Universally Designed mHealth App for Individuals Aging with Multiple Sclerosis

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***Abstract*—Multiple Sclerosis (MS) presents with chronic symptoms that share many of the functional limitations associated with aging. Additionally, following the period of five years post-diagnosis a large number of individuals diagnosed with MS experience a major decline in their abilities due to the progression of MS. Consequently, they need to learn how to cope with the functional limitations caused by the disease and in addition to those caused by aging. These individuals have to manage the effects of the disease on their lives every day. mHealth apps provide potential support for disease self-management. However, the number of mobile apps design specifically for individuals with MS is inadequate. Additionally, there is no evidence that utility and usability of these current consumer mobile apps were tested with their target population. This research paper describes the design of the mHealth app MS Assistant, an evidence-based app that provides the daily support and self-management of the disease to individuals aging with MS. It was developed based on the Universal Design Mobile Interface Guidelines, UDMIG v.2.1 and the results of the two previous studies that assessed the health and wellness self-management needs in individuals with MS and tested the usability of current mHealth apps. The paper presents an app refinement based on the suggestions of the expert reviewers who tested the effectiveness of the implementation of the UDMIG v.2.1 in the app design and provided possible recommendations for its redesign.**

Keywords-mHealth apps; multiple sclerosis; aging with disabilities; universal design.

I. INTRODUCTION

The size of the population aging with disabilities is growing [1][2]. Individuals aging with Multiple Sclerosis (MS) are one example of this population. MS is an inflammatory disorder of the Central Nervous System (CNS). This chronic and progressive disease is affecting around 400,000 individuals in the US and 2.5 million people worldwide, with approximately 10,000 newly diagnosed cases of MS annually [3]. It is one of the most common causes of disability in young adults.

MS presents with chronic symptoms that share many of the functional limitations associated with aging (e.g., fatigue, problems with balance, weakness, vision impairments, cognitive impairment, pain, sleep disorders, bowel and bladder dysfunction) [4]-[7]. Additionally, a large number of people diagnosed with MS experience a major decline in their abilities due to the progression of MS after five years post-diagnosis [8]. Consequently, these individuals need to learn how to cope with the functional limitations caused by the disease and in addition to those caused by aging.

MS has significant consequences on patients' Quality of Life (QOL) [9][10]. Individuals with MS experience a large number of physical, cognitive and emotional challenges on a daily basis [11][12]. As the most common symptoms in people with MS, fatigue, functional disability, and cognitive impairment have an enormous impact on a person's health-related QOL [13]. As a result, these individuals have to manage the effects of the disease on their lives every day. More specifically, they need a continuous disease, symptom, and medication management, coupled with education and effective strategies for addressing the exacerbations (i.e., a worsening of old symptoms or an onset of new symptoms for at least 24 hours, also called a relapse) [12].

mHealth apps provide potential support for disease self-management [14]. These health and wellness self-monitoring mobile apps can assist with the daily organization of health and wellness, communication with the healthcare providers, and patient education. The majority of individuals diagnosed with MS already use modern communication technology regularly [15]. They accepted and adopted new forms of electronic communication (e.g., mobile app, text messaging, email, and website) for exchanging information about MS with the health care providers for the management of MS and scheduling appointments.

However, the number of mobile applications designed specifically for the people with MS is inadequate. Additionally, there is no evidence that utility and usability of these consumer mobile apps were tested with their target population.

This paper describes the design of the mHealth app MS Assistant, an evidence-based app that provides individuals aging with MS with the daily support and self-management of their disease [16]. It was developed based on the Universal Design Mobile Interface Guidelines, UDMIG v.2.1 [17]-[20] and the results of the two previous studies [16][18] that assessed the health and wellness self-management needs in individuals with MS and tested the usability of current mHealth apps. The paper presents an app refinement based on the suggestions of the expert reviewers who tested the effectiveness of the implementation of the UDMIG v.2.1 in the app design and provided possible recommendations for its redesign.

