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Usability testing of a tablet-based self-management application for older adults with T2DM: The ASSISTwell application

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Abstract

Background: Usability improvements are pivotal to technological applications in the healthcare industry. However, while they can transform healthcare, such applications are useless if they are not effective or easy to use.
Objective: To examine the usability factors of the tablet-based ASSISTwell self-management application for older adults with type 2 diabetes mellitus (T2DM) and refine the application.
Methods: This study used qualitative semi-structured interviews and end-user testing using the think-aloud technique, whereby a purposive sample of 12 older adult individuals with T2DM was recruited. Descriptive and inferential analyses were used to analyze the quantitative data, and thematic analysis was used to organize the emerging usability themes.
Results: The overall experience was expressed in 10 overarching usability themes, namely overall satisfaction, ease of use, ease of navigation, simplicity, usefulness and helpfulness, presentation, efficiency, application errors, and excitement and acceptance. End-user testing data showed that most participants were able to complete easy and moderate tasks with a high success rate (95-100%), in a short amount of time (0.08 to 2.21 minutes per task), and with minimal errors (0-3 errors per task). The average System Usability Scale (SUS) score was 91.60 (SD =5.65) and 92.05 (SD =11) for weeks 1 and 4, respectively. The study highlighted 23 suggested features to be considered in the next version of the ASSISTwell or any future T2DM application.
Conclusion: Examining usability is an essential step in application development to ensure that the application's features match users' expectations and needs and to minimize the likelihood of user errors and difficulties in using the system.

Keywords: Self-management, diabetes mellitus, usability testing, tablet-based application

Introduction

The global incidence of chronic illnesses in general, and diabetes mellitus (DM) in particular, is increasing significantly despite medical treatment advances and prevention efforts. Approximately 463 million adults worldwide are currently living with diabetes; by 2045, this number is expected to rise dramatically to 700 million (Yuen et al., 2019). A recent study estimated the prevalence of DM among adults in the US general population at 9.7%, of which 91% have type 2 diabetes mellitus (T2DM) (Xu et al., 2018). Another recent study indicated that by 2030, the prevalence of DM will increase to approximately 54.9 million Americans (Rowley, Bezold, Arikan, Byrne & Krohe, 2017. The considerable increase in T2DM prevalence results in significant human, social, and economic costs to individuals, families, communities, societies, and healthcare systems. The DM medical and societal cost in the US is estimated to increase by 53% to more than $622 billion by 2030 (Rowley et al., 2017).

Managing DM in general, and T2DM in particular can be challenging for older adults, particularly those with one or more chronic conditions, and may limit their ability to live independently as they age. Uncontrolled and unmanaged DM often results in serious medical complications, including kidney failure, lower-limb amputations, adult-onset blindness, obesity, hypertension, nerve damage, heart disease, and stroke (Offringa et al.,2018; Erdem & Korda, 2014). Moreover, ineffective self-management can have a substantial effect on general health, leading to the exacerbation of disease symptoms, emergency room visits, hospitalizations, and complex, high-cost treatment (Spector, Mutter, Owens, & Limcangco, 2012).

Background

Self-management and technological interventions

Advances in medical treatments and disease prevention efforts have led to the development of new interventions to help adults better man-

age their health and maintain their independence as they age. Technological applications such as mobile health, telehealth, tablet-based computers, interactive response voice systems, and computer software are now widely used in the field of healthcare in response to the considerable demand for innovative health interventions (Veazie et al., 2018). According to a recent report from the IQVIA Institute for Human Data Science, approximately 318,000 mobile health applications were available to consumers worldwide during 2017, with diabetes applications accounting for 16% of disease-specific applications (Veazie et al., 2018; Aitken, Clancy & Nass, 2017). Such interventions can have positive effects on both health and health service delivery processes (Wu et al., 2018; Free et al., 2013). Technological interventions supporting self-management focus on engaging individuals in their care process by encouraging behaviors such as medication compliance, exercise, monitoring symptoms, dietary change, weight control, reminders, social support, and alcohol and smoking restrictions (Bashi, Windsor, & Douglas, 2016; Kleinman, Shah, Shah, Phatak & Viswanathan, 2016; Kim, Wineinger, & Steinhubl, 2016). Empowering individuals and supporting their adherence to positive behaviors in relation to diet, medication management, and exercise can lead to improved diabetes-related outcomes (Veazie et al., 2018). Additionally, new technological advances show great potential to improve self-management outcomes by encouraging individuals to participate in practices and routines related to their illness and providing educational and motivational support for day-to-day diabetes management (Hunt, Sanderson, & Ellison, 2014).

Usability in technological interventions

The term *"usability"* derives from the term *"user-friendly"* and is defined as a quality attribute that determines how easy an application interface is to use (Shultz & Hand, 2015; Nielsen, 2003). An individual's opinion regarding the overall usability of a technological application in relation to ease of use, ease of navigation, and simplicity is influenced by various factors, including personal values, activities, circumstances, and frameworks of utilization (Hertzum et al., 2011). In addition, the user's level of understanding, the computer's capacity, and hardware/software can contribute to the program's overall usability (Issa & Isaias, 2015). High demand for highly effective and user-friendly technological applications forces researchers and application developers to deeply explore the factors and themes affecting their usability. Ultimately, technological applications can transform healthcare, yet they are useless if they are neither effective nor easy to use.

