CASE REPORT

Factors Affecting Acceptability and Usability of Technological Approaches to Diabetes Self-Management: A Case Study

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Abstract

Purpose: This study explored the impact of personal digital assistant (PDA) features, users' perceptions, and other factors that may have hindered PDA acceptability and usability as technology advances in e-health diabetes self-management.

Study Design and Results: An ongoing study on PDA usage is set within the context of the advancements of Web 2.0 for type 2 diabetes mellitus (T2DM) self-management e-interventions. Advancements in technology as it relates to the future of T2DM mobile applications are discussed as possible deterrents of PDA acceptability and usability.

Conclusions: This case study illustrates the importance of addressing factors that may impede the adoption of electronic devices intended for sustained health behavior change. Recognizing the importance of individual perception within the context of rapid technological advancements is imperative for designing future health interventions. Incorporating electronic devices that individuals are more inclined to utilize, such as smartphones, as the platform for health interventions is a promising strategy to improve acceptability and usability, allowing researchers to more accurately assess the health benefits of self-management programs.

Introduction

EFFECTIVE DIABETES MANAGEMENT requires medication usage and behavioral changes to improve glycemic control to ultimately reduce excess morbidity and mortality.¹ Emphasis has shifted from physician-directed management to patient self-management as 95% of the variance in glycemic control is due to patient-level factors.^{1,2} Technological advances such as remote monitoring devices and electronic diaries are changing chronic disease management.³

Electronic diaries assist in behavioral self-monitoring to control surrogate outcomes such as glycated hemoglobin (HbA1c) levels. The personal digital assistant (PDA) has been considered a promising management tool to improve patient satisfaction and increase compliance with recommended behaviors for diseases, including diabetes.^{4–11} In fact, PDAs have been used extensively throughout the world, including the United States, some European countries, such as The Netherlands, France, Germany, and the United Kingdom, China, and India.^{12,13} However, advancements in mobile de-

vices and Web 2.0 have been superseded by other technological platforms. This article explores the impact of technological advances in diabetes self-management through one illustrative case study and how PDA technology has helped shape the development of current type 2 diabetes mellitus (T2DM) mobile applications. The case study will describe PDA features, users' perceptions, and factors that may have hindered PDA acceptability and usability in the context of changing technology.

Materials and Methods

This case study is part of an ongoing study to evaluate the effectiveness of T2DM self-management interventions in reducing disease severity and medical costs. The targeted sample was 50% minority (equal percentages of African Americans and Hispanics) and 50% non-minority, with 60% females and 40% males. Recruitment strategies included physician letters to prospective participants and oral referrals by physicians and patient educators. Participants ($n=376$)

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were randomized into four arms: (1) PDA, (2) Chronic Disease Self-Management Program (CDSMP), (3) PDA + CDSMP, and (4) control (i.e., usual care). Participants assigned to the PDA arm were trained to use a diabetes self-management software, Diabetes Pilot™ (Digital Altitudes, Arlington Heights, IL), developed for PalmOS® (Palm, Sunnyvale, CA)-compatible PDAs, such as the Tungsten™ E2 (Palm) handheld device (Fig. 1).¹⁴ Participants were able to monitor their blood glucose, blood pressure, medication usage, physical activity, and dietary intake using the device. Individual PDA instruction was provided by a project coordinator covering areas such as data entry, food database utilization, and reports/graphing features. Participants were instructed to enter information throughout the day and were expected to input daily. An instructional manual was given as a supplementary reference to assist in navigating the Diabetes Pilot program. Participants were asked to contact project coordinators with additional concerns/questions regarding the PDA and/or software. Those in the CDSMP arm attended a 6-week classroom-based community program for diabetes self-management. Individuals within the PDA + CDSMP arm were given both interventions. Demographic characteristics were collected at orientation using a questionnaire. Qualitative data were collected on participant attitudes regarding PDA use from a 15-item questionnaire conducted upon study exit. Enrollment log

FIG. 1. Personal digital assistant displaying the Diabetes Pilot program. BP, blood pressure; Exer, exercise; Gluc, glucose; Med, medication. Color images available online at www.liebertonline.com/dia

records maintained by project coordinators that documented participant commentary and project coordinator interviews were also utilized as the questionnaire was not implemented until the third year of the study.

Results

For each aspect, facilitators and barriers will be described that may have hindered PDA acceptance and usage.

PDA and Diabetes Pilot

Several participants expressed that their primary reason for discontinuing PDA use was their frustration with the device and/or program. In evaluating this, several limitations emerged that may have contributed to the observed frustration, including usability, data loss/errors, and time constraints.

PDAs were at risk of data loss once battery was low, often resulting in complete loss of information, which explains one participant's criticism that the PDA did "not keep ANY type of record."

