.001), a new variable, *Psychological Distress,* was computed by summing the mean anxiety and depression scores for each time interval. Scores range from 0 to 8 with higher scores indicating more distress. The combined subscales of anxiety and depression as a measure of psychological distress have been used by others (Coyne, Benazon, Gaba, Calzone, & Weber, 2000).

Physical Component Summary (PCS), one of the summary measures of health-related quality of life from the Medical Outcomes Study Short Form (SF-36) v2 (McHorney & Ware, 1995), was calculated using transformed T-scores ranging from 0 to 100, with higher scores indicating better physical health in the previous four weeks. Cronbach's alpha for PCS on LTR was 0.83 (DeVito Dabbs, Dew et al., 2009). PCS was measured at 2, 6, and 12 months post-transplant. Three mean PCS scores were calculated for each time interval: > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 2 to 12 months.

Health control beliefs. Health control beliefs were measured at baseline by the Multidimensional Health Locus of Control scale, including two subscales assessing the extent to which persons believe that their health outcomes are primarily their own responsibility (*Internality*) or depend on following their health professionals' recommendations (*Externality*). The Cronbach's alpha for the two subscales was reported from 0.67 to 0.77 (Wallston & Wallston, 1978; Wallston, Wallston, & DeVellis, 1978). Similar internal consistency reliability for internality (α=0.78) and externality (α=0.67) were found in the LTR (DeVito Dabbs, Kim, Hamdan-Mansour, Thibodeau, & McCurry, 2006). Subscale scores range from 6 to 36 with higher subscale scores indicates higher beliefs.

Self-care agency. *Self-Care Agency* was assessed at baseline and 2, 6, and 12 months after transplantation using the Perception of Self-Care Agency scale (Gast et al., 1989), with higher scores indicating higher perception of ability to engage in self-care activities (ranging from 53 to 265). The Cronbach's alpha was 0.93, and 1-week test-retest reliability was 0.85 (Hanson & Bickel, 1985). In LTR, the Cronbach's alpha was 0.95 (DeVito Dabbs, Terhorst et al., 2013). Mean self-care agency scores were calculated for each time interval.

Environmental factors. *Quality of Recipient-Caregiver Relationship* was assessed at baseline using an adaptation of the Dyadic Adjustment Scale (Spanier, 1976), which measures the quality of the relationship between the person and their primary caregivers. Previous studies of LTR reported Cronbach's alpha of 0.86 (DeVito Dabbs, Terhorst, et al., 2013) and 0.94 (DeVito Dabbs, Dew et al., 2009). This study used the sum score of the first 15 items for analysis, because these items apply to any type of recipient-caregiver relationship. Scores range from 15 to 75 with higher scores indicating higher relationship quality.

Satisfaction with Technology Training. Satisfaction with training was assessed by the After-Scenario Questionnaire (ASQ) (Lewis, 1995), a 3-item, 7-point Likert scale, with Cronbach's alpha ranging from 0.90 to 0.96. Scores range from 1 to 7 with higher scores representing greater satisfaction. Since the data were highly skewed, the variable was dichotomized by the median as Low satisfaction (<7) vs. High satisfaction (=7).

Socio-demographic factors. Socio-demographic factors were assessed at baseline and included age, gender, race, marital status, education, employment, and income. The questionnaire also assessed previous experience in using a cell phone, Personal Digital Assistant

(PDA), other hand-held device (e.g., MP3, Digital Camera, etc.), and computer. A new variable, *Experience with Technology*, was generated to represent general prior experience with technology by summing scores of frequency of use of each technology.

2.4.4 Data Analysis

Statistical analyses were conducted by using SPSS (version 22.0, IBM, Inc., Chicago, IL). The amount and pattern of missing data were evaluated. Since the Technology Acceptance Subscales were administered after the trial was underway, the first 33 participants did not have the measures of IU, PU, and PEU. Missing data were assessed by the amount and pattern of missing. Since the missing was more than 5% and not missing completely at random, multiple imputation was conducted to impute the missing data. Pooled analysis results were generated from five complete imputation datasets. Mainly pooled statistical analysis results were reported except when reporting mediation and moderation effects in the results section.

Descriptive statistics were used to characterize the sample and the use of Pocket PATH for health self-monitoring for each time interval. Relationships between potential predictors and use of Pocket PATH in each time interval were examined by univariate (single predictor) and multivariate (multiple predictor) ordinal logistic regression analyses. Because model building was of interest, only predictors with $p \leq 0.25$ in univariate analyses were included in the final multivariate analysis (Bendel & Afifi, 1977; Mickey & Greenland, 1989). Interactions between predictor variables were assessed. The assumption of linearity in the logit between use of Pocket PATH in each time interval and each continuous predictor variable was assessed by the addition of an interaction term of the predictor with the natural logarithm of the predictor in the models, and the linearity in the logit assumption was determined to be satisfied. Deviation from the mean of continuous variables was introduced in the model to eliminate non-essential multicollinearity among continuous predictor variables or due to computation of interaction terms. Appropriateness of model fit and the specific assumption of identical odds between each level of use of Pocket PATH in the proportional odds model for ordinal logistic regression were assessed and satisfied. Four-step simple mediation models were used to assess mediation effects of IU (Baron & Kenny, 1986). Moderator effects of age, gender, and experience with technology were evaluated by adding the interaction term of the potential moderator with the predictor in binary logistic regression (Intention to use as the dependent variable) or ordinal logistic regression (Use of Pocket PATH as the dependent variable). The significance level was set at $p < 0.05$ for the first aim and $p < 0.10$ for the exploratory mediation and moderation aim.

2.5 RESULTS

2.5.1 Description of the Sample

The summary of demographic and clinical characteristics is shown in Table 3. LTR in this study were on average 57 years old. Most were male, white, currently married/living with a partner, unemployed, had more than a high school education, and reported that their current household income met their basic needs. They had moderate experience with technology, with average 30 days of length of hospital stay. About half were re-hospitalized at some point during the first year.

Table 3. Summary of Sample Characteristics (*n*=96)

Category	Characteristic	Mean (*SD*)	Range
Demographics	Age (years)	57 (14)	18-74
	Experience with Technology	5 (2)	1-8
		n	**%**
	Gender (male)	49	51
	Race (white)	89	93
	Marriage (married or living with a partner)	71	74
	Employment (unemployed)	81	84
	Education (> high school)	54	56
	Income (basic needs met)	85	89
Clinical Characteristics	**Characteristic**	**Mean (*SD*)**	**Range**
	LOS (days)	30 (23)	9-134
	Length of ICU stay (days)	9 (11)	1-49
		n	**%**
	Underlying disease (obstructive/COPD)	41	43
	Type of transplant (double)	78	81
	Post-op ventilator needs (< 48 hours)	66	69
	Re-intubated (No)	81	84
	Return to ICU (No)	83	87
	Discharge destination(home or local residence)	87	91
	Re-hospitalization (Yes)		
	0 to 2 months	52	54
	> 2 to ≤ 6 months	53	55
	> 6 to ≤ 12 months	46	48

Notes: LOS: Length of Stay (in hospital); ICU: Intensive Care Unit.

2.5.2 Use of Pocket PATH

Eight of the 96 LTR (8%) started using Pocket PATH at the 2- or 6-month post-discharge home visit due to their poor health status. One recipient (1%) died in the > 2 to ≤ 6 months interval and 3 died in the > 6 to ≤ 12 months interval. Three LTR missed measures of use of Pocket PATH in at least two time intervals. Therefore, the number of LTR who had data to compute use of Pocket PATH for health self-monitoring in each time interval was: 88 (0 to 2 months), 92 (> 2 to ≤ 6 months), 90 (> 6 to ≤ 12 months), and 93 (0 to 12 months).

Use of Pocket PATH daily for health self-monitoring decreased over time (Figure 5). Approximately half (48%, *n*=42) showed high use of Pocket PATH daily (>75% days used) in the first 2 months. However, this percentage decreased to 28% (*n*=26) in > 2 and ≤ 6 months and 19% (*n*=17) in > 6 and ≤ 12 months. Concurrently, the percentage of low use (≤ 25% days used) increased from 22% (*n*=19) to 34% (*n*=31) and 58% (*n*=52) in the three time intervals, respectively.