Study aims

The aim of this study is to examine the usability factors (e.g., satisfaction, effectiveness, efficiency, simplicity, overall experience, and feedback) of a tablet-based application (the ASSISTwell application) in older adults with T2DM. The authors also aim to determine what features, changes or key information users would like to have added or removed to/from the ASSISTwell application.

Methods

Study design

Two evaluation methods were employed in this study to examine the usability of the ASSISTwell application in the context of daily living over a 30-day period: (1) Qualitative interviews and (2) end-user-testing using the think-aloud technique. Qualitative data were collected using the semi-structured interview technique, which is frequently used in social science and generally employs a framework of themes to be explored (Cohen & Crabtree, 2006). This approach was considered appropriate as it allowed the participants to express their overall experiences, feedback/comments, and suggestions for improvement. Furthermore, it enabled the researchers to design a set of questions to guide the interviews, providing a close examination of the participants' experiences and giving them more freedom in expressing them (Manen, 2016).

End-user testing using the think-aloud technique was employed following the three stages proposed by Nielsen (1993): (1) preparation, (2) testing, and (3) follow-up (Nielsen, 1994). This technique was described by Nielsen (2012) as a method of "asking test participants to use the system while continuously thinking out loud-that is, simply verbalizing their thoughts as they move through the user interface" (Nielsen, 2012). This approach was appropriate as it enabled the researchers to understand how end-users view the application and value its design, thereby revealing numerous usability weaknesses at detailed levels and facilitating the transference of testing results into actionable redesign recommendations (Nielsen, 2012).

Sample inclusion/exclusion criteria

The following inclusion criteria were used in the study: (i) male or female 55 years or older; (ii) with T2DM diagnosed by a health professional; (iii) able to read and speak English; (iv) measuring blood glucose level at least once a day; and (v) able to use a tablet computer after participating in a training session and able to provide research consent. Participants with chronic psychotic disorders, delirium, dementia, or any other issue that could affect cognitive ability were excluded, as were those unable to use a tablet device.

Tablet-based self-management application

The ASSISTwell is an interactive, computer-based self-management application designed for use on mini-tablet-based devices (Jacelon et al., 2018). It was primarily designed to support the self-management activities and behaviors of individuals with chronic conditions. ASSISTwell has several functionalities and features that allow individuals to set and complete various tasks set by their care providers on a daily or weekly basis and based on their healthcare needs. Additionally, the application allows individuals to assess, track, and record several health parameters throughout the day and the week according to their preferences. First, activity parameters consisting of activity of daily living (ADL), the instrumental activity of daily living (IADL), and physical activities (steps walked); second, health parameters consisting of weight, blood glucose level, blood pressure, temperature, oxygen saturation (SpO2), medication, water intake, and meals information; and third, psychological function (e.g., attitude scale), role function (e.g., sense of control scale), and social function (e.g., Lubben social network). The application also allows individuals to set up reminders to complete tasks/surveys, and one feature asks the user, *"How well did you manage today?"* to provide data on how well the user believes he/she is managing over time; this information can be compared to other physiological, psychological, and social data.

The application supports both manual data entry and automated data collection via Bluetooth connection to peripheral devices (e.g., glucometer, blood pressure monitors, activity monitors). The assessment and tracking data can be stored in the system and retrieved for review by the end-user or healthcare providers. The regular use of physiological, psychological, and social measures will provide older adults with information regarding the overall function and may indicate changes in patterns of behavior over time. The application also allows individuals to review and summarize data using data visualization, including graphs and run charts.

The Maintaining the Balance model was used as the theoretical framework to guide the ASSISTwell application design (Jacelon et al., 2018; Jacelon, 2010). In this model, the broad focus is on self-management encompassing many aspects of older adults' lives beyond managing disease processes. Hereby, individuals manage their health by crafting a management plan combining strategies to monitor health status, keep track of medications, and balance the management of individuals' health, activity, attitude, autonomy, and relationships in their daily lives.

Human subject protection

The study obtained Institutional Review Board (IRB) approval from the University of Massachusetts Amherst, USA. A consent form describing the aim of the study, study procedure, risks, benefits, rights of participants, and how confidentiality and privacy would be protected was reviewed with and signed by each participant. Study data including interviews, participants' demographic information, and end-user testing data were kept in a secure Research Electronic Data Capture (RedCap) database hosted on an internal server at the University. Participants' privacy and confidentiality were maintained through the study by using participant IDs with numbers assigned randomly by a computer.

Recruitment, sampling, and sample

Participants were recruited using purposive sampling from two locations; one a community based senior center and the other a community health center. A diabetes specialist and a registered nurse who worked at the recruitment sites agreed to distribute study notices and refer potential participants to the study team. Individuals were contacted via telephone by a trained research assistant (RA), screened for inclusion, and subsequently contacted by the principal investigator (MA) to meet and discuss potential participation in the study. The participants were given the options of meeting at the community senior center or the participant's residence. Twenty-one potential participants were screened for eligibility. Of the 21 referrals, 12 persons met the inclusion criteria and agreed to participate (57%). Five participants (41.67%) were from the community senior center, two participants (16.7%) were from the community health center, and an additional five participants (41.67%) were referred by word of mouth from enrolled participants. An 85-year-old participant, who was not able to complete the full 30-day study due to community service commitments and travel arrangements during the study period, dropped out after seven days. Hence, 11 older adults completed the entire 30-day study. Kaufman and colleagues (2003) report that usability testing produces informative results even with small sample sizes, while Nielsen (2003) also suggests that 80% of usability problems can be identified with four or five subjects and 95% of usability issues can be identified by 9 subjects.