Second, the Diabetes Pilot was open to error. Without filters preventing erroneous information from being inputted, mistyped numbers were accepted. Data extracted from PDAs revealed several out-of-range values across categories. In particular, blood glucose recordings had numbers surpassing 700 mg/dL and even reaching 4,000 mg/dL. Blood glucose levels greater than 600 mg/dL are considered a medical emergency as the body is in a hyperosmolar hyperglycemic state, where lack of treatment may result in coma and eventual death.¹⁵ Even empty entries, observed in many PDAs, contributed to the overall average. These erroneous entries and inaccurate numbers detracted from PDA usefulness because it provided misleading reports.

Third, data entry was considered to be extremely time-consuming and tedious. The post-PDA questionnaire revealed time as one of the most cited reasons for discontinuing PDA use. Calculating carbohydrates, often involving multiple food-item searches, and medication entries, because many patients were on numerous prescriptions, also contributed time. The data entry burden may have been difficult to manage.

Individual perception

Individual perception may have been an influential factor in PDA adherence. According to the technology acceptance model, intention to use is based on perceived ease of use and perceived usefulness.¹⁶ Individuals are more inclined to incorporate a technological device into their lives if performance outweighs effort. PDAs were not considered straightforward and user-friendly. Some participants had challenging experiences using PDAs, which may have outweighed the positive impact from continuing. In addition, perceived behavioral control may have impeded continuation. Individuals who believe they have a firm handle on their health may be unwilling to incorporate an unfamiliar method, especially if its benefits are uncertain. These individuals may not have believed there would be a positive health impact from using PDAs and resorted to what they already knew.

Participant characteristics

The PDA and CDSMP + PDA arm had 180 participants with an average age of 58 years. Age has been reported as

an important factor of technology use.^{17,18} Although the digital divide appears to exist between the older and younger generation, the technology adoption rate has increased for computerized devices and the Internet among older adults.¹⁹ Almost 90% of PDA users reported prior computer use, whereas over 80% had regular access (Table 1). With 72% and 77% reporting e-mail and Internet usage, respectively, study participants were not considered technologically inexperienced.

Unfamiliar devices may have lower adoption rates because of minimal mainstream presence. Over 80% of participants had no prior experience using PDAs. Anxiety toward a new device may have contributed to PDA aversion. Throughout the study, we observed a resistance in PDA usage, with 23 participants choosing to continue without the device and 14 voicing their reason for withdrawal were due to the device.

TABLE 1. SELECT CHARACTERISTICS OF PERSONAL DIGITAL ASSISTANT USERS

Characteristic	Participants (n=180)	
	Number ^a	%
Arm		
PDA only	81	45.0
CDSMP + PDA	99	55.0
Gender		
Female	100	55.6
Male	80	44.4
Education		
Less than high school	7	3.9
Some high school	11	6.1
High school graduate	37	20.6
Some college/vocational school	67	37.2
College graduate	37	20.6
Graduate school	21	11.7
Minority		
No	116	64.4
Yes	64	35.6
Income		
Less than \$15,000	18	10.0
\$15,000–\$24,999	33	18.3
\$25,000–\$49,999	69	38.3
\$50,000–\$75,000	35	19.4
More than \$75,000	20	11.1
Prefer not to answer	5	2.8
Ever used a computer		
No	22	12.3
Yes	157	87.7
Regular access to a computer		
No	30	16.7
Yes	150	83.3
Use e-mail		
No	50	27.8
Yes	130	72.2
Use Internet		
No	41	22.8
Yes	139	77.2
Ever used a PDA		
No	148	82.2
Yes	32	17.8

^aMissing data not included.

CDSMP, Chronic Disease Self-Management Program; PDA, personal digital assistant.

Numbers underestimate those withdrawing owing to PDA usage because they were based on coordinator records, which vary on detail. Interviews with project coordinators revealed higher estimates of individuals withdrawing because of PDA usage.

Discussion

PDA-based interventions in diabetes self-management have been observed to have significant benefits. Tsang et al.¹⁰ observed a significant HbA1c reduction among patients using PDAs to track dietary intake and blood glucose readings over a 6-month period compared with standard paper-based tracking methods. This finding was similarly observed when PDAs were introduced in four central Texas family-practice clinics.⁵ Forjuoh et al.⁶ further found greater HbA1c reductions among patients reporting high PDA use compared with lower use. Individuals who are educated, with medium/high incomes, and who have prior computer knowledge may benefit more from PDAs as they are more likely to adopt the technology.⁵

One of the major limitations of our study involved PDA instruction. Because PDA overviews were provided in one session, participants may not have been able to fully grasp the fundamental basics, which may have contributed to the confusion and frustration with the device. In addition, PDA data were only downloaded after participants exited the study. Had PDA data been extracted periodically and provided to the participant, he or she would have had the opportunity to discuss concerns. These study design factors may have contributed to low PDA use.

Early literature on PDA usage in medical settings was for the physician's benefit. In 2004, approximately 40% of practicing physicians owned PDAs.²⁰ The benefits of PDA usage in clinical settings include greater access to clinical test results from any location, instantaneous generation of clinical orders, and sending consultation requests to specialists.²⁰ The research project surrounding this case study is an early account of PDA usage to the public, rather than medical professionals. Participants were given PDAs to input data into the Diabetes Pilot application to better enable them to monitor the course of their T2DM. During the change in how information was delivered and received and in speed and ease of usage, PDAs did not respond to the demands of evolving technology.

