ACCESSIBILITY OF MHEALTH SELF-CARE APPS FOR INDIVIDUALS WITH SPINA BIFIDA

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Abstract

As the smartphone becomes ubiquitous, mobile health is becoming a viable technology to empower individuals to engage in preventive self-care. An innovative mobile health system called iMHere (Internet Mobile Health and Rehabilitation) has been developed at the University of Pittsburgh to support self-care and adherence to self-care regimens for individuals with spina bifida and other complex conditions who are vulnerable to secondary complications. The goal of this study was to explore the accessibility of iMHere apps for individuals with spina bifida. Six participants were asked to perform tasks in a lab environment. Though all of the participants were satisfied with the iMHere apps and would use them again in the future, their needs and preferences to access and use iMHere apps differed. Personalization that provides the ability for a participant to modify the appearance of content, such as the size of the icons and the color of text, could be an ideal solution to address potential issues and barriers to accessibility. The importance of personalization—and potential strategies—for accessibility are discussed.

Keywords: mobile health, accessibility, smartphone apps, wellness, self-care

Introduction

Mobile health (mHealth) initiatives are those that use mobile communications for health services and information.[1] They involve the use of mobile devices to wirelessly connect remote and highly itinerant populations directly with healthcare systems.[2] The mHealth approach has been described as a patient-centered approach to care[3] and has been popularly utilized to deliver medical reminders, provide treatment support, and collect data[4] for healthcare delivery and research.[5, 6]

More than 50 percent of all Americans have at least one chronic illness,[7] and about one-fourth of people with chronic conditions have a disability that limits one or more daily activities.[8] Strong evidence supports the importance of self-management skills for improved health outcomes and independence in daily living activities for persons with disabilities.[9, 10] One such population is individuals with spina bifida (SB). SB is the most common permanently disabling birth defect in the United States.[11]

Individuals with SB are vulnerable to secondary complications (e.g., urinary tract infections and skin breakdown)[12] that can in part be prevented with self-care activities. A wellness pilot project was developed at the Spina Bifida Association of Western Pennsylvania (SBAWP) in which two clinicians—wellness coordinators (WCs)—supervised the care of 35 individuals with complex medical needs. The role of the WCs as a liaison and director of care empowered the individuals to be responsible for their own treatment. Results show that the individuals in the wellness program had shorter lengths of hospital stays, with admission rates of only 12.9 percent compared to the national rate of 26.9 percent.[13, 14] The participants also had lower rates of skin breakdown (9.7 percent) and UTIs (16.1 percent) compared to those with SB in the general population (35.5 percent and 35.2 percent respectively).

The success of the in-person SB pilot project[15] in promoting wellness as well as achievements in other wellness programs[16–20] provides evidence that the goal of improving health and function through self-management is attainable with appropriate support. However, this in-person wellness program also had significant limitations in the number of persons that could be served due to geographic and clinical-resource constraints. The use of mobile technology in healthcare, as with mHealth, is one way to reduce these constraints. An mHealth system would allow WCs to serve a larger number of individuals, making the wellness program both cost-effective and scalable. Using mHealth technologies might also improve health outcomes of individuals by reducing secondary complications and help to reduce the cost of care for people with chronic conditions, which account for three-quarters of healthcare expenditures in the United States.[21–23]

An innovative system called iMHere (Internet Mobile Health and Rehabilitation) was developed at the University of Pittsburgh to enable self-care for individuals with SB. As shown in Figure 1, the iMHere system consists of smartphone apps, a clinician portal, and two-way communication connecting the two to support self-management and service delivery.[24] A web-based portal provides clinicians with the ability to monitor individuals' conditions and send treatment plans to individuals via smartphones. The iMHere apps on smartphones allow individuals to set up reminders according to their preferences, respond to alerts, and report symptoms. (See Figure 1.)

A previous study[25] focused on the usability of iMHere. Three phases of usability testing were conducted to evaluate the self-care workflow, general issues with navigation and the user interface, and the reliability of communication between the apps and the portal.

Accessibility is a subset of usability and is the degree to which a person can use a product regardless of ability or disability. As applied to mHealth, accessibility refers to the extent to which participants have access to the on-screen information presented from a sensory, motor, or cognitive perspective. The aim of the present study was to explore the accessibility of the iMHere apps, focusing on the user interface and navigation, which might affect users' performance and satisfaction with the system.