Data collection

Each participant who agreed to participate in the study and signed a consent form received a mini-tablet device containing the ASSISTwell application, a 30-minute training session conducted by the study PI (MA), and trained RA on how to use the application, and an instruction package. The instruction package contained written informa-

Table 1. Tasks set to evaluate the functionality of the ASSISTwell

Task level	Task	Task Category	Task description
I (Easy)	1	Health	Log blood glucose to 140
	2	Health	Log your weight
II (Moderate)	3	Survey	Complete the Activities of Daily Living Survey
	4	Survey	Complete the Jacelon
III (Advanced)	5	Medication	Add a medication reminder (Metformin 500mg-2 times a day)
	6	Set-up new account	Add a new user and set up the following: 1. Blood glucose before breakfast. 2. Blood glucose before bedtime. 3. Add the Activity of Daily Living survey and set it up to be completed once a day. 4. Add the Sense of Control Survey to once a day. 5. Add new medication (e.g. Metformin 500mg)

Note: Each participant completed the first and second testing sessions at the end of weeks 2 and 4, respectively.

tion on how to use the application, what to do on a daily and weekly basis, what to do when experiencing technical issues, and the study team's contact information. As part of the training objectives, participants were expected to practice six tasks successfully (easy and moderate levels) before starting to use the application. Following training, participants' accounts were created on the devices, and daily and weekly tasks and activities were set up based on each individual's self-management activities chosen by the individual. The participants were then asked to use the ASSISTwell application for a period of 30 days, during which the study PI (MA) and the RA trained on the study protocol met each participant in-person three times for initial training, account setup, to check for technical issues and to answer any questions/concerns, and for data collection. Additionally, a registered nurse, trained on the study protocol, contacted each participant via a phone call in week three to check for technical issues, and answer any questions/concerns.

Qualitative interviews

All participant interviews were conducted by the study PI (MA) and one RA between October 2016 and January 2017. To enhance the quality of the interviews, the PI conducted two pilot interviews prior to the actual data collection for the purpose of testing the interview questions and identifying any potential challenges. The PI was responsible for leading the interviews and asking questions while the RA observed and took notes. Two interviews lasting 45 minutes each on average were conducted with each participant during the study period. The first interview was completed at the end of week 2 and the second interview was completed at the end of week 4. The interviews took place in locations agreed upon by the study PI and participants.

The semi-structured interviews were guided by open-ended questions prepared by the study PI in accordance with the study methodology and research question. The interview questions aimed to determine participants' overall experiences and what features, changes, or key information the users would like to have added or removed to/from the ASSISTwell application. These questions focused on two main domains: first, the overall experience of using the application and second, the feedback/comments or suggestions for improvement. The questions guiding the interviews were embedded from validated usability scales (Brooke, 1996; Lewis, 1995) and informed by previous qualitative studies (Breakey et al., 2013; Waite, Martin, Curtis, & Nugrahani, 2013). The data from the interviews, field notes, check-in phone calls, and reflective journals describing the initial findings, non-verbal cues, and initial interpretations were subsequently transcribed by the RA, verified by the study PI, and uploaded to the qualitative data analysis software Dedoose by the RA and made available for analysis.

End-user testing using the think-aloud technique

Participants were invited to two separate 30-minute testing sessions at weeks 2 and 4, respectively, to complete the end-user testing during, whereby a total of 22 testing sessions were performed. The testing sessions took place at either the participants' own homes or the community senior center. As proposed by Nielsen (1993), three stages were used to guide the data collection and analysis processes, as described below.

Preparation stage

After they had completed the qualitative interviews, the 11 participants were invited to complete the end-user testing sessions. To enhance the quality of the data, each participant received a full training session and had the opportunity to practice at least two tasks before the actual testing and data collection. Data from practice sessions were not included in the analysis. During the testing sessions, participants were asked to complete six tasks related to T2DM self-management activities covering most of the ASSISTwell application's functions and features (*Table 1*) divided into three difficulty levels: easy level I (tasks 1 & 2), moderate level II (tasks 3 & 4) and advanced level III (tasks 5 & 6).

During the testing sessions, the four-usability metrics of effectiveness, efficacy, errors or simplic-

ity, and overall system usability satisfaction were examined. Effectiveness refers to the completeness and accuracy in achieving the desired task, measured by the success percentage in completing each task. Efficacy refers to the effort and resources consumed in achieving the desired task, measured by recording the time taken in minutes to complete each task; participants were not limited to a specific time to complete the tasks but were instructed to try their best to complete the task. Errors or simplicity were measured by counting the number of errors made while performing each task, such as choosing the wrong screen, clicking the wrong icon, choosing the wrong button, or being unable to find specific information. These usability metrics were guided by a set of questions developed by the study PI and used in a recent usability study (Waite et al., 2013; Or & Tao, 2012). The participants' overall system usability satisfaction was measured with the System Usability Scale (SUS), which is a 10-item validated questionnaire (Brooke, 1996). The SUS is a robust and reliable tool for measuring usability that offers easy application for the user (Bangor, Kortum, Miller, 2008; Borsci, Federici, & Laurici, 2009; Vaziri et al., 2016). Recent studies demonstrate a meaningful application of the SUS in various settings with older adults (Grindrod, Li, Gates, 2014; Nawaz et al., 2014; Vaziri et al., 2016).