This paper is organized into six sections. Section II reviews the related work about technological support for people with MS and other chronic conditions that share

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similar symptoms with MS. Section III describes the initial design of MS Assistant. Section IV summarizes the evaluation of the effectiveness of implementing UDMIG v.2.1 in the design of the app through an expert review. Section V presents the refinement of MS Assistant based on the recommendations of the expert reviewers. Section VI provides a conclusion and proposes future work.

II. RELATED WORK

The majority of individuals with MS use modern communication technology regularly (i.e., personal computer, internet, email, mobile phone) [15]. They have high levels of acceptance for using electronic communication methods for exchanging information with health care providers. Ninety six percent of them possessed mobile phones and older participants used it less frequently. However, there is a lack of relevant previous research on needs and concerns of individuals aging with MS [7] to inform the design of the mHealth apps for this group of end-users.

There are only nine current mobile applications available to this group of users, which primarily focus on providing basic information about latest research, news, and practical tips on health, nutrition, and fitness, self-recording of health status, medication adherence, daily activities, symptoms, mood, and similar, and/or sharing the data with healthcare providers. These nine mobile apps provide only basic functionality that can be found in other health apps for the general population and individuals with other chronic conditions. Multiple Sclerosis Association of America (MSAA) released a mobile phone app for health self-reporting, My MS Manager, for individuals with MS and their caretakers [21]. Similarly, MS self app offers a journal that can be later easily accessed by the user who can share their data with the healthcare team [22]. Another self-reporting app is called MySidekick for MS [23], which also provides medicine reminders and a memory exercise. My MS Conversations provides an interactive group session with experienced virtual patients on selected topics [24]. MS Journal is an injection reminder tool for individuals with MS and their caregivers limited to UK market only [25]. My Multiple Sclerosis Diary [26] is another injection reminder mobile app that offers injection location and time set up. SymTrack was designed as a health self-reporting tool that stores shares the health charts with healthcare providers [27]. Social app MS Buddy [28] pairs individuals with MS with another person with MS to chat daily. MS Attack app [29] helps users learn about MS symptoms, how these present themselves during the MS attack and provides a location of the UT MS Clinic and the Neuro Eye Center.

III. MS ASSISTANT

MS Assistant is an evidence-based app, which provides the health and wellness self-management-based functionality, allows for personalization, assists with medication adherence and other daily tasks with alert and reminder systems, and sends alerts to the caregivers, family members, and healthcare providers in a case of an emergency. Its eight functions were selected based on the findings of a qualitative study [16], which was conducted to identify the specific needs for self-management of health and wellness among people aging with MS and to recognize the opportunities to meet those needs through mobile apps. The functions include diary, reports, MS friends, games, education, goals, vitals, and emergency. In addition, profile and settings were designed to offer personalization and customization. Additionally, MS Assistant was designed using the UDMIG v.2.1, which were prioritized based on the previous study [18] that assessed the usability of the two current mHealth apps for people with MS and one for the general population to provide the recommendations for the design of mobile health and wellness app for individuals with MS.

A. Functionality

Diary provides a comprehensive tool for understanding the disease on a daily basis and over time, and how best to manage it through everyday self-management tasks, such as mood, symptoms, energy level, activity, sleep length and quality, and diet. Reports allows users to compile their health management data into useful reports that can be shared electronically with healthcare providers and caregivers. MS Friends is a social support feature that connects users with other people with MS to share their experiences and everyday challenges. Games features VR games that would enable users to perform real-world activities that they might find challenging. In addition, this feature has cognitive and classic games that help people with MS with cognitive functioning, and physical games, which help them with the balance. Education provides the latest news and research about MS as well as health and wellness tips. Goals enables users to set up their personal health and wellness goals to keep them motivated and inspired. Vitals offers remote health and wellness monitoring through the Bluetooth connected devices, such as blood pressure monitoring devices, scales, sleep and activity trackers (e.g., Fitbit), and similar. Emergency lets users place calls directly to their healthcare providers, caregivers, and 911.