Methods

Six participants were recruited at the University of Pittsburgh and provided informed consent for this study under an Institutional Review Board–approved protocol. The choice of sample size was based on previous studies that found that 80 percent of usability problems can be revealed with only five participants,[26–28] with almost all high-severity usability problems being uncovered with only three participants.[29] In general, the estimated required sample size for a usability test depends on the problem space.[30] Since the issues related to overall usability were addressed in a different study,[31] the sample size of six participants in this descriptive study can be considered sufficient for discovering accessibility problems of the user interface and navigation.

Inclusion criteria were (1) age 18 to 40 years, (2) diagnosis of SB and hydrocephalus, and (3) ability to use a smartphone. Exclusion criteria were severe intellectual disability and any problem in vision, hearing, speech, or finger movement that precluded use of the phone. Both experienced users of iMHere who participated in the previous study and inexperienced users were included. Experienced users had stopped using iMHere apps for more than five weeks before participating in this study to minimize the learning effects that might carry over from the previous experiences.

Five apps that constitute the iMHere gallery were released to support preventive self-care for managing medications (MyMeds), neurogenic bladder (TeleCath) and bowel (BMQs), mood (Mood), and skin breakdown (SkinCare). Self-created reminders with customized alarm tones and messages prompted individuals to perform tasks related to self-care at home. The following tasks were selected on the basis of the complexity and types of daily activities for self-care and were randomly assigned to each participant:

1. Schedule a new medication: participants had to locate a correct medication, add more information about this regimen such as their reason for taking the medication, and set up a reminder.
2. Report a skin breakdown issue: participants were required to respond to reminders, take a picture, and fill out a form describing the affected skin including location, color, size, depth, and tissue condition.
3. Set a schedule to monitor mood: participants were required to set a repeating alert time, such as once per week or biweekly, and enter a valid start date for the alert.
4. Respond to a mood alert: participants had to answer 10 binary questions (yes or no) to express their feelings.
5. Respond to a TeleCath once-per-day alert: participants had to report their number of self-catheterizations performed.
6. Respond to a BMQ alert: participants had to report their adherence to a bowel program and report any symptoms.

Each of the six tasks was repeated three times within two hours for a total number of data points (*n*) of 108 (six participants, six tasks, repeated three times). Android devices with keyboards that participants could physically slide out of the smartphone were used in this study. Researchers manually recorded the time and steps to complete each task and the number of mistakes made by each participant for statistical analysis.

Researchers also used step-by-step observation notes to record the verbal and nonverbal behaviors and frustrations of participants in the lab tests. Weighted scores were added to all mistakes to describe the difficulty-on-performance (DP) for participants to solve problems: a score of 1 was assigned if the participant could solve the problem without any help; 2, if the participant needed help consisting of one sentence; 3, if the participant needed help consisting of two to four sentences; and 4, if the participant was unable to solve the problem. The DP score was calculated as the sum of weighted scores divided by the total number of steps to complete a task.

After the tasks, participants were asked to complete the modified Telehealth Usability Questionnaire (TUQ) to reveal their levels of satisfaction with the iMHere apps. TUQ is a comprehensive usability questionnaire that covers six usability factors including usefulness, ease of use and learnability, interface quality, interaction quality, reliability, and satisfaction and future use.[32] The TUQ utilizes a seven-point Likert scale to measure usability, with the value of 1 for least usable and 7 for most usable.

Standard deviation was calculated to reveal the dispersion patterns of the previously mentioned variables. A paired *t*-test was utilized to explore the difference in the time for completing all tasks between different testing scenarios (tasks 1 and 2, 2 and 3, or 1 and 3). Person's correlation coefficient and Spearman's rank correlation coefficient were used to measure an association between the previously mentioned variables.

Results

Six participants (five males and one female) completed this study. Their ages ranged from 23 to 36 years with an average of 29 years (*SD* = 5.09). No participants were excluded on the basis of the exclusion criteria. Except for participant 4, all others were cell phone users prior to participating in the study. Participants 4 and 5 were new to iMHere. Participants 1, 2, and 3 had tested the MyMeds app in the previous study more than five weeks earlier. These participants remembered about 25 percent of the processes in the MyMeds app. Participant 6 had tested the MyMeds and SkinCare apps about six months before, but he had completely forgotten how to use these apps.