Testing stage

All participants attended a full training session that provided instructions on how to perform the tasks while thinking aloud and vocalizing whatever they did, thought, or felt during the task to enable the researchers to comprehensively and reliably elicit usability concerns (Jaaskelainen, 2010). The participants were then asked to practice at least two tasks and were encouraged to ask questions before performing the actual testing. Following the training and practice sessions, the participants were asked to complete the six tasks. PI led the testing sessions and all performance measures and notes were collected with the help of RA. The prompting technique was used to complete the advanced level III tasks.

Follow-up stage

In the follow-up stage, all usability metrics data were double-checked for completeness and accuracy by the RA trained on the study protocol and then entered into the RedCap database and made available for analysis.

Demographic and general characteristics data

At the end of the study, all participants were asked to complete a one-page form on their demographic and general characteristics (age, gender, race, ethnicity, use of tablet devices, use of the internet at home or work, use of self-management applications, number of years living with T2DM, and type of self-management support). The demographic questions were embedded from the NIH form (NIH, 2016), while the use of tablet devices and the internet at home or work questions were embedded from a recent usability study (Stinson et al., 2010). The demographic and general characteristics data were entered into a RedCap database built specifically for this study.

Data analysis

Descriptive statistics were used to describe and summarize the participants' demographic and general characteristics. Qualitative data from the 22 interviews were transcribed verbatim in their entirety. The participants' interview transcripts, field notes, and demographic information were uploaded to Dedoose software for data organization and analysis. Thematic analysis, as outlined by Braun and Clarke (2006), was employed to guide the qualitative data analysis. The data from each participant were read entirely line-by-line multiple times by and any emerging initial ideas and interesting features were noted (referred to as tags in Dedoose). The noted tags were assigned codes and sub-codes. The coding was completed systematically across the transcripts. The initial coding was completed by the study RA; subsequently, the study PI (MA) reviewed the initial codes using an iterative process until data saturation was reached and no additional data could be added to the codes. A higher level of abstraction was employed to cluster initial codes under larger themes. The study team reviewed the emerging larger themes multiple times and a final list of themes was created.

Four criteria suggested by Lincoln and Guba (1985) were applied during the data collection and analysis process to enhance the trustworthiness of the data. First, confirmability was achieved by asking two participants to read their transcripts, which resulted in no changes. Also, in addition to using experts from engineering and informatics departments, the study team met several times to discuss the analysis and results until the entire study team was satisfied with the findings. Second, transferability was attained through the focused and in-depth nature of the 22 interviews. Third, credibility was achieved by having verbatim transcripts, reflective journals, and field notes. Fourth, dependability was assured by using Dedoose to systematically organize and analyze the data in addition to keeping an audit trail.

The four-usability metrics of effectiveness, efficacy, errors or simplicity, and overall system usability satisfaction were employed to organize the data analysis for the end-user testing using the think-aloud technique, which included descriptive statistics of means, frequencies, minimum and maximum values, and standard de-

viations. Additionally, a paired sample t-test was employed to test statistical differences between the scores in weeks 1 and 4.
As outlined by Chen, Hailey, Wang and Yu (2014), the most common attributes of data quality are the data collection process, completeness, and accuracy. Thus, to enhance the quality of data collection and analysis, two experts from the field of nursing informatics and human factors engineering reviewed the data collection process, completeness, and accuracy of the data analysis.

Results

Demographic and general characteristics

Twelve adults with T2DM participated in the 30-day usability study, of which eleven (96%) completed the entire study period. One participant (4%) withdrew from the study after participating for 7 days due to minimal experience with computer-based applications and a commitment to community activities.

The average age of the participants was 69 and ranged between 56 and 81. Female participants were on average 69 years old (n=7, 58.3%) and male participants were on average 70 years old (n=5, 41.7%). The majority of the participants were white non-Hispanic or Latino (n=9, 75%) and the remainder were African American non-Hispanic or Latino (n=3, 25%).

The majority of the participants (n=11, 91.7%) reported having a computer-based device (smartphone, tablet, or computer) at home while one (8.3%) reported having no computer-based devices at home. Participants were asked to report their comfort level with computer-based devices in general on a scale of 1 (not at all comfortable) to 4 (very comfortable); 41.7% (n=5) of the participants were very comfortable, 25% (n=3) were comfortable, and 33.3% (n=4) were a little comfortable. On average, the participants had experienced living with diabetes for 11 yrs (range 5-20 years). Only two participants reported having used the Glucose Buddy and ForDiabetes applications to support their T2DM self-management activities. Ten participants (83%) reported having limited family, peer, provider, or other forms of support for their T2DM management.