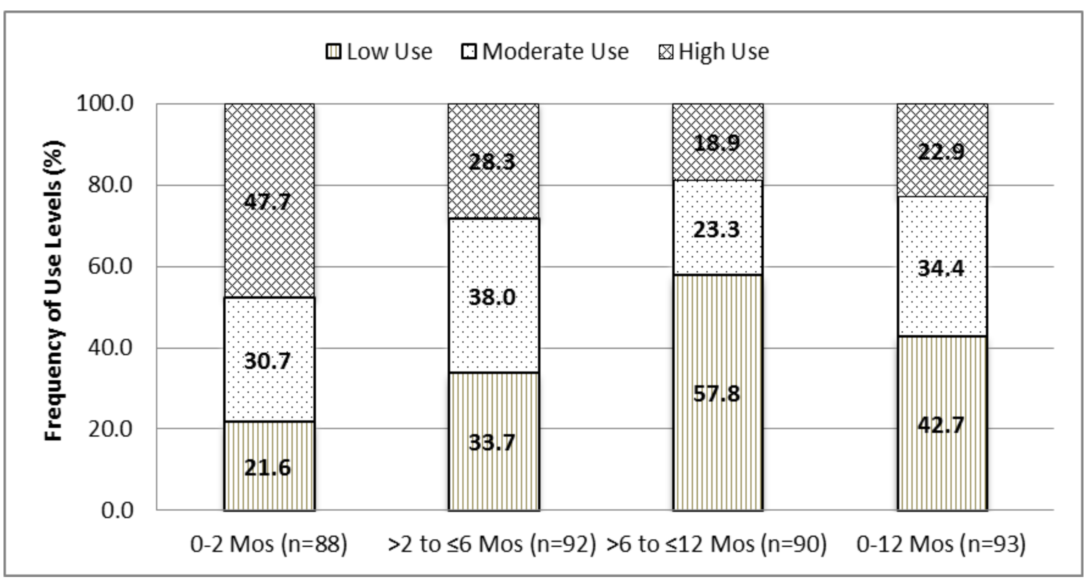


Figure 5. Use of Pocket PATH for Health Self-Monitoring during 12 Months Post-Transplantation

First 2 months. Based on univariate modeling, the final multivariate model of use of Pocket PATH for self-monitoring included the screened ($p \leq 0.25$ based on univariate analyses) predictors of age, gender, LOS, self-care agency, quality of recipient-caregiver relationship, and satisfaction with technology training. Table 4 displays the modeling results. Two significant interactions were found between self-care agency and gender (OR=0.94, 95% CI 0.88 to 0.99, p=0.04) and between self-care agency and satisfaction with technology training (OR=0.93, 95% CI 0.87 to 0.99, p=0.02), which indicated that self-care agency moderated both the effects of gender and satisfaction with technology training on use of Pocket PATH in the first 2 month. Specifically, self-care agency increased the odds of women, and men with low satisfaction to be in the higher use group.

> 2 to ≤ 6 months. The final model included seven screened predictors: age, gender, LOS, psychological distress, PCS, self-care agency, and satisfaction with technology training. Results are displayed in Table 4. A significant interaction was identified between age and mean psychological distress at > 2 to ≤ 6 months (OR=0.96, 95% CI 0.92 to 0.999, p=0.04), indicating that with an increase of psychological distress, use of Pocket PATH increased in younger LTR, but decreased in older LTR; whereas, with an increase of age, use of Pocket PATH increased in LTR with lower psychological distress, but decreased in LTR with higher psychological distress. Satisfaction with technology training (OR=3.00, 95% CI 1.13 to 7.96, p=0.03), and LOS (OR=0.98, 95% CI 0.96 to 0.998, p=0.04) significantly independently predicted use of Pocket PATH at > 2 to ≤ 6 months. No significant interactions were found to be associated with these two factors.

> 6 to ≤ 12 months. The multivariate model included 10 screened predictors (age, experience with technology, LOS, re-hospitalization, psychological distress, PCS, internality,

Table 4. Multivariate Ordinal Logistic Regression for Screened Predictors of Use of Pocket PATH

Predictor	*b*	*p*	OR	95% CI	*b*	*p*	OR	95% CI
0 to 2 Months	**Original Results (*n*=86)**				**Pooled Results# (*n*=88)**			
Gender (Male)	1.26	0.02	3.52	1.24-9.99	1.23	0.02	3.40	1.18-9.87
ASQ (High)	1.25	0.03	3.50	1.15-10.69	1.54	0.01	4.65	1.53-14.06
PSCA	0.12	0.001	1.13	1.05-1.21	0.12	0.003	1.13	1.04-1.22
Gender*PSCA	-0.05	0.11	0.95	0.90-1.01	-0.07	0.04	0.94	0.88-0.99
ASQ*PSCA	-0.09	0.01	0.92	0.86-0.98	-0.08	0.02	0.93	0.87-0.99
> 2 to ≤ 6 Months	**Original Results(*n*=89)**				**Pooled Results# (*n*=92)**			
Age (years)	0.04	0.04	1.04	1.001-1.07	0.04	0.03	1.04	1.01-1.08
ASQ (High)	1.03	0.04	2.80	1.04-7.55	1.10	0.03	3.00	1.13-7.96
LOS (days)	-0.03	0.02	0.97	0.95-0.995	-0.02	0.04	0.98	0.96-0.998
PsychoDistress	-0.49	0.13	0.62	0.33-1.15	-0.48	0.17	0.62	0.31-1.23
Age*PsychoDistress	-0.04	0.03	0.96	0.92-0.996	-0.04	0.04	0.96	0.92-0.999
> 6 to ≤ 12 Months	**Original Results (*n*=81)**				**Pooled Results# (*n*=90)**			
PsychoDistress	-0.54	0.16	0.59	0.28-1.24	-0.87	0.04	0.42	0.18-0.96
PCS	0.09	0.02	1.09	1.02-1.17	0.07	0.04	1.07	1.01-1.15
0 to 12 Months	**Original Results (*n*=78)**				**Pooled Results# (*n*=93)**			
Age (years)	0.05	0.01	1.05	1.01-1.09	0.04	0.03	1.05	1.01-1.09
ASQ (High)	0.89	0.11	2.44	0.82-7.24	1.02	0.05	2.78	1.01-7.66
PCS	0.07	0.07	1.07	0.995-1.15	0.09	0.03	1.09	1.01-1.19

Notes. ASQ: Satisfaction with Technology Training; CI: Confidence Interval; LOS: Length of Hospital Stay; OR: Odds Ratio; PCS: Physical Component Summary; PSCA: Self-Care Agency; PsychoDistress: Psychological Distress.

#: Pooled results from multiple imputation.

externality, self-care agency, and satisfaction with technology training). Modeling results are displayed in Table 4. Psychological distress (OR=0.42, CI 0.18 to 0.96, p=0.04) and PCS (OR=1.07, 95% CI 1.01 to 1.15, p=0.04) were found to be significant independent predictors of Pocket PATH use at > 6 to ≤ 12 months. No interaction was identified.

0 to 12 months. Eight screened predictors (age, LOS, re-hospitalization, psychological distress, PCS, internality, self-care agency, and satisfaction with technology training) were included in the 0 to 12-month multivariate model. Modeling results are displayed in Table 4. Age (OR=1.05, 95% CI 1.01 to 1.09, p=0.03), satisfaction with technology training (OR=2.78, 95% CI 1.01 to 7.66, p=0.05), and PCS (OR=1.09, 95% CI 1.01 to 1.19, p=0.03) were found to be significant predictors of Pocket PATH use in the total 12 months. No interaction was identified.

2.5.3 Mediation and Moderation Effects

Intention to Use (IU). In the original dataset, 56 out of 66 participants (85%) rated IU as 7 (strongly agree with intention to use). Also, participants reported high ratings for PU (n=53, 80% with rating >24) and PEU (n=54, 82% with rating >24). None of three factors, IU, PU, and PEU demonstrated a significant relationship with the use of Pocket PATH for health self-monitoring during any time interval (p=0.45~0.96). Based on simple mediation analyses, no mediation effect was found for IU on the relationship between PU and use of Pocket PATH, or between PEU and use of Pocket PATH at any time interval in either the original or pooled analysis results (p>0.10).

Age. Age was not found to be a moderator of the relationship between PU and IU, or between PEU and IU (p>0.10). However, age showed a trend to moderate the relationship between psychological distress and use of technology at > 2 to ≤ 6 months (p=0.08), and the relationships between quality of recipient-caregiver relationship and use of technology at both > 6 to ≤ 12 months (p=0.08) and 0 to 12 months (p=0.07).

Gender. Gender was not found to have any moderation effect on relationships between PU and IU, and between PEU and IU (p>0.10).

Experience with technology. Experience with technology did not moderate the relationship between PEU and IU (p>0.10), but it showed a trend to moderate the relationship between re-hospitalization and use of technology at > 6 to ≤ 12 months (p=0.08) as well as the relationship between internality (p=0.05) and externality (p=0.08) on use of technology at 0 to 12 months.