Different methods were utilized to evaluate the previously mentioned data instruments. The results were analyzed from the perspectives of usability that include effectiveness, efficiency, and satisfaction.[33]

Effectiveness of Task Completion in Three Tests

In total, 108 tasks were executed by the six participants. Figure 2 illustrates the average time for all participants to complete the tasks. Generally, they spent the most time on scheduling a medication (127 seconds, about 38 percent of the total time) and responding to a skincare alert (96 seconds, about 29 percent). About 33 percent of the total time was used to complete the other four tasks: responding to a BMQ alert (36 seconds, about 11 percent), responding to a TeleCath once-per-day alert (6 seconds, about 2 percent), scheduling a mood alert (44 seconds, about 13 percent), and responding to a mood alert (26 seconds, about 8 percent). (See Figure 2.)

According to Pearson's correlation coefficient, a slightly negative correlation was revealed between the order of tests (tests 1, 2, and 3) and the completion time, $r = -0.165$, $n = 108$, $p = 0.04$. A significant positive correlation was found between time and the steps to complete tasks, $r = 0.635$, $n = 108$, $p < 0.001$. A paired t-test with a 95 percent confidence interval ($n = 108$) revealed a significant difference in the time for completing all tasks in test 1 ($M = 71.03$, $SD = 75.17$) and test 2 ($M = 49.14$, $SD = 46.76$) conditions, $t(35) = 2.88$, $p = 0.007$, as well as for test 1 ($M = 71.03$, $SD = 75.17$) and test 3 ($M = 47.64$, $SD = 46.78$) conditions, $t(35) = 3.715$, $p = 0.001$. However, no significant difference was identified for test 2 ($M = 49.14$, $SD = 46.76$) and test 3 ($M = 47.64$, $SD = 46.78$) conditions, $t(35) = 0.34$, $p = 0.74$. (See Table 1.)

As mentioned previously, both experienced and inexperienced users were included in this study. The overall average time in seconds for each group of participants to complete tasks are shown in Table 1. According to a paired t-test, no significant difference was identified between the experienced ($M = 57.67$, $SD = 46.86$) and inexperienced participants ($M = 47.5$, $SD = 41.27$) at the $p < 0.05$ level, $t(5) = 2.33$, $p = 0.067$. This finding suggests that the experienced participants might not benefit in terms of time efficiency from their prior experience with iMHere after a five-week washout period.

Efficiency of Performance

As shown in Table 2, 60 steps on average were required for a participant to complete six tasks in each test. According to Pearson's correlation coefficient, significant positive correlations were identified between the following variables at the $p < 0.05$ levels:

1. The steps to complete tasks and the mistakes encountered by participants, $r = 40$, $n = 108$, $p < 0.001$;
2. The steps and the time to complete a task, $r = 64$, $n = 108$, $p < 0.001$; and
3. The time to complete a task and the mistakes encountered by participants, $r = 715$, $n = 108$, $p < 0.001$.

(See Table 2.)

Because of the tasks' complexity, more steps on average were required for participants to complete four tasks. First, adding a new medication required participants to locate a correct medication, add more information about this regimen such as their reason for taking the medication, and set up a reminder (17 steps). Second, responding to a skincare alert required participants to respond to a reminder, take a picture, and fill out a form describing the affected skin (11 steps). Third, when scheduling a mood alert, participants were required to set an alert time (12 steps), such as once per week or biweekly, and enter a valid start date for the alert. Finally, when responding to a mood alert, participants also had a relatively high average number of 12 steps to complete a binary mood survey with answers of "Yes" or "No."

Twenty-eight mistakes were identified throughout the participants' tests. Sixteen mistakes (57 percent) were found when participants tried to schedule a medication. Ten mistakes (36 percent) were associated with the task of recording a skin issue. The remaining two mistakes (7 percent) were related to scheduling a mood alert. The overall error rate was 2.7 percent, which signifies five mistakes in the 181 steps that the participants averaged to complete all six tests. Higher error rate were identified in the tasks of scheduling a medication and recording a skin issue.

As shown in Table 3, 14 mistakes (50 percent of 28) were found in test 1. In test 2, there were 12 mistakes, and only 2 mistakes occurred in test 3 (respectively, 43 percent and 7 percent). The mistakes could be categorized into the following three groups:

- Type A: Four mistakes (14 percent) were associated with participants' understanding of words. For instance, participants 1, 2, and 4 had difficulty understanding the meanings of the words "alias" and "once per week" on the MyMeds app and/or the meaning of "start date" on the Mood app.
- Type B: Twenty-one mistakes (75 percent) were associated with participants' familiarity with the activity flows of the apps. Problems were identified in the following activities:
    - Participants experienced problems in locating the plus symbol for adding a new medication schedule (participant 3) or adding a new skincare report (participants 2, 3, 4, 5, and 6).
    - Participants 1 and 6 saved a medication without scheduling an alert.
    - Participants 3 and 6 encountered a problem in adding a new skin record.
    - Participant 1 saved a skin problem without completing the survey.
    - Participants 1, 2, 5, and 6 forgot to save the alias and notes for completing the task to schedule a new medication.
- Type C: The remaining three mistakes (11 percent) were associated with participants' interactions with the apps:
    - Participant 3 did not notice that he had to click on a medication to select or expand for a detailed list.
    - Participant 1 clicked the save button twice, which caused a run-time system error

displaying the message "iMHere application is not responding" in the task for scheduling a Mood alert.

As previously mentioned, weighted scores were added to all mistakes to describe the difficulty-on-performance (*DP*) preceding task completion. As shown in Table 3, with the exception of participant 1, who received a two-sentence reminder to save the alias and notes (*DP* = 3), all other participants were able to self-correct the mistakes without any help (*DP* = 1) or with one-sentence assistance (*DP* = 2). Additionally, a decrease in the scores for *DP* was observed in test 1 (*total DP* = 27) to test 2 (*total DP* = 19) and test 3 (*total DP* = 2). Scheduling a new medication was the most complicated task, with an overall *DP* score of 31 (the sum of *DP* scores from test 1, test 2, and test 3) (see Table 3). The task of responding to a skincare alert to record a skin problem was the second most complicated task, with an overall *DP* score of 14. The tasks of scheduling a mood alert (*total DP* = 3), responding to a mood alert (*total DP* = 0), responding to a TeleCath once-per-day alert (*total DP* = 0), and responding to a BMQ alert (*total DP* = 0) were easier for participants compared to the previously mentioned tasks.

About 93 percent ($n = 26$) of mistakes were prevented after test 2. In test 3, participants 2, 4, 5, and 6 were able to conduct all tasks without mistakes, and participants 1 and 3 were able to self-correct the mistakes without any help (*DP* = 1). Twenty mistakes (about 70 percent) were able to be corrected by participants after a one-sentence reminder from the researcher (*DP* = 2) in tests 1 and 2. Two mistakes (7 percent) required a two-sentence reminder for participants, and that occurred in test 1 only.

Users' Satisfaction with iMHere Apps

The iMHere apps received a high average TUQ score of 6.52 out of 7 points (93.1 percent, $SD = 0.58$). As shown in Figure 3, the factors for reliability and usefulness obtained lower average scores at 6.08 and 6.22 (87 percent and 89 percent; see Figure 3). Two participants gave low scores of 3 on the questions under usefulness because they still had concerns as to how effectively iMHere improves access to healthcare services. Since all participants encountered at least two mistakes during the tests, three of them gave relatively lower scores of 4 for the reliability of the system in giving error messages. (See Figure 3.)

Table 4 shows the TUQ score obtained from each participant, his or her average time to complete the tasks, and the number of mistakes preceding task completion. According to Spearman's correlation, a slightly negative relationship was identified between participants' TUQ scores and the average time, with $r = -0.257$ and $n = 6$, but this correlation was not significant, $p > 0.05$. An insignificant negative correlation was also identified for TUQ scores and mistakes, $r = -0.203$, $n = 6$, $p > 0.05$. Additionally, a positive correlation was identified for the average time to complete tasks and the mistakes encountered by participants, $r = 0.464$, $n = 6$, $p = 0.354$, but this correlation was not significant at the $p > 0.05$ level. See Table 5.

The five iMHere apps in this study were developed to encourage important self-care activities for individuals with SB. Depending on participants' individual medical and psychological needs for self-care, their preferences for using iMHere apps might differ. As shown in Table 5, all participants were interested in using the Skincare app because they all used wheelchairs and could easily develop pressure wounds due to insensate areas of skin. Four out of six participants thought the MyMeds app for medication management was important because they had up to 10 routine medications.

Participants 1 and 2 said staff members would always remind them about managing their bowel movements, so the BMQ app might not be necessary for them. The mood survey for preventing depression was commonly recommended on a biweekly or monthly basis; participants 3, 4, and 6 thought the Mood app might not be as important as the other apps. Participants 4, 5, and 6 did not think the TeleCath app would be very helpful considering that they do not have problems with neurogenic bladder. Besides their preference of apps, the following quotes highlight participants' feedback on the iMHere apps:

Participant 1: "*Like in skincare that uses color to separate body parts, if we have different colors to separate each application, that will help me to know which app I am using now*."