Findings from the qualitative interviews

The data from the qualitative interviews focused on two aspects, namely participants' overall experience and what features, changes, or key information they would like to have added or removed to/from the ASSISTwell application.

Participants' overall experience

The overall experience results from the qualitative interviews demonstrated that the participants were very satisfied with the application and that they found it very easy, helpful, and useful in supporting their self-management activities. Ten overarching themes emerged, namely overall satisfaction, ease of use, ease of navigation, simplicity, usefulness and helpfulness, presentation, efficiency, errors, and excitement, and acceptance. These themes are described in greater detail in the following.

Overall satisfaction

Most participants positively described their experience of using the application using the terms *"I like it"* or *"I love it"*, *"it is fun"*, *"I enjoy it"* or *"very interesting"*, and *"it is a great application"* or *"wonderful tool"*.

The following quotes are examples from the participants. Frank, a 71-year-old stated: *"I think it's a wonderful tool because it reminds me to do things I should do. I love it. I love the feature of recording blood sugar, weight, and blood pressure. The study went by fast; I didn't want it to end."*

Similarly, Camilia, a 62-year-old woman, noted, *"I think this is a great application and I told my providers about it, and they're very excited about it."*

Ease of use

Participants reported that the application was easy to use, expressing this 21 times during the interviews. Regina, a 70-year-old woman, used the application for the entire study duration despite reporting that she had minimal or no application/computer experience. Victor, a 68-year-old man, stated: *"I think a person not familiar with apps/computers could use this application, without a problem. Believe me, I do not use fancy phones, and I can do it by myself."*

Ease of navigation

Participants highlighted that the ASSISTwell application was very easy to navigate, expressing this seven times during the interviews. Despite their lack of experience with smartphones, tablet-based devices, and computer applications, they expressed that they were able to navigate all tasks without problems. Donna, a 58-year-old woman, expressed that the application was easy to navigate, stated: *"It's easy to get through the tasks. I do my blood glucose in the morning and complete the surveys in the evening with no problems."* Similarly, Frank, a 71-year-old man, noted: *"The application is easy to use and navigate, believe me, I do not use fancy applications, and I can do it by myself."*

Simplicity

User-friendly applications should be free from errors, obstacles, and problems. The participants expressed that the ASSISTwell application was simple and self-explanatory, highlighting the

application's simplicity eight times during the interviews. Most participants believed that anyone could use the application and that there was nothing confusing about it. Sherry, a 64-year-old woman, stated: *"I believe anyone can use it even if they never use it before."* Paul, a 73-year old man, expressed the simplicity of the application and noted: *"I don't think there's anything hard or confusing about it."*

Usefulness and helpfulness

The terms *"usefulness"* and *"helpfulness"* refer to the degree to which the application enables users to achieve their goals, which is important in assessing user willingness to use an application. Participants reported that the application was very useful and very helpful. The terms *"usefulness"* and *"helpfulness"* were reported 10 times during the interviews. Victor, a 68-year old man, stated: *"I definitely felt like it was very useful. It is really helpful; I always keep forgetting to use my blood glucose log, but to be honest because I am using this application, I am on track."* Similarly, Frank, 71-year-old noted: *"It is a very helpful tool; it keeps reminding me to do things, it's like a mother saying no."*

Presentation

Presentation refers to an application's images and text and common issues in technological applications tend to be color, text font size, and image display. Determining their appropriateness is crucial to usability testing. In this study, the users reported that they had no issues with the text, color, font size or image display. The terms *"the screen was easy to read"*, *"good picture"*, and *"good font size"* were reported 14 times during the interviews. Paul, a 73-year-old man, reported *"The screen was bright, and I like that. I did not even need my reading glasses."* Similarly, Sherry noted: *"The screen is easy to read, and the font and display were perfect."*

Efficiency

Efficiency refers to how much effort and resources the user consumes in achieving the desired objective. The participants reported that the ASSISTwell application did not consume much effort and that completing tasks within the application was very fast and easy. They reported that the application is *"fast, quick, and easy"* 22 times during the interviews. Jennifer, a 67-year old woman, stated: *"The application is not time-consuming at all, it says do it and click! It's done."* Additionally, Paul, a 56-year-old man, noted: *"It is very easy and does not take a long time to do the tasks."*

Application errors

This theme refers to messages on the screen when the application fails to function properly, the seriousness of the errors, and how easily users can recover from the errors. All 11 participants reported that they did not receive any error messages, they were able to recover easily after selecting the wrong button, and the application did not freeze or hang. Donna, a 58-year-old woman, expressed enjoying using the application and reported, *"No errors or problems at all. The application did not freeze or hang"*. Victor, a 68-year-old man, reported no errors while used the application, stating, *"No problems, I was able to recover easily from pushing the wrong button."*

Excitement and acceptance

Participants showed a great deal of excitement and acceptance toward using the application. Excitement and acceptance were reported nine times during the interviews. Paul, a 73-year-old man, stated: *"This is what I need; this is what we need (referring to diabetic individuals)."* Donna, a 58-year-old woman noted: *"When I heard about the study, I was very surprised that it was made mainly for the older adults' individuals. You do not see many apps made specifically for the older adults. I was happy and excited. It's incredible that an app, internet application, or a tablet was tailored to just 55 years and older. I think this population is in need of such an intervention, which could help them and provide good support for their diabetes management."*