2.6 DISCUSSION

This study described intention to use and actual use of mobile technology (Pocket PATH) for health self-monitoring during the first 12 months post-lung transplant, and explored predictors of use of mobile technology at the first 2 months, > 2 to ≤ 6 months, > 6 to ≤ 12 months, and 0 to 12 months. LTR reported high intention to use mobile technology before discharge from the hospital. However, intention to use at baseline did not predict actual use at any time interval. In addition, PU and PEU were not found to be associated with IU or actual use at any time interval, which is inconsistent with most literature reports (Jian et al., 2012; Jimison et al., 2008; Or & Karsh, 2009; Or et al., 2011). Previous studies mainly focused on the exploration of relationships within these three variables (Or & Karsh, 2009). Fewer studies explored their relationships with actual use of technology for health self-monitoring (Kirwan et al., 2012; Lee & Rho, 2013). Similarly, Kirwan et al (2012) reported that perceived usefulness did not predict use of a smartphone application for self-monitoring of physical activity in a small group of healthy adults (*n*=50).

Actual use of mobile technology by LTR for health self-monitoring was found to decrease across three time intervals in 12 months. This finding is consistent with the patterns of use of home electronic spirometry systems by LTR (Adam et al., 2007; Karl et al., 2006; Morlion et al., 2002; Sengpiel et al., 2010) and use of mobile health services by other population, such as overweight adults (Carter, Burley, Nykjaer, & Cade, 2013), indicating sustained use of mobile technology for health self-monitoring may be an issue. This finding also suggests that use of mobile technology for health self-monitoring is linked to behavior patterns in performing health self-monitoring. It seemed to be a good strategy to add variables related to health self-monitoring into the conceptual model as potential predictors to help understand technology use patterns in health self-monitoring. A dramatic decrease in use of mobile technology for health self-monitoring can be found after 6 months post-discharge. This decrease may be associated with improvement in post-surgical pulmonary functions and normalization from surgical restrictions after the first 6 months (Laporta Hernandez, Lazaro Carrasco, Varela de Ugarte, & Ussetti Gil, 2014). By then, it is possible for some LTR to perceive their health condition as good and become less likely to perform daily self-monitoring (Sabati et al., 2001).

Satisfaction with technology training was a strong predictor of use of technology at the first 6 months and the total 12 months. During the training session, LTR received not only information about how to use the device, but also interventionists' encouragement to be an activated partner in the use of the device for daily health self-monitoring. It was found that those who were less satisfied with training were more likely to be influenced by their perceived self-care abilities in the early months post-discharge, which reflects the importance of self-confidence in health self-monitoring when encouragement from outside is lacking. The impact of technology training appeared to be less important in the later time period (> 6 months), perhaps due to lack of continuous encouragement from outside, indicating that LTR may need persistent reinforcement for their use of technology for health self-monitoring.

The effects of clinical characteristics and health status, such as LOS, psychological distress, and PCS, on use of mobile technology for health self-monitoring were evident after the first 2 months. Although the negative effect of LOS tended to be small, it implies that poor general health status pre-discharge is associated with a decreased use of mobile technology for health self-monitoring in > 2 to ≤ 6 months. Similarly, the positive effect of PCS indicates that LTR with better physical health function have higher use of technology in > 6 to ≤ 12 months. Previous studies reported that both better and poorer health status can be associated with use of technology (Chae et al., 2000; Jeannot et al., 2004; Kugler et al., 2010; Millard & Fintak, 2002). Specifically, Sabati et al. (2001) reported that LTR who felt too sick or too well discontinued using a home electronic monitoring system, because they did not want a reminder of their deteriorating status or they saw no need to use the system for monitoring. Psychological distress was found to interact with age in > 2 to ≤ 6 months, indicating that with an increase of psychological distress, use of technology increased in younger LTR, but decreased in older LTR. Psychological distress is a common symptom in LTR. Previous studies reported that psychological distress was an important predictor of adherence to treatment and performance of self-care in LTR (Barbour, Blumenthal, & Palmer, 2006; DeVito Dabbs, Terhorst et al., 2013; Rosenberger, Dew, DiMartini, DeVito Dabbs, & Yusen, 2012). This study, for the first time, reveals that the influence of psychological distress on use of technology for health self-monitoring may differ between younger and older LTR. However, this finding may need to be further explored in future studies with a larger sample size.

Based on the conceptual model adapted from the UTAUT, the potential mediation effect of IU and moderator effects of age, gender, and experience with technology were also explored in this study. As mentioned above, no associations were found between IU, PU, or PEU and actual use of mobile technology for self-monitoring. Therefore, IU was not supported as a mediator between PU or PEU and use of mobile technology in any time interval. However, this finding needs to be interpreted with caution. As recommended by the developers of the Technology Acceptance Model (TAM), the acceptance variables were only measured at baseline since the TAM was meant to be assessed after technology training but prior to independent use of the technology (Davis et al., 1989). However, perceptions of LTR may change over time. In particular, heavy self-monitoring in this study may alter recipients' initial perceptions and intention to use. Since the TAM measures were added after the trial was underway, data were not available for the first one-third of participants. Although multiple imputations were conducted and similar results were reported between the original and pooled analysis, limitations due to small sample size and imputation of a large amount of missing data may have biased results. In addition, dichotomizing of the variables to overcome their high skewness may have caused further loss of information and inaccurate representation of the original measures. This limitation may also explain the lack of significance of the moderation effects of age, gender, and experience with technology on relationships between PU and IU, between PEU and IU, and between facilitating conditions and use of mobile technology.

However, findings from this study add to our understanding of using technology to promote self-monitoring after lung transplantation. For example, facilitating conditions related to the context of health self-monitoring, such as health status, health control beliefs, self-care agency, and environmental factors, were included in the conceptual model to help understand complex behavioral patterns in LTR, which should be considered an appropriate adaptation of the UTAUT model to fit the clinical context (Griebel, Sedlmayr, Prokosch, Criegee-Rieck, & Sedlmayr, 2013). In addition, predictors of both short- and long-term use of mobile technology in 12 months were explored, revealing variation in predictors of use of mobile technology for health self-monitoring in each time interval.

2.7 CONCLUSIONS AND IMPLICATIONS

This study indicates that using mobile technology for health self-monitoring after lung transplantation is a complex behavior. Use of mobile technology for health self-monitoring tends to decrease across time intervals in 12 months post-lung transplant, suggesting that providing encouragement and support overtime may help sustain health self-monitoring. Feasible communication features and advanced technical designs built in the mobile technology systems should be able to satisfy recipients' needs for receiving support and feedback from health care providers during health self-monitoring. For examples, automatic alerts can be sent to health care providers when the recipients stop using or become less frequent users of the systems for health self-monitoring; health care providers can conduct assessment and delivery educational support through text messages or video phone; and as more self-monitoring behavioral data are gathered and analyzed, recipients' future use of technology for health self-monitoring may be able to be predicted ahead of time. Additional features that are embedded or can be embedded in the mobile technology, such as social networking, online access to health information or patient forums, game playing, and virtual visits, should be fully explored and adopted to support lung transplant recipients' needs for health self-management, in order to improve their quality of life and survival.

This study has identified predictors of both short- and long-term use of mobile technology for health self-monitoring in 12 months. Higher satisfaction with technology training at baseline is a strong predictor of use early after transplant. Use in the later months may be able to be improved if LTR can receive follow-up educations and reinforcement from clinicians. As health status deteriorated, LTR were more likely to abandon self monitoring, raising the importance of increasing surveillance by the transplant team when LTR develop complications. Perceived psychological distress increased use of mobile technology in younger LTR, but decreased use in older LTR. Awareness of the differential effect of psychological distress may help nurses target age appropriate interventions to promote self-monitoring among LTR with psychological distress. Furthermore, there is a need to identify the most appropriate time to introduce mobile technology systems to LTR for health self-monitoring. Some recipients may be too ill after the transplantation to receive the technology training for health self-monitoring. Introducing technology for self-monitoring prior to transplant may increase the likelihood of incorporating self-monitoring into health habits. The list of predictors identified in this study may contribute to the development of a screening tool in the future to identify users who are the least possible to adopt mobile technology-based health self-monitoring, which may help provide the right patient with the right interventions, and facilitate optimal allocation of health care resources.