Technological advancements developed in the wake of Web 2.0 are being heralded as the future of chronic self-care management. The Pew Internet & American Life Project defines Web 2.0 as an umbrella term referring to a new era of Web-based applications built around user-generated/user-manipulated content, such as Wikis, blogs, podcasts, and social networking.²¹ Web 2.0 concepts and technology have the potential to improve health decision-making and community health; therefore, accelerating dissemination of evidence into practice.²² Advancements in mobile device capabilities have coincided with Web 2.0 advancements. These devices are no longer viewed as simply a means to verbally communicate, but rather a powerful tool to accomplish a multitude of tasks through Internet connectivity and applications (Apps). Apps are able to fulfill users' needs involving productivity, entertainment, management, and information acquisition. Research has consistently shown diabetes management as an area where mobile devices could

enhance quality of life for people living with chronic diseases.²³ Chomutre et al.²³ analyzed several diabetes self-management App features, including self-monitoring, blood glucose, integration of social media functions, and synchronization with personal health record systems/patient portals, stating that although these features are distinct, they have the potential to work as an integrated self-management tool.

Diabetes Apps are advancing to better fulfill individual needs. Those, such as Glooko™ (Glooko, Palo Alto, CA), allow users to connect their glucose meters to the iPhone® (Apple, Cupertino, CA) using a MeterSync Cable to download blood glucose readings.²⁴ Even a glucose meter with wireless capabilities has been released, permitting data uploads to a Web portal that can be shared with their physician.²⁵ An innovative glucose meter designed specifically for the iPhone, iBGStar® (Sanofi, Bridgewater, NJ), is currently under development that connects directly to the device.²⁶ Diabetes self-management is more likely to continue on a smartphone because it encapsulates daily activity.

Cell phones and PDAs have essentially no spatial or temporal limits, making them particularly attractive and adaptive to mediating social networks.²² Among adults with diabetes, social support improves adherence to blood glucose self-monitoring, recommended dietary intake, physical activity, and glycemic control.²² The increased use of Web 2.0, especially among racial/ethnic minorities, provides potential opportunities to engage people in health-related issues, stimulate an active role in their own healthcare, connect them with others and evidence-based interventions, and create social action focused on social determinants of health disparities.²¹ Web 2.0 has the potential to connect underserved and underrepresented populations to important health information resources and to build social supports for those affected by healthcare issues.²¹ Social networks in Web 2.0 oriented to health and medical issues can expand the reach of social networks that have traditionally relied on face-to-face interactions among family and friends for uptake and maintenance of recommended chronic disease self-management practices.²²

The usage of technological devices to improve health and healthcare services is of major interest. Over \$10 million has been invested to advance knowledge of e-health (electronic health) effectiveness in health behavior change and chronic disease management.²⁷ e-Health refers to the usage of interactive technologies such as the Internet, PDAs, and computer kiosks to improve healthcare services and overall health.²⁷ As a subset of e-health, m-health (mobile health) is rapidly gaining popularity due to mobile device pervasiveness. Almost 30 million people in the United States are accessing health information via smartphones.²⁸

With over 7,000 health Apps, individuals are turning toward smartphones for health guidance and assistance.²⁹ By 2015, 500 million are projected to use a health App.²⁸ Tracking Apps are in high demand, according to an online questionnaire of 231 m-health-related companies.³⁰ With diabetes considered the therapeutic area with the highest business potential for App developers,²⁹ the emergence of additional diabetes Apps is likely. Almost 100 million individuals have iPhones; 7 million of these are individuals with diabetes.²⁸ It may be advantageous to focus diabetes self-management efforts on a more familiar and accessible platform to achieve better adoption.

Conclusions

It is interesting how rapid changes in technology often propel research and intrigue in several novel approaches to disease management. Frequently the arrival of a technological advancement is subsequently followed by an alternative that is able to perform with higher efficiency and ease. Our study began in 2007, coinciding with the release of the revolutionary iPhone. This new technology allowed individuals to be constantly connected through various functionalities. The advent of the iPhone paved the way for other successful smartphone releases. The rapid progression of technology frequently replaces once-novel concepts/devices even before dissemination of research findings can fully occur. Incorporating past and current technology may be advantageous in diabetes self-management efforts.

As T2DM shifts from a disease primarily affecting older adults to one affecting the younger generation, it is important to utilize technological devices that may better serve in self-management. It is essential that individuals are effectively engaged for sustained behavior change. Although PDA adoption was low, it does not negate the potential benefit of electronic diaries. Electronic diaries have been observed to increase compliance and assist in behavioral modifications.³¹ The health benefits of electronic diaries may have been overshadowed by PDA resistance. Simplifying PDA training by separating basic and advanced users into separate sessions could foster a more conducive learning environment. Future studies are recommended to incorporate more technologically appropriate teaching methods to improve adoption and usability of unfamiliar devices. Utilizing smartphones as the platform for self-management programs is also recommended to fully assess its health benefits.

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