General comments

When assessing the usability of any technological application, it is necessary to obtain general comments from the users to help build more robust applications. The ASSISTwell application was hosted on a mini-tablet-based computer and users reported that the tablet was *"portable enough, handy, easy to carry, and perfect size."* Participants repeated these terms 17 times during the interviews. Sherry, a 64-year-old woman, stated: *"The size is great; you can keep it close. It fits in my pocketbook; it's lightweight."* Similarly, Paul, a 56-year-old man, commented on the convenience of hosting the application on a mini-tablet device, stating, *"It's handy, and easy to carry."*

In summary, the participants expressed that the application is easy to use, it is easy to navigate, its features are simple and self-explanatory, and it enables users to easily achieve their goals, such as tracking glucose levels. Also, users had no issues with the text, color, font size, or image display presentation and they liked the application's stability. The participants showed positive signs of excitement and acceptance as part of their daily routine in managing their diabetes.

The ASSISTwell application's features, changes or key information

This section refers to what features, changes or key information the participants would like to

Table 2. Features suggested by users

#	Suggested Feature	Short description
1	Printing capability	Allow users to print data from the application.
2	Export capability	Allow users to export data to other devices.
3	Color coded results	"Hypo" alert "Normal" alert "Hyper" alert
4	Feedback	Give a short warning message if the result is low or high.
5	Enter data retrospectively	Ability to enter data retrospectively
6	Educational support	Feature to provide DMII educational resources
7	Food/meal diary	Feature to record daily meal/food
8	Musical choices for alarms/reminders	Add musical choices to the alarm settings
9	Graphic	Prediction of personal trends based on data stored in the application
10	Reminder/record exercise	Feature to record exercise in minutes
11	Data display	Feature to display the data average from the last 7, 14, or 30 days.
12	Timed blood glucose	Feature to record blood glucose 2 hours pre-prandial, fasting, 2-hours post-prandial
13	Doctor appointments	Feature to add a doctor appointments reminder
14	Comments section	Open text feature to record comments related to diabetes
15	Ideas for healthy diet	Feature to provide users with options/ideas of healthy snacks for diabetic patients
16	Track carbs	Feature to track the net carbs consumed by the patient
17	Color coded surveys results	Display survey results with a specific color based on the results (e.g. below average, normal, above average)
18	Troubleshoot	Add a troubleshoot support
19	Humorist feedback	Funny/humorist feedback (e.g. oops! It looks like you ate too many cookies!)
20	Reminder to get up and exercise	Feature to remind the user to get up and exercise
21	Exercise ideas	Feature to give users exercise options
22	Meal planner	Feature to help the user plan a single, daily or weekly meal
23	Social communication capability	Feature to connect the app with Facebook, Twitter, and other communication forums

have added or removed to/from the ASSISTwell application.

Features suggested by users to be added

Qualitative analyses of the participants' interviews and field notes highlighted 23 features to be considered in the next version of the ASSISTwell application or any other T2DM/chronic conditions application. All suggested features are tailored to the management of chronic illnesses in general and T2DM in particular. Suggested features are described briefly in *Table 2*. The following are two examples of features that users suggested could be added:

(1) Frank, a 71-year-old man, highlighted the importance of adding a troubleshooting support option and noted, *"A troubleshoot option within the application would be excellent. When there is a problem, there is no way to fix it unless I call you (referring to the study PI)."*

(2) Jennifer, a 67-year old woman, expressed the importance of adding a feature to give users exercise options and stated, *"If the application could tell you, get up and walk back and forth to the kitchen three times or if the weather is good,*

Table 3. Features suggested by users to be changed or revised

Features to be revised	Reason	Instances (n)
Alarm/reminder	The Reminder/Alarm does not go off on its own unless you open the tablet. The alarm does not stop unless you skip the task.	Nine times
Survey questions	Questions in each survey do not display in a random order.	Three times
Survey repetitions	ADL and IADL surveys are redundant when setting up to be performed daily.	Seven times
Survey applicability	Surveys do not apply to every participant.	Two times
Numeric data entry	Incorrect keyboard display during numeric data entry.	Six times
Interface display	No data display when user holds the tablet horizontally.	Two times
Data entry instructions	Lack of data entry instructions for scheduled tasks.	Four times

go for a five-minute walk."

Features suggested by users to be changed or revised

Seven existing features were highlighted to be reconsidered or revised in the next version of the ASSISTwell application. These were divided into the two categories of technical aspects (e.g. alarm/reminder, interface display) and self-management activities (e.g. survey repetition and applicability). Suggested revisions are highlighted in *Table 3*. The following are two examples of features that users suggested be revised. Donna, a 58-year-old woman, noted, *"Surveys are overwhelming and not sure if other people will be willing to do them very often since they are asking the same thing over and over."*

Sherry, a 64-year-old woman, stated, *"The alarm just kept going off, and it does not stop. That is kind of distract you."*

End-user testing using a think-aloud technique

Twenty-two testing sessions were completed during the study, whereby each participant completed the first and second testing sessions at the end of weeks 2 and 4, respectively. The performance data from the four usability metrics of effectiveness, efficacy, errors or simplicity, and overall system usability satisfaction are described below.