3.0 MANUSCRIPT #2: MOBILE TECHNOLOGY DECISION SUPPORT FOR HEALTH SELF-MONITORING IN LUNG TRANSPLANT RECIPIENTS DURING THE FIRST YEAR POST-TRANSPLANTATION

3.1 ABSTRACT

Background and Objective Lung transplant recipients (LTR) are encouraged to perform daily health self-monitoring to detect and report critical condition changes. However, LTR often have problems recognizing critical values and making decisions about when to contact clinicians. Pocket PATH®, a smartphone application developed for LTR health self-monitoring, provided automatic feedback to support LTR decision making for reporting critical values. The purpose of this study was to examine the degree to which LTR followed technology decision support for reporting recorded critical values in the device, and to explore predictors of reporting critical values during the first year after transplantation.

Methods Among 96 LTR randomly assigned to use the Pocket PATH for daily health self-monitoring, only 53 had critical values entered in the device and had critical feedback messages generated in 12 months. Their reporting of recorded critical values was calculated by the total number of critical feedback messages appropriately handled divided by the total number of critical feedback messages generated. A cut point of 100% reporting was used to dichotomize this variable, in order to identify the group of LTR who are less likely to follow technology decision support for reporting critical values. Binary logistic regression was used to explore predictors of reporting critical values in 12 months.

Results On average, LTR reported 90.4% recorded critical values in the device in 12 months. Over three-fifths (62.3%, $n=33$) of 53 LTR had 100% reporting, indicating fully following technology decision support. A significant interaction of gender and past technology experience indicated that with increased past technology experience, the odds of reporting all critical values decreased in men but increased in women ($p=0.03$). LTR whose income met their basic needs ($p=0.02$), or with longer hospital stay ($p<0.01$), were less likely to report all critical values. In addition, use of Pocket PATH for self-monitoring predicted reporting of critical values ($p=0.02$); the moderate use group (>25% to ≤75% of days used) was less likely to report than the high use (>75% of days used) and the low use (≤25% of days used) groups (both $p=0.02$).

Conclusion The majority of LTR responded appropriately to decision support feedback and reported critical condition changes to clinicians. Their responses to decision support were associated with gender, technology experience, income, length of hospital stay, and self-monitoring frequency. Mobile technology with decision support appears to promote reporting of critical values; however, clinicians should assess LTR who are at risk for poor reporting of critical values even when provided with mobile technology decision support.

KEYWORDS: Mobile technology, health self-monitoring, decision support, critical values, communication, lung transplantation

3.2 INTRODUCTION

Lung transplantation has been increasingly performed in persons with end-stage lung diseases (Hartert et al., 2014) and has improved their quality of life and survival (Singer & Singer, 2013; Yusen, 2011). However, survival rates of lung transplant recipients (LTR) are still lower than those of other solid organ recipients. Infection is the leading cause of death in the first year post-lung transplantation. Up to 75% of LTR are affected by infection and 55% by acute rejection in the first year (Burguete, Maselli, Fernandez, & Levine, 2013; Martinu, Howell, & Palmer, 2010). LTR who survive infection and acute rejection are at higher risk for chronic rejection (bronchiolitis obliterans syndrome, BOS), which is the leading cause of death beyond the first year (Burton et al., 2009; Valentine et al., 2009). Prompt recognition of condition changes that may be associated with complications of rejection or infection is crucial for improving recipients' survival. In addition to their regular follow-up visits to the transplant center for bronchoalveolar lavage or transbronchial lung biopsy to detect critical condition changes, LTR are highly encouraged to perform daily health self-monitoring of spirometry, vital signs, weight, and symptoms at home, and report any early signs of complications to clinicians (Kotsimbos, Williams, & Anderson, 2012).

However, LTR often have problems recognizing critical values and making decisions about when to contact clinicians (DeVito Dabbs, Myers et al., 2009). Although all LTR receive discharge instructions for detecting and reporting critical values during home self-monitoring, it can be challenging for them to remember the thresholds of critical values of multiple health indicators, and to recognize critical changes from their own personal baselines (DeVito Dabbs, Myers et al., 2009). With the amount of self-monitoring data generated by all LTR, it is time-consuming for clinicians to track and screen critical values for each LTR (Wang, Finkelstein, &

Hertz, 2013). At the same time, LTR are encouraged to be engaged in self-care and expected to be able to self-monitor daily condition changes. Therefore, LTR are in need of decision support for detecting and reporting critical values when performing daily health self-monitoring.

Electronic spirometry systems have been reported to be reliable and valid for LTR health self-monitoring (Jaana, Pare, & Sicotte, 2009; Kugler et al., 2009; Wang et al., 2013). However, most electronic spirometry systems were designed to send self-monitoring data to clinicians for interpretation, and did not provide decision support for LTR (Ewert, Wensel, Muller, & Hetzer, 2000; Finkelstein & Ratner, 2006; Karl, Finkelstein, & Robiner, 2006; Morlion, Knoop, Paiva, & Estenne, 2002; Wagner et al., 1999). Few systems can provide reminders or alerts for LTR to take action, such as reassessing their first FEV_1 when the value was below 100% of the reference value (Morlion et al., 2002), or contacting the transplant center when newly entered symptom data matched with the predefined alarm symptoms (such as fever, sputum discoloration, dyspnea, nausea, emesis, etc.) (Sengpiel et al., 2010). Kugler et al. (2010) described one electronic spirometry system that could provide specific traffic light colors to instruct patients on how to interpret and respond to the actual FEV_1 value, including when to contact the clinician.

Pocket Personal Assistant for Tracking Health (Pocket PATH®) is a smartphone application, developed by a multidisciplinary research team from the University of Pittsburgh and Carnegie Mellon University to assist LTR to perform health self-monitoring. It supports both log and graphical displays of monitoring data over time and automatically generates feedback messages when critical values of health indicator are entered into the device, providing specific decision support for LTR about when and what to report to their transplant coordinators (DeVito Dabbs, Song et al., 2013). Patients may not always comply with clinical or self-management recommendations. Non-adherence to medical regimen in transplant recipients has been widely reported (Burra et al., 2011; De Geest, Dobbels, Fluri, Paris, & Troosters, 2005; Kung, Koschwanez, Painter, Honeyman, & Broadbent, 2012; Morrissey, Flynn, & Lin, 2007; Wray, Waters, Radley-Smith, & Sensky, 2006).

It is unknown whether transplant recipients would follow self-monitoring recommendations made by mobile technology, especially when reporting critical values is the concern. It is important to identify the factors that may affect the degree to which LTR follow technology-generated decision support for reporting critical values, which can help develop effective solutions to improve the quality of health self-monitoring and improve early identification of complications. Although a previous study of transplant recipients reported that demographics, social support, and perceived health were not associated with non-adherence to medical regimen (Dew et al., 2007), no studies have explored whether such factors predict responses by LTR to decision support for reporting critical values. It is very possible that the more frequent use of mobile technology for self-monitoring, the more critical values can be detected by the technology. Therefore, frequency of use of mobile technology should be considered when assessing the factors associated with the reporting of critical values.

No previous conceptual framework has been specifically utilized to identify factors associated with appropriate response to technology decision support for reporting critical condition changes during patient health self-monitoring. Based on a widely used technology acceptance model, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003), and the literature (DiMatteo, 2004; Sherbourne, Hays, Ordway, DiMatteo, & Kravitz, 1992), two exploratory models (Figure 3 and Figure 4), were adapted in this study that posit that socio-demographic factors and context-related facilitating conditions, such as clinical characteristics and health status, health control beliefs, self-care agency, and environmental factors (quality of recipient-caregiver relationship and satisfaction with technology use), may affect LTRs' response to technology decision support for reporting recorded critical values in the device. In addition, the frequency of use of mobile technology for health self-monitoring may have direct or indirect influence on reporting of critical values. These two exploratory models propose that use of mobile technology is a potential moderator and a mediator of relationships between those predictors and reporting of recorded critical values, respectively.

Using the Pocket PATH as an exemplar of mobile technology, the purposes of this study were to examine the degree to which LTR acted upon mobile technology decision support feedback by reporting recorded critical values during health self-monitoring, to explore predictors of reporting critical values during the first 12 months post-transplantation, and to assess whether the frequency of use of Pocket PATH was a potential mediator or moderator of relationships between predictors and reporting of critical values.

3.3 MATERIALS AND METHODS

3.3.1 Study Design and Sample

This study was a cross-sectional correlational design where existing data were analyzed from the mobile technology intervention group of a randomized controlled trial that tested the efficacy of use of Pocket PATH for health self-monitoring versus usual care for promoting self-care agency, self-care behaviors, and transplant-related health during 12 months post-lung transplantation. Participants (N=99) were randomly assigned to the intervention group; however, 2 participants died and 1 participant refused before the intervention started. Therefore, data from 96 participants in the intervention group were ultimately analyzed. All participants were recruited from December 2008 to December 2012 at the acute cardiothoracic unit of the University of Pittsburgh Medical Center. They were at least 18 years old, with no prior organ transplant, stable enough to be discharged from the hospital, likely to be involved in their own post-transplant care, and able to read and speak English.