Participant 2: "*Light text color is a little bit hard for me to read*."

Participant 3: "*That will be great if I can change the text color and/or size*."

Participant 5: "*Some buttons are kind of small, a little bit bigger should be better*."

Participant 6: "*Buttons might be small, I have a big finger*."

Conclusion

In general, the smartphone is an ideal tool for implementing wellness programs,[34] but it poses accessibility challenges because of the lack of screen space,[35] small form factors,[36, 37] and the high number of steps to accomplish a task in an app.[38] Previous studies have suggested that auditory feedback could be used to enhance the accessibility of mobile phones.[39–43] Sound feedback can be used to improve the usability of buttons.[44] Universally designed models featuring large font sizes can help visually impaired users to have access to e-mail messages and mobile Internet sites.[45]

This study explored the accessibility of iMHere apps, focusing on the user interface and navigation. Scores from the TUQ indicated that the iMHere apps were viewed positively (6.52 out of 7 points, 93 percent). All of the participants were satisfied with the iMHere apps and would use them again in the future. Neither the longer average time to complete tasks nor the number of mistakes significantly affected participants' perception of iMHere usability (TUQ score). Participants' actual experiences with the apps might play a more important role in the overall usability and satisfaction. Since the lowest score was received under the usability factor of reliability on the TUQ, the ease of noticing and recovering from mistakes might have a negative impact on satisfaction levels. Shorter times to complete tasks and reduced error rates were seen over repeated trials. Learning effects, specifically, might play an important role in the continuity of training and the effective use of iMHere apps because participants' experiences from prior tests appeared to have carried over to the next test.

Several important findings from this study reveal ways to improve the accessibility of smartphone apps:

1. Appropriate use of words: Although the iMHere apps were designed by clinicians with expertise in the care of individuals with SB, 14 percent of mistakes were still associated with participants' perception of words. Using simple and common words such as "the reason to take medication" to replace the word "Alias" in the MyMeds app might be more effective to ensure the readability and understandability of the text for participants, particularly those with cognitive impairments or problems with reading comprehension.
2. Appropriate use of text style: Using a light text color such as white or yellow on a light background (e.g., gray) is not recommended. Using contrasting colors between the text and background and adding shadows to text may enhance the contrast and improve readability.
3. Use of in-app directional notes: Seventy-five percent of mistakes that were encountered by participants were related to task procedures. For instance, participants forgot to click the plus sign to add a new schedule, forgot to save data, or saved data without completing a survey. A short, one-sentence reminder providing directional guidance might be useful to prevent these types of mistakes.
4. Use of large target size: Small target size of icons or buttons is not only a problem for users with dexterity impairments, but also an accessibility issue for people with large fingers or for those who prefer to have larger icons. Using larger icons or buttons would improve physical access to icons and buttons.
5. Use of thematic colors: Participants highlighted the usefulness of colors to indicate the status of whether or not a medication is scheduled (green vs. red). The use of color to separate body parts also helped participants to correctly specify the location of problem skin areas. Using color to separate the apps would easily let users know which app they are using.
6. Use of personalized app lists: Not all five apps are useful for all participants. Providing the ability for users to choose which apps they want to use might help increase user satisfaction.

One limitation of this study is the small sample size. Individuals with spina bifida have a broad range of abilities. Because all the users were able to use a smartphone, and because prior work has shown that three to five participants are sufficient to uncover most of the basic accessibility issues of a system, our sample was likely sufficient to assess the accessibility challenges of a larger population. In fact, our study shows that some common accessibility challenges can be solved by a few simple design changes such as providing the ability to change the size of text and icons or providing in-app directional notes to prevent errors, and we expect these changes to have applicability for a broad number of users with various impairments. More work is planned to evaluate individuals who have more complex cognitive, sensory, or motor impairments that make use of a smartphone difficult.

Moreover, personalization provides the ability for a participant to modify the appearance of screen contents including size, color, and a list of apps based on his or her needs and to address concerns related to accessibility. Because users' needs for iMHere apps and their interactional preferences, including text color and button size, vary by individual, personalization may enhance accessibility for people with and without disabilities. For instance, a larger display text could benefit participants with visual impairment or farsightedness; larger target size could benefit participants with dexterity issues or large fingers. Designing and developing personalizable and fully accessible iMHere apps will be the next step in improving the accessibility of these mHealth tools.

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