Effectiveness

All participants were very successful at completing level I and II tasks without assistance from the research team. At the level I, the participants had a 99% and 100% success rate for logging their blood glucose and weight at weeks 1 and 4, respectively. The minimum mean success scores for weeks 1 and 4 for the level II tasks were 85% and 90%, respectively. The users had the lowest success score for the level III tasks, whereby the minimum score for both weeks 1 and 4 was 60%. Furthermore, all participants had difficulty completing level III independently without assistance or guidance from the research team. A paired sample t-test was conducted to compare the success scores between week 1 and week 4, but there was no significant difference for all six tasks.

Efficacy

All participants took very little time completing the level I tasks; for example, they took 0.13 minutes to log their weight in weeks 1 and 4. The participants needed more time to complete level II tasks; for example, they took 1.19 minutes on average to complete the JAD survey. Level III tasks took longer to complete; for example, the average time taken to add a medication reminder was 2.36 minutes and 2.19 minutes for weeks 1 and 4, respectively. Among all tasks, the longest time it took to complete a task was the time it took to add a new user and set up an entire account (task 6), which took 5.27 minutes and 4.1 minutes in weeks 1 and 4, respectively. A paired-sample t-test was conducted to compare the average time taken to complete each task at weeks 1 and 4. There were no statistically significant differences in the scores for tasks 1, 2, 3, 4 and 5 (all $p > .05$), but there was a statistically significant difference between the scores for task 6 in week 1 ($M=5.27$, $SD=1.8$) and week 4 ($M=4.11$, $SD= 1.10$) ($t(9) = 2.44$, $p=0.03$).

Errors or simplicity

Both tasks I and II had minimum and maximum error numbers of 0 and 3, respectively. Furthermore, the participants made a high number of errors while completing the level III tasks. The minimum and maximum errors number for tasks III were 0 and 8, respectively. However, paired-sample t-tests showed that the differences were not statistically significant. In summary, all users made fewer errors on the level I and II tasks. Level III tasks were more advanced and required clearer instructions to complete. The number of errors in week 4 was less than in week 1, but the difference was not statistically significant.

Overall system usability satisfaction

Eleven participants completed the SUS at weeks 1 and 4 with a 100% response rate, whereby the average score was 91.60 ($SD =5.65$) and 92.05 ($SD =11.00$) for weeks 1 and 4, respectively. A paired sample t-test comparing the satisfaction scores in weeks 1 and 4 showed no significant difference between the mean SUS scores (paired $t(10)= -0.12$, $p= 0.90>.05$). There was a small improvement in the satisfaction average overall score between week 1 and week 4, but the dif-

ference was not statistically significant.

Discussion

Technological healthcare applications can transform healthcare; however, they are useless if they are not effective, efficient, and easy to use. Thus, by preventing errors, boosting efficiency, and making technological interventions easier to use, the quality of healthcare can be greatly improved (McHome, Sachdeva & Bhalla, 2010). This study examined the usability of the ASSISTwell application in supporting older adults' self-management of T2DM through qualitative interviews and end-user testing using the think-aloud technique. The findings demonstrated that the application is usable as it was positively expressed in 10 usability themes. Additionally, the findings from the end-user quality metrics indicated that the application is usable, learnable, and accepted in the context of daily living.

Qualitative Interviews

The findings from the interviews demonstrated qualitatively that all participants were satisfied with the overall experience of using the application and were able to provide valuable feedback on existing features and offer suggestions for ways to improve and develop this and future applications.

Participants were satisfied with the overall experience of using the application

The study highlighted 10 critical usability themes that were important to users. Prior usability studies are often limited to a few usability themes, such as satisfaction, ease of use, and feedback (Gabrielian et al., 2013). In this study, a wider range of critical usability themes was highlighted, namely simplicity, presentation, efficiency, application errors, and application acceptance, thus helping to identify design weaknesses and usability issues for further improvement of the application. Additionally, the qualitative positive feedback expressed in the abovementioned 10 usability themes demonstrated that the application and its capability to support T2DM self-management activities are usable and, in particular, accepted by older adults. These themes are similar to the guidelines and recommendations suggested by the Institute of Medicine (Broderick et al., 2014) and, importantly, are critical in enabling older adults to better utilize applications to improve health (Levy, Janke and Langa, 2015).

Feedback on existing features and suggestions for future improvement

The participants were able to provide valuable and critical feedback on existing features and suggestions to improve and develop the ASSISTwell application. Such feedback and suggestions from users' perspectives are considered critical themes of any system's usability; for example, Waite et al. (2013), in exploring the usability of three mobile applications supporting diabetes self-management, considered users' suggestions and feedback to be the main usability themes in the study and, based on users' suggestions, were able to list 13 features to be considered in future developments. Similarly, by combining qualitative interviews and end-user testing in data collection with prolonged user engagement, the usability testing in this study highlighted 23 suggested features to be considered in the next version of the ASSISTwell application or any future T2DM applications. These suggested features (*Table 2*) are vital to improving the overall usability of the ASSISTwell application and are considered important aspects of diabetes self-management as they are derived from users' needs and expectations. All 23 suggested features, along with users' feedback, will be incorporated into future versions of the ASSISTwell application or can be utilized in future chronic illness applications.