3.3.2 Procedure

All 96 participants received a 30-45 minute technology training session before discharge from the hospital. They were instructed to enter the spirometry, vital signs, weight, and symptoms into the daily checklist of Pocket PATH. The application was programmed to generate automatic feedback messages when the following critical values were recorded: a temperature >101° Fahrenheit (or 38.3° Celsius), a blood pressure of systolic >160 or <88 or diastolic >100 mmHg, and a pulse <60 or >120 beats/min (Kovach, Aubrecht, Dew, Myers, & Dabbs, 2011). These feedback messages provided instructions for LTR to take action, such as to report the critical values to the transplant coordinator. Response to Pocket PATH's decision support features was considered acceptable when LTR appropriately acted upon these critical feedback messages. A data monitoring algorithm was used to code appropriateness of handling critical feedback messages (Appendix B). If data fit with three codes in the algorithm: (1) critical value returned to acceptable level; (2) participant reported critical value; or (3) clinician was already aware of critical value, LTR were considered as "yes" for appropriately handling critical feedback messages. To be consistent with the parent study, in this study recipients' appropriateness of handling critical feedback messages indicated that they followed technology decision support for reporting critical values. Project staff assessed data for critical feedback messages every 72 hours and retrieved values recorded in the device. The information about whether the participant reported a critical value or the clinician already was aware of a critical value was obtained from the transplant coordinators' progress notes.

3.3.3 Measures

Reporting of recorded critical values. This variable referred to the total number of reports of critical values to the clinicians out of the total number of recorded critical values in Pocket PATH. It was calculated by the number of feedback messages appropriately handled divided by the total number of feedback messages generated by the device, and multiplied by 100. Since only 53 participants had at least one critical value recorded during 12-month self-monitoring, analysis of this variable focused on the subgroup of 53 LTR. Because the data were highly skewed and could not be normalized through variable transformation, the variable was dichotomized by whether or not 100% reporting of all recorded critical values by the device occurred. The proportion of 100% reporting of all recorded critical values was of interest since it represents optimum response to technology decision support.

Socio-demographic factors. Socio-demographic factors were measured at baseline (before discharge), including *Age* (years), *Gender* (male vs. female), *Marital Status* (currently married vs. not-married), *Education* (≤ high school vs. > high school), *Employment* (employed vs. unemployed), and *Income* (current household income met basic needs vs. unmet basic needs). All 53 participants in the study were Caucasians. The questionnaire also assessed the recipient's previous experience in using a cell phone, Personal Digital Assistant (PDA), other hand-held device (e.g., MP3, Digital Camera, etc.), and computer. A new variable, *Experience with*

Technology, was calculated by summing frequencies of use of these 4 technologies (range 0-8), with the higher score indicating more experience.

Clinical characteristics and health status. Clinical characteristics were obtained from patient medical records, including *Underlying Lung Disease* (obstructive vs. non-obstructive), *Type of Transplant* (single vs. double), *Re-intubation* (yes vs. no), *Return to ICU* (yes vs. no), *Post-operative Ventilator Needs* (<48 hours vs. ≥48 hours), *Length of ICU Stay* (days), *Length of Hospital Stay* (LOS, days), *Discharge destination* (home vs. facility), and *Re-hospitalization* (yes vs. no) in 12 months post-discharge.

Health status included physical and psychological health function post-transplantation. *Physical Component Summary* (PCS) is a summary measure of Health-Related Quality of Life (HRQoL) from the Medical Outcomes Study Short Form (SF-36) v2 (McHorney & Ware, 1995). HRQoL was measured in participants at 2 months, 6 months, and 12 months post-transplantation, reflecting recall of their health status in the previous four weeks. A mean PCS score over time was calculated and ranged from 0 to 100, with higher scores indicating better physical health function.

Psychological Distress was measured by the Anxiety and Depression subscales of the Symptom Checklist 90-Revised (SCL-90-R) at baseline, 2 months, 6 months, and 12 months (Derogatis, 1994). Cronbach's alphas for the two subscales, Anxiety and Depression, range from 0.80 to 0.88 (DeVito Dabbs, Hoffman, Swigart et al., 2004). The average scores of anxiety (10 items) and depression (13 items) were summed to generate a measure of general psychological distress, since anxiety and depression scores were highly correlated (r=0.684 to 0.740, p<0.001) in this study. A mean psychological distress score over time was calculated, with a range of 0-8; higher scores indicated more distress.

Health control beliefs. Two subscales, Internality and Externality, were measured at baseline by the Multi-dimensional Health Locus of Control scale. Cronbach's alphas were reported to range from 0.83 to 0.86 for the instrument and its subscales (Wallston & Wallston, 1978; Wallston, Wallston, & DeVellis, 1978). Internality (6 items) and Externality (6 items) assessed the extent to which LTR believe that their health outcomes are primarily their own responsibility or depend on following their health professionals' recommendations. Scores for each subscale ranged from 6 to 36, with higher scores indicating higher internal/external beliefs.

Self-care agency. The Perception of Self-Care Agency scale was used to measure participants' perceived abilities to engage in self-care at baseline, 2 months, 6 months, and 12 months post-transplantation (Gast et al., 1989). Cronbach's alpha of the scale was reported as 0.93, and 1-week test-retest reliability was 0.85 (Hanson & Bickel, 1985). A mean self-care agency score over time was calculated, ranging from 53 to 265, with higher scores indicating higher self-care agency.

Quality of recipient-caregiver relationship. This variable was measured at baseline using an adaptation of the Dyadic Adjustment Scale (Spanier, 1976). Only the sum score of the first 15 items was counted, assessing any type of recipient-caregiver relationship. Scores ranged from 15 to 75, with higher scores indicating less distress in the relationship.

Satisfaction with technology training. This variable was measured by the After-Scenario Questionnaire (ASQ). Cronbach' alpha was reported from 0.90 to 0.96 (Lewis, 1995). The average score of three items ranged from 1 to 7. Since the data were highly skewed, the variable was dichotomized by the median score of 7, indicating two levels, fully satisfied and less than fully satisfied.

Use of technology. Use of Pocket PATH for health self-monitoring in 12 months was measured by percentage of days using the device for transmitting data on any self-monitored health indicator. It was calculated as the total number of days using the device in 12 months divided by the total number of participation days, and multiplied by 100. Re-hospitalization days during 12 months were excluded from participation days. Since the data were highly skewed and could not be normalized through data transformation, use of technology was categorized into three levels: Low use (≤25% of days used), Moderate use (>25% to ≤75% of days used), and High use (>75% of days used) (Adam, Finkelstein, Parente, & Hertz, 2007; Yoon, Guo, Hertz, & Finkelstein, 2008).

3.3.4 Data Analysis

Statistical analyses were conducted by using SPSS (version 22.0, IBM, Inc., Chicago, IL). Descriptive statistics were used to describe the sample and the number of recorded critical values by the device and reported to clinicians in up to 12 months post-transplantation. Not every recipient in the study had recorded critical values in the device. Also there may be many unknown reasons for zero recording of critical values. Using Mann-Whitney U tests (continuous variables), or Chi-Square/Fisher's Exact tests (categorical variables), sample characteristics were compared between LTR who had at least one critical value recorded and those who had zero critical values recorded, in order to identify whether the two groups had any baseline differences. Similarly, sample characteristics were compared between the group that reported 100% recorded critical values and the group that reported less than 100%. Univariate logistic regression was conducted to screen for candidate predictors (the cutoff p-value ≤ 0.25) for inclusion in the final multivariate (multiple predictors) logistic regression model (Bendel & Afifi, 1977; Mickey &

Greenland, 1989), since no previous conceptual models can be used to guide the exploration of predictors of reporting of critical values in LTR. Interactions between predictor variables were assessed, and if severe multicollinearity was indicated, the deviation from the mean for continuous variables was used in the final model. The percent correct prediction of the binary logistic regression model, including sensitivity, specificity, and overall correct prediction, was evaluated based on a classification table. The potential mediation and moderation effects of use of Pocket PATH in 12 months were assessed by simple mediation models and multiple regression analysis (Baron & Kenny, 1986). The level of significance was set at $p<0.05$ for the final logistic regression modeling and $p<0.10$ for the exploration of mediation and moderation effects.