The mHealth app sends alert messages to the caregivers, family members, and/or healthcare providers in a case of an emergency (i.e., when the values of certain vitals go above the threshold, such as blood pressure, self-reported depression, extreme values of the symptoms severity, etc.).

B. Navigation

MS Assistant provides two types of navigation: linear and random access. Linear interaction allows users to go through the pages by making or skipping a selection and pressing the Next button. Users can go through the whole interface in a linear fashion by using the Next and Back buttons on every page, which provides consistency and simplicity. After a selection is made, the Next button takes users to the following page of the interface. When the user taps on any button, the button changes to the selected colored background and white text that visually emphasizes the selection. To change the selection, user can tap the button again to deselect it (Figure 1). Random access allows skipping the options and provides a faster pace of the navigation through the direct selection (Figure 2).

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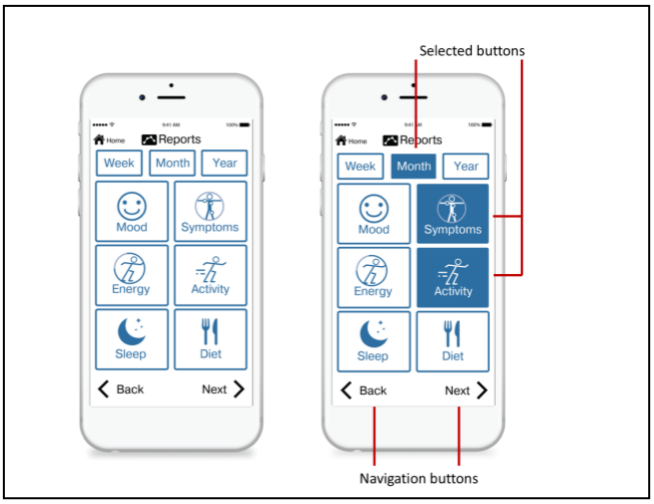

Figure 1. Linear navigation on Reports page.

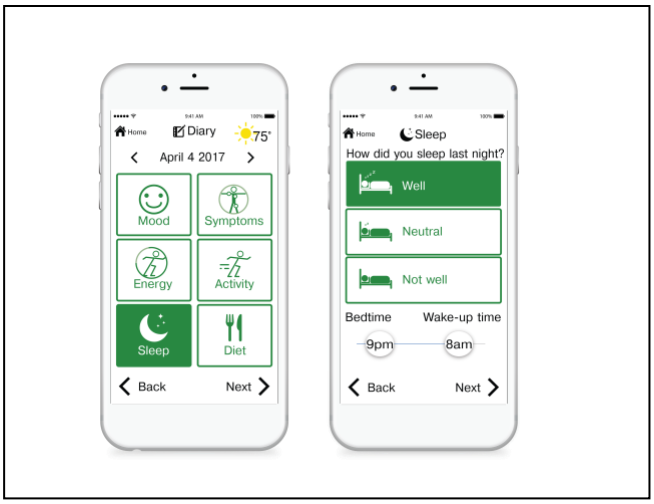

Figure 2. Random access on Diary page.

C. Design Decisions

MS Assistant was designed based on the UDMIG v. 2.1 and corresponding design criteria, which has been previously reported [20]. For example, the design goal was one mobile app for all users, rather than accessible design for people with disabilities, and avoidance of specialized design and language (*Same means of use*). Consistent sequences of actions are required in similar situations (*Consistency with expectations*). Complexity is eliminated by having simple screen designs that require a small number of tasks per screen (*Simple and natural use*).

IV. Evaluation of the Effectiveness of Implementing the UDMIG v.2.1

Evaluation of the effectiveness of implementing UDMIG v.2.1 in the design of MS Assistant was conducted with expert reviewers who identified design elements that needed improvement to successfully apply the guidelines and recommend possible refinements [20].