As part of the usability testing of the ASSISTwell application, it was critical to review the functionality and applicability of the application's existing features. The results from the qualitative and end-user testing analyses highlighted seven existing features to be reconsidered or revised for the next version of the ASSISTwell application – an important step to producing a more usable, effective, and engaging application.

End-user testing

As a result of the two iterative cycles of the end-user testing sessions, several design issues, problems, and areas that could improve the usability of the ASSISTwell were identified in this study. Based on these findings, we conclude a number of significant implications for the overall usability of the ASSISTwell application.

First, well-designed features within an application have a significant impact on the usability themes of user satisfaction, ease of use, ease of navigation, effectiveness, efficacy, and errors or simplicity. The participants had no issues in completing level I and II tasks completely and independently. All performance metrics, such as success rate, the time required to complete the tasks, and the number of errors while performing the level I and II tasks, indicate that the features needed to complete those tasks were well designed and positively impacted the overall usability of the application.

Second, for the level III tasks, the performance metrics indicated a design issue related to three features of the ASSISTwell application, namely medication and setting up new medication reminders, setting up activity reminders, and

completing surveys. The results from the three usability metrics suggested that the three features were difficult to use and navigate, which was likely due to confusing interface design. To avoid this issue in future mobile health application development, we suggest that developers carefully take into consideration the following three factors: First is older adults' cognitive ability in terms of comprehending as well as their ability to navigate the application simply; second is avoiding feature overload, and third is older adults' struggle with touch-sensitive user interfaces. Hence, simple interface design is recommended, particularly for applications targeting older adults. In contrast, confusing interfaces and difficulties in using and navigating features can lead users to have higher error rates, longer times to complete tasks, and lower success rates. This design issue was highlighted and considered for improvement to enhance the overall usability of the application.

Third, the think-aloud technique allowed the study team to observe the participants' use and navigate the application's features and complete the assigned tasks, which was extremely beneficial to identify design issues. Although some of the identified issues were minor and did not cause errors, they indicated a need to change the design and improve the functionality of the features to obtain maximum usability and meet user expectations.

The overall satisfaction with the system usability suggested that the participants were very satisfied with the capability of the application in supporting their self-management activities and the average SUS scores improved from 91.60 in week 1 to 92.05 in week 4. This is a positive indication that the application is usable. When comparing the SUS scores to the normative data, the results were associated with *"best imaginable"* for adjective ratings, which corresponds to *"A-"* on the grading scale, and *"acceptable"* for acceptability ratings (Bangor, Kortum, & Miller, 2009). Furthermore, all participants' SUS scores for weeks 1 and 4 exceeded the average SUS score of 68.20 for mobile applications shown in a previous study (Bangor et al., 2009).

Implications for clinical practice and future research

Examining the usability themes in the context of daily living presents a to examining usability issues among healthcare applications. This approach allowed researchers to identify elements that are considered essential aspects when developing new effective and engaging self-management applications that integrate seamlessly into older adults' daily routines. Additionally, the study presents a systematic method of assessing usability by integrating qualitative usability testing with lessons learned from experienced patients. The findings from this study present a list of suggestions and proposed features for future self-management applications that will greatly benefit future research in this field. The findings from this study provide valuable learned lessons for the clinical applicability of future research. First, it is feasible to partner with targeted clinicians for better recruitment outcomes. Second, enrolment can be enhanced through word-of-mouth participant recruitment. Third, it is necessary to recruit individuals who are not committed to activities that could prohibit them from actively participating. Fourth, older adults experience significant challenges when using touch-sensitive screens. Fifth, it is critical to avoid overloaded features in the case of older adult end-users. Additionally, this study illuminates the capability of older adults in using technological applications, particularly in their home settings.

Strengths and limitations of the study

This study had several strengths. First, compared to previous usability studies, this study combined two usability methods, namely qualitative interviews and end-user testing using the think-aloud technique. This resulted in rich data to identify usability issues, problems, and common ways to improve the quality of the application. Second, our usability testing involved a relatively larger sample size compared to previous usability studies, which helped to identify design weaknesses and usability issues for further improvement of the application. Third, the usability testing in this study involved obtaining user feedback in the context of daily living over a 30-day period. Qualitative interview and end-user testing data were collected at two timepoints while participants used the ASSISTwell application in their homes.

Despite the strengths of the study design, there are some limitations. First, the sample size was small from the quantitative outcome viewpoint, and the findings related to no differences in SUS overall satisfaction between weeks 1 and 4 might have been underestimated. Second, the sample might be biased as the users who volunteered to participate might have been more comfortable with technological applications than those who did not. It should be noted that the users in this study were older adults and most experienced problems with the touch-sensitive user interface.

Conclusion

Examining usability is an essential step in application development to ensure that the application's features match users' expectations and needs as well as to minimize the likelihood of user errors and difficulties. The two methods of usability testing revealed that the application was very

simple and easy to use, had a high overall satisfaction rate, and was well accepted by the older adults. In addition to the participants' positive comments and feedback, the investigators were able to highlight several features for improvements and developments as well as suggestions for future versions or similar applications. Addressing the suggested areas for development and improvement will be critical to developing a usable, effective, and engaging application to support older adults' self-management activities.

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