3.4 RESULTS

3.4.1 Summary of the Sample and Reporting Critical Values

Among 96 participants who used Pocket PATH for health self-monitoring, 53 (55%) had recorded at least one critical value in the device during 12 months post-transplantation. LTR did not differ in socio-demographics or baseline measures ($p\geq0.05$), except for external health control beliefs, based on whether they recorded any critical values. LTR with at least one critical value recorded had stronger beliefs that their health outcomes primarily depend on following health providers' recommendations ($p=0.028$). In addition, a significant difference in frequency of using of technology in 12 months was found between LTR with or without recorded critical values ($p<0.001$). About 78% of participants in the low use group (≤25% days used) did not have any critical values recorded, while in the high use group (>75% days used) this percentage was only 5%. About 96% of participants in the high use group had at least one critical value recorded in 12 months.

Table 5 summarizes the sample characteristics. The 53 LTR who recorded any critical values during the 12 months were on average 59 years old, with moderate experience with technology. Most were male, married, unemployed, with more than high school education, and reported that their current household income met their basic needs. This group also had an average 29 days of LOS and 8 days of ICU stay. Most had obstructive pulmonary disease before surgery, underwent double-sided lung transplantation, and needed <48 hours post-operative ventilation, had no re-intubation, and had no return to ICU. However, the majority were re-hospitalized at least once during 12 months post-discharge. Most were identified as having moderate use or high use of technology for health self-monitoring.

Table 5. Sample Characteristics: Total Sample, Subgroup of 100% Reporting, and Subgroup of Less Than 100% Reporting

Characteristic		**Total Sample (*n*=53)**	**100% Reporting (*n*=33, 62%)**	**< 100% Reporting (*n*=20, 38%)**	
		Mean (*SD*)			***p***
Age (years)		59 (12)	58 (12)	61 (10)	0.33
Experience with Technology		5 (2)	6 (2)	5 (2)	**0.17***
LOS (days)		29 (25)	24 (15)	38 (34)	**0.08***
Length of ICU stay (days)		8 (11)	6 (9)	12 (13)	**0.02****
		***n* (%)**			***p***
Gender	Male	31 (59)	16 (52)	15 (48)	**0.06***
	Female	22 (41)	5 (23)	17 (77)	
Marriage	Married	42 (79)	25 (60)	17 (40)	0.50

Table 5. Sample Characteristics: Total Sample, Subgroup of 100% Reporting, and Subgroup of Less Than 100% Reporting (continued)

	Unmarried	11 (21)	8 (73)	3 (27)	
Employment	Unemployed	46 (87)	29 (63)	17 (37)	1.00
	Employed	7 (13)	4 (57)	3 (43)	
Education	> High School	28 (53)	18 (64)	10 (36)	0.75
	≤ High School	25 (47)	15 (60)	10 (40)	
Income	Met Basic Needs	46 (87)	27 (59)	19 (41)	**0.23***
	Not Met Basic Needs	7 (13)	6 (86)	1 (14)	
Underlying Disease	Obstructive/COPD	30 (57)	18 (60)	12 (40)	0.70
	Non-obstructive	23 (43)	15 (65)	8 (35)	
Type of Transplant	Double	42 (79)	25 (60)	17 (40)	0.50
	Single	11 (21)	8 (73)	3 (27)	
Post-op Ventilator Needs	< 48 Hours	37 (70)	24 (65)	13 (35)	0.55
	≥ 48 Hours	16 (30)	9 (56)	7 (44)	
Re-intubated	No	47 (88)	30 (64)	17 (36)	0.66
	Yes	6 (12)	3 (50)	3 (50)	
Return to ICU	No	49 (93)	33 (67)	16 (33)	
	Yes	4 (7)	4 (100)	0 (0)	**0.02****
Re-hospitalized in 12 Months	Yes	43 (81)	28 (65)	15 (35)	0.48
	No	10 (19)	5 (50)	5 (50)	
Use of Technology in 12 Months	Low Use (≤25%)	9 (17)	6 (67)	3 (33)	
	Moderate Use (>25% to ≤75%)	23 (43)	12 (52)	11 (48)	0.42
	High Use (>75%)	21 (40)	15 (71)	6 (29)	

Notes: LOS: Length of Stay (in hospital); ICU: Intensive Care Unit.

*: *p*-value ≤0.25; **: *p*-value ≤0.05.

On average, 53 LTR reported about 90% (±20%) of recorded critical values by the device. As Table 5 showed, thirty-three (62%) LTR reported all recorded critical values (100%), and 20 (38%) did not report any recorded critical values or only partially reported recorded critical values (<100%). Using the *p*-value of 0.25 as the cutoff to screen for candidate predictors for multivariate analysis, LTR who reported 100% of recorded critical values were significantly different than those who reported less than 100% by gender, income, experience with technology, LOS, length of ICU stay, and return to ICU.

3.4.2 Predictors of Reporting Critical Values

Univariate logistic regression modeling (*p*-value ≤ 0.25) identified several candidate predictors for the final multivariate modeling of reporting critical values, including gender (*p*=0.06), income (*p*=0.20), experience with technology (*p*=0.17), LOS (*p*=0.07), and length of ICU stay (*p*=0.10). In addition, the group with moderate use of technology was found to be significantly different than the high use group (*p*=0.19) in reporting critical values. Since LOS and length of ICU stay were highly correlated (*r*=0.84, *p*<0.001), only LOS was included in the final model. Therefore, the final multivariate (multiple predictors) logistic regression model include 5 predictor variables, gender, income, experience with technology, LOS, and use of technology.

The final modeling results were presented in Table 6, revealed that LTR whose income met their basic needs (OR=0.01, *p*=0.02), or with longer LOS (OR=0.94, *p*<0.01), were less likely to report all recorded critical values. A significant interaction of gender and experience with technology indicated that with increased experience with technology, the odds of reporting all recorded critical values decreased in men but increased in women (*p*=0.03). In addition, use of Pocket PATH for self-monitoring predicted the reporting of recorded critical values (*p*=0.02); the moderate use group was less likely to report than the high use and the low use groups (both *p*=0.02). No interaction was found between use of Pocket PATH and any other predictors in the model.

Table 6. Multivariate Logistic Regression for Predictors of Reporting All Recorded Critical Values (*n*=53)

Predictor	*b*	SE(*b*)	*p*-value	OR	95% CI for OR	
					Lower Limit	Upper Limit
Gender (Male)	-1.65	0.91	0.07	0.19	0.03	1.14
Income (Met Basic Needs)	-4.26	1.80	0.02#	0.01	<0.01	0.48
Experience with Technology	1.26	0.64	0.05#	3.53	1.01	12.36
LOS	-0.06	0.02	<0.01##	0.94	0.90	0.98
Use of Technology (Low Use)	0.96	1.23	0.44	2.61	0.23	29.14
Use of Technology (Moderate Use)	-2.22	0.93	0.02#	0.11	0.02	0.67
Gender* Experience with Technology	-1.58	0.75	0.03#	0.21	0.05	0.89

Notes. CI; Confidence Interval; SE: Standard Error; LOS: Length of Stay (in hospital); OR: Odds Ratio.

#: *p*-value ≤0.05; ##: *p*-value ≤0.01.

According to the classification table generated in the final logistic regression model, with the cutoff set at 0.5, the prediction for reporting recorded critical values in 12 months had a sensitivity of 87.9% and specificity of 75.0%, indicating a high proportion of correctly classified events (100% reporting) and nonevents (less than 100% reporting). The false positive rate was 14.7%, and the false negative rate was 21.1%. The overall correct prediction was 83%.

3.4.3 Mediation or Moderation Effects of Use of Technology

Use of technology was not found to mediate relationships between gender, income, experience with technology, or LOS and the reporting of recorded critical values in 12 months (p>0.10). In addition, the use of technology did not moderate any relationships between the above predictors and the reporting of recorded critical values (p>0.10).

3.5 DISCUSSION

This study aimed to explore the degree to which LTR act appropriately to follow technology decision support for reporting recorded critical values during health self-monitoring in 12 months post-transplantation. The findings revealed that the majority of recorded critical values by the device were reported by recipients. About 62% of LTR fully followed technology decision support and reported all recorded critical values (100%). Current literature about technology acceptance focuses on the users' adoption of technology systems. No studies specifically targeted patients' responses to decision support recommendations made through mobile technology, especially regarding the reporting of critical condition changes to clinicians. A few studies reported that 66% - 85% of patients would comply with telephone-based triage self-care recommendations delivered by nurses (O'Connell, Towles, Yin, & Malakar, 2002; Rimner, Blozik, Begley, Grandchamp, & von Overbeck, 2011). Findings from this study of decision support by mobile technology are consistent with the results that 57% of patients complied with advice (to contact the doctor or perform self-care) provided by a web-based triage system (Nijland, Cranen, Boer, van Gemert-Pijnen, & Seydel, 2010).

This study also explored the factors that predicted recipients' response to technology decision support for reporting recorded critical values. A previous study reported that patients' adherence to triage self-care recommendations differed by age. However, this study did not find an age difference between recipients who fully (100%) followed technology decision support and those who reported less than 100% of critical values recorded. This study found that men and women responded differently in reporting recorded critical values. In addition, gender significantly interacted with prior experience with technology. With increased experience, the odds of reporting all recorded critical values increased in women but decreased in men. Previous studies reported inconsistent gender differences in technology adoption, specifically, women were found to have higher perception scores in their intention to use mobile monitoring services (Lee & Rho, 2013), and they adopted patient web portal more rapidly than men (Carrell & Ralston, 2006). However, in a different survey study, men reported higher intention to adopt mHealth services than women (Zhang, Guo, Lai, Guo, & Li, 2014). Regarding health condition monitoring and reporting, women were consistently shown to report more symptoms than men (Barsky, Peekna, & Borus, 2001; Kroenke & Spitzer, 1998). Although prior experience with technology was generally found to be associated with increased technology acceptance (Or & Karsh, 2009), the significant interaction between gender and experience with technology identified in this study, for the first time, indicated that with the increase of prior experience with technology, the likelihood of following technology decision support for reporting critical condition changes increased in women, but decreased in men.

Income was not identified as an influential factor in the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003). However, this study found that the low-income group (basic needs were unmet by household income) was more likely to fully report recorded critical values. This finding may be partially explained by evidence that low-income patients often have high trust in their doctors and relying more on their doctors as the top source of health information (Bylander, 2013; O'Malley, Sheppard, Schwartz, & Mandelblatt, 2004). According to a report from Pew Research Center, mobile phones also play an important role for assessing health information in those with low household incomes (less than $30,000) (Smith, 2015), and they are more likely to be smartphone-dependent, and therefore, they may tend to accept information generated by mobile technology, such as decision support.

Length of hospital stay, one of the patients' clinical characteristics and an indicator of patient general health status, was found to be associated with following technology decision support for reporting recorded critical values in this study. Health status is a potential predictor of patients' acceptance of consumer health information technology (Or & Karsh, 2009). Both better health and poorer health have been reported to be associated with increased acceptance of or adherence with technology use (Chae, Park, Cho, Hong, & Cheon, 2000; Jeannot et al., 2004; Kugler et al., 2010; Millard & Fintak, 2002). Specifically, Sabati, Snyder, Edin-Stibbe, Lindgren, & Finkelstein (2001) found poor health status was a barrier to adherence to an electronic home monitoring system in LTR. Similarly, this study revealed that LTR with a longer hospital stay (poor health status) were more likely to have less than 100% reporting of critical condition changes.

Although use of mobile technology for health self-monitoring was not found to be either a mediator or a moderator of relationships between predictors and reporting of recorded critical values, use of technology itself was identified as a direct predictor of reporting recorded critical values. The difference in reporting was mainly between the moderate use of technology group and the high use or low use group. It is understandable that the high use group is more engaged in their use of technology for health self-monitoring and thus may be more engaged in following technology decision support for reporting critical condition changes. It is interesting to note that although the low use group did not frequently use the technology for self-monitoring, if and when they used it, they tended to more actively report all critical values identified by the technology than the moderate use group. This finding suggests that it is LTR who have moderate use of technology for health self-monitor who tend to be less likely to fully report identified critical condition changes. The reasons for the recipients to use the technology less for health self-monitoring are complex and need to be further explored.

This study has a few limitations. Firstly, the sample size (n=53) is small; thus, the study may lack the power to reveal the true relationships between potential predictors and the outcome variable. Although univariate analyses were conducted to decrease the number of predictors included in the final model, generalization of findings of this study needs to be confirmed in a larger sample. Secondly, some approaches for managing the variables in the study may cause loss of information. For example, a few variables, such as use of technology and satisfaction with technology training, were categorized due to data skewness in the study; the variable of psychological distress was composited by summing the mean scores of anxiety and depression, due to high correlations between two variables; and deviation from the mean for continuous variables in the model were used in order to eliminate non-essential multicollinearity. Thirdly, this study only focused on the subgroup of LTR who have recorded critical values and considered those who had 100% reporting of recorded critical values as fully following technology decision support. However, those LTR who did not have recorded critical values by using the technology and then had no critical values reported were not taken into account. They did act correctly during health self-monitoring, i.e., no reporting of critical values due to no critical feedback message generated by the technology. Basically they followed the technology decision support. However, it is difficult to separate LTR whose zero-recorded critical values were truly due to the absence of any critical condition changes with those whose zero-recorded critical values were due to low performance of health self-monitoring. In addition, 100% reporting of critical values included the code for critical values that returned to the acceptable level according to the data management algorithm in the parent study, which does not precisely reflect the recipients' following technology decision support. Lastly, there was no specific theoretical framework to guide the understanding of acceptance of the technology decision-making support function, especially for reporting critical condition changes. Although the UTAUT model was adapted to guide this study, the UTAUT was originally developed to explain behaviors of people using the whole technology system. It is possible that some potential predictors were missed in the consideration. However, the final model presented both high sensitivity (87.9%) and specificity (75%) in prediction of reporting of critical values. With an overall 83% of all cases correctly predicted, predictors identified in this study can be useful in future studies to further understand patients' behavior of following technology decision support.

3.6 CONCLUSION

Lung transplant recipients using a mobile technology with decision support features responded appropriately to decision support feedback and reported critical condition changes to clinicians. Gender, experience with technology, income, length of hospital stay, and frequency of self-monitoring were associated with recipients' reporting in response to decision support feedback. The identification of these predicators may help clinicians assess LTR who are at high risk for poor reporting of critical values even when provided with mobile technology decision support. Alternatively, in order to improve reporting in the high risk group, automatic critical values reporting features may need to be added in the system design. Obviously, the recipients' involvement in the verification of critical values should be considered, and they should be allowed to choose their preferred way to report the recorded critical values.

Appendix A

PRELIMINARY STUDIES: TWO ABSTRACTS

1. Technology Experience among Lung Transplant Recipients

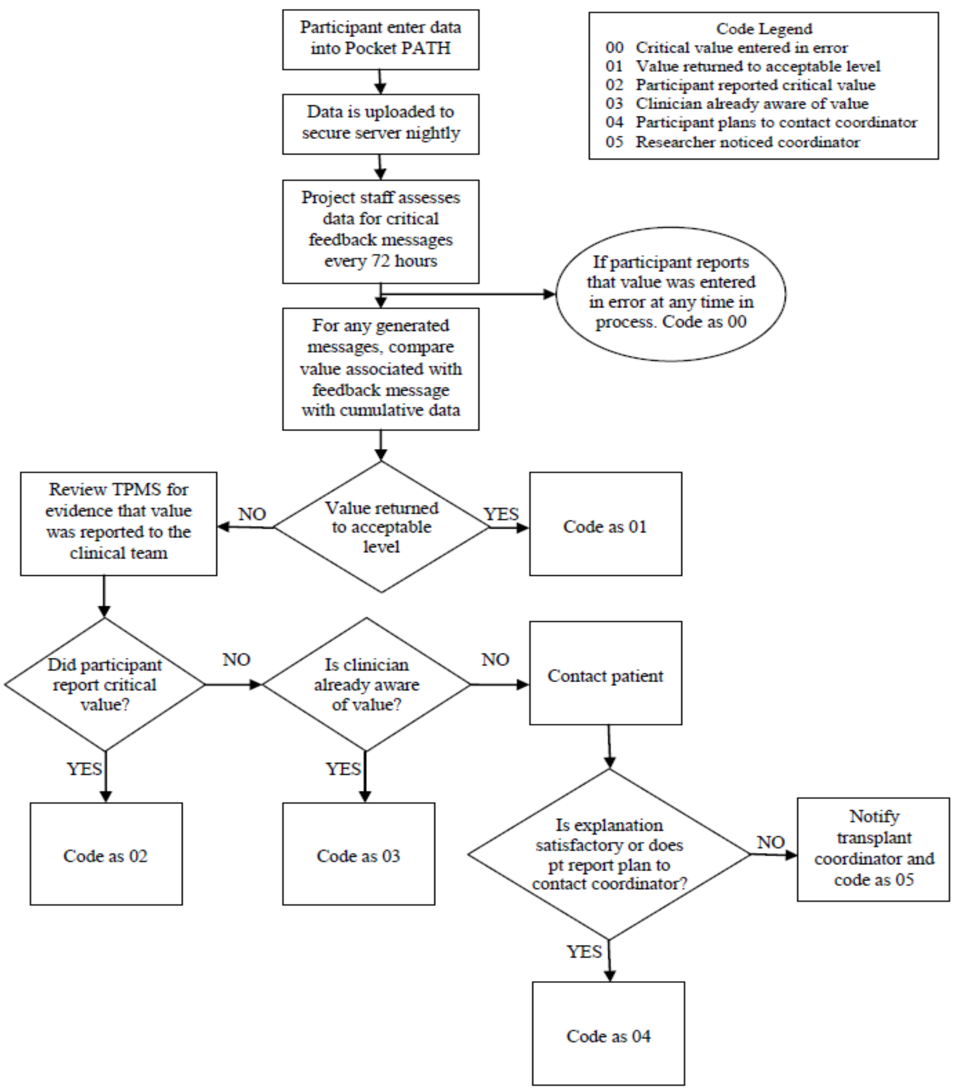
Purpose: Prior technology experience is known to affect acceptance and adoption of technology-based interventions. Recognizing the pattern of technology use in a specific population will help develop interventions and training strategies that are more acceptable and thus more likely to achieve the intended health outcomes. The study purpose was to describe the pattern of technology use among lung transplant recipients (LTR).
Materials and Methods: Data for socio-demographic factors and prior technology use were collected at baseline from 147 adult LTR participants of an RCT designed to evaluate the efficacy of Pocket PATH® a technology-based intervention to promote self-care. Sample characteristics were summarized using descriptive statistics; relationships between demographics and prior technology use were assessed with Chi-Square, Mann-Whitney U-test, Kruskal Wallis test, or simple logistic regression.
Results: Mean age was 57.35 years; approximately half were male and completed high school; and 90.5% were white; the majority was married or living with a partner. Household income levels for one third of LTR were ≥ $50,000, yet 16% earned less than $20,000. Older LTR had less prior technology use ($r=-.177 \sim -.363$, $p < 0.05$). Higher education was significantly related to prior use of cell phones, PCs and PDAs ($p=.002$, $p<.001$, and $p=.029$, respectively). Higher income was significantly related to prior use of cell phones, PCs and other hand held devices ($p=.002$, $p=.003$, and $p=.029$, respectively). Younger age and higher education were significant predictors of more general computer system use ($p=0.001$-0.12).
Conclusions: These findings suggest that prior technology use is important to assess. To meet the unique needs of older, less well-educated, and economically disadvantaged LTR, they should be included in the development and testing of technology-based interventions and training should be tailored and reinforced to meet the needs of LTR with limited technology experience.
Funded by NINR: R01NR010711 (DeVito Dabbs, PI)

2. The Relationships Between Technology Training Satisfaction, Technology Acceptance, and Recipients' Adoption of Pocket PATH®

Background: Lung transplant recipients (LTR) are expected to perform self- monitoring of health indicators in order to prevent and or detect complications after transplantation. Pocket PATH®: Personal Assistant for Tracking Health, a smartphone application with custom programs, is designed to assist LTR to track a variety of health indicators (e.g., spirometry, temperature, blood pressure, pulse, weight, and symptoms). Users' satisfaction with technology training and degree of acceptance of the technology is purportedly important predictors of technology adoption, yet these relationships have not been explored with regard to adoption of Pocket PATH by LTR.
Purpose: The aims of this study were to describe rates of Pocket PATH adoption by LTR and to examine the relationships between satisfaction, technology acceptance, and adoption.
Methods: A cohort of 55 LTR participating in a larger clinical trial, were randomly assigned and trained to use Pocket PATH to track health indicators for the first 12 months after discharge. Immediately following training, a subsample of 29 LTR completed the After Scenario Questionnaire (ASQ) to rate satisfaction with training and 4 technology acceptance measures: Perceived Ease of Use, Perceived Usefulness, Attitude toward the Technology, and Intention to Use the Technology. Possible scores range between 1-7; lower scores mean higher satisfaction and acceptance. Adoption rates (percentage of days that LTR tracked health) were calculated for 3 consecutive intervals: 0-2 months, 2-6 months and 6-12 months post-discharge.
Results: Mean scores for satisfaction and all 4 acceptance measures ranged between 1.22-1.39. The satisfaction and all acceptance measures were significantly correlated ($r = .43$ to $.52$, $p < .05$). Adoption rates were on average 53%, 42%, and 25% for consecutive intervals. Satisfaction with training was significantly correlated with adoption at all 3 intervals ($r = -.62$, $-.52$, and $-.38$, respectively, $p < .05$). Three of the acceptance measures (ease of use, attitudes, and intention) were significantly correlated with adoption at the 0-2 month interval only ($r = -.37$ to $-.41$, $p < .05$,).
Conclusions: LTR rated satisfaction and acceptance with Pocket PATH highly. Although higher satisfaction and acceptance predicted higher rates of adoption, the strength of the associations weakened overtime. Further research is needed to identify other explanations for low adoption rates.
Funding Source: NIH, NINR R01NR010711 (DeVito Dabbs, PI)

Appendix B

DATA MONITORING ALGORITHM



Appendix C

IRB APPROVAL LETTER FOR THE DISSERTATION STUDY

University of Pittsburgh
Institutional Review Board

3500 Fifth Avenue
Pittsburgh, PA 15213
(412) 383-1480
(412) 383-1508 (fax)
http://www.irb.pitt.edu

Memorandum

To: Yun Jiang

From: IRB Office

Date: 2/24/2015

IRB#: PRO15010376

Subject: Factors Associated with Acceptance and Use of Mobile Technology for Health Self-Monitoring and Decision Support in Lung Transplant Recipients

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The above-referenced project has been reviewed by the Institutional Review Board. Based on the information provided, this project meets all the necessary criteria for an exemption, and is hereby designated as "exempt" under section

45 CFR 46.101(b)(4)

Please note the following information:

- Investigators should consult with the IRB whenever questions arise about whether planned changes to an exempt study might alter the exempt status. Use the "**Send Comments to IRB Staff**" link displayed on study workspace to request a review to ensure it continues to meet the exempt category.
- It is important to close your study when finished by using the "**Study Completed**" link displayed on the study workspace.
- Exempt studies will be archived after 3 years unless you choose to extend the study. If your study is archived, you can continue conducting research activities as the IRB has made the determination that your project met one of the required exempt categories. The only caveat is that no changes can be made to the application. If a change is needed, you will need to submit a NEW Exempt application.

Please be advised that your research study may be audited periodically by the University of Pittsburgh Research Conduct and Compliance Office.

Appendix D

IRB APPROVAL LETTER FOR THE RENEWAL OF THE PARENT STUDY

University of Pittsburgh
Institutional Review Board

3500 Fifth Avenue
Pittsburgh, PA 15213
(412) 383-1480
(412) 383-1508 (fax)
http://www.irb.pitt.edu

Memorandum

To: Dr. Annette De Vito Dabbs

From: IRB Office

Date: 4/7/2015

IRB#: REN15030291 / PRO08070401

Subject: Comparing Methods for Tracking Health Information at Home after Lung Transplant

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Your renewal for the above referenced research study has received expedited review and approval from the Institutional Review Board under:

45 CFR 46.110.(5)
45 CFR 46.110.(6)
45 CFR 46.110.(7)

Please note the following information:

Approval Date: 4/7/2015
Expiration Date: 4/6/2016

Please note that it is the investigator's responsibility to report to the IRB any unanticipated problems involving risks to subjects or others [see 45 CFR 46.103(b)(5) and 21 CFR 56.108(b)]. Refer to the IRB Policy and Procedure Manual regarding the reporting requirements for unanticipated problems which include, but are not limited to, adverse events. If you have any questions about this process, please contact the Adverse Events Coordinator at 412-383-1480.

The protocol and consent forms, along with a brief progress report must be resubmitted at least **one month** prior to the renewal date noted above as required by FWA00006790 (University of Pittsburgh), FWA00006735 (University of Pittsburgh Medical Center), FWA00000600 (Children's Hospital of Pittsburgh), FWA00003567 (Magee-Womens Health Corporation), FWA00003338 (University of Pittsburgh Medical Center Cancer Institute).

Please be advised that your research study may be audited periodically by the University of Pittsburgh Research Conduct and Compliance Office.

Appendix E

ABBREVIATION

FEV_1	Forced Expiratory Volume in the First Second
HRQoL	Health-Related Quality of Life
ICU	Intensive Care Unit
IU	Intention to Use
LOS	Length of Stay in Hospital
LTR	Lung Transplant Recipients
MCS	Mental Component Summary
PCS	Physical Component Summary
Pocket PATH	Pocket Personal Assistant for Tracking Health
PEU	Perceived Ease of Use
PU	Perceived Usefulness
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
UTAUT	Unified Theory of Acceptance and Use of Technology

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