A. Methods

Ten researchers and/or designers with experience in aging, accessibility, human-computer interaction, human factors, industrial design, universal design, and/or usability participated in the study. They completed a demographic questionnaire [20], performed directed tasks using the script and MS Assistant without any training or assistance. The script included entering health and wellness data, emailing the reports, calling MS friend, finding virtual reality games, reading the MS news, setting up the weight goal, inputting the blood pressure, calling the healthcare provider, entering the personal information, and increasing the text size [20]. The whole study was audio recorded. Experts then used the UDMIG v.2.1 design criteria questionnaire to rate how well each guideline was implemented, to identify design elements needing improvement, and to provide possible recommendations for their refinement on the 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree with each of the applicable design criteria. Additionally, the audio files during the participants' use of MS Assistant and administration of the talk aloud protocol were analyzed to extract more usability problems they encountered during the interaction with the app.

B. Results From the UDMIG v.2.1 Design Criteria Questionnaire

10 participants rated 50 items (i.e., design criteria) on the checklist. The total number of responses was 484, with 16 missing responses that were not used in the data analyses. The mean of all the design criteria ratings per participant was within a range of 3.90 – 4.89. Out of a total of 484 responses, almost 70% (n=332) of the design criteria was rated as 5. An additional one-quarter (n=126) was rated as 4. The lowest rating for any criterion was 2 (n=6) and remaining 20 design criteria were rated as 3. Among the 10 participants, mean ratings ranged from 3.86 – 4.92. The participant with the lowest overall mean rating (M = 3.86) did not give a rating higher than 4 to any individual criterion with 44 rated as 4 and 6 rated as 2 or 3.

C. Results from the Audio Transcripts

During the talk-aloud protocol expert reviewers identified usability problems with the interface. Audio transcripts revealed some additional usability problems reported by the participants and the existing problems were reported by a larger number of participants verbally, except in the case of the color contrast and alternative voices in Settings. All usability problems were grouped into the problematic design features and related characteristic so that appropriate design response could be specified.

Main usability problems were labeling of the buttons, use of Next and Back buttons for the linear navigation, design of a number of UI elements, lack of page scrolling with the use of a keyboard, layout of a number of the buttons, certain feature requests, miscategorization of a number of labels, and

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navigation related to the design of the buttons and pages. For example, problems with the labels for Education, Emergency, Input, and Output buttons were reported by a majority of the participants (Table I). Labeling of the Speech button was reported by 40% of the participants. Additionally, participants commented unfavorably on the use of Next and Back buttons for the linear navigation. However, they understood that the linear navigation using these two buttons might be more usable for the aging population of users. Moreover, they acknowledged that the smart interface and an option to switch from novice to expert user skips this way of the navigation for the more tech-savvy users.

Design of certain UI elements was reported as well. For example, Profile and Settings did not look like buttons, and the slider needed some redesign to half of the participants. Thirty percent of participants reported that Header looked like a button and that certain icons need to be redesigned. Additionally, half of the participants reported that the page scrolling should be present while using the keyboard. Sixty percent of participants reported that the layout of the buttons needed to be changed (e.g., locations of Email Reports and View Reports buttons should be switched). Additionally, 40% of them thought that the spacing between the top buttons (e.g., Manual input button in Vitals, Week, Month, Year buttons in Reports) and the buttons bellow should be increased. Total of 30% of participants thought that after missing to fill out all the fields on one page, the prompt that follows should give them two options. First, it should let them go back to the previous page to fill out the missing content. Alternatively, it should allow them to go to the following page and leave certain fields empty.

There was a number of problems that were found on the audio transcripts, which were not reported on the questionnaire. For example, 60% of participants thought that the app would benefit from the additional features (e.g., a place to specify the body area in Difficulties, the user's current weight with the text "This is what your weight is right now" in the weight goals, a lauder sound feedback with the use of the buttons, etc.). Miscategorization of certain labels was a problem to half of the participants. Additionally, 60% of participants reported problems with navigation due to the lack of direction, page design, and multiple selections.

Moreover, there was a number of problems and related design features and characteristics that were reported by a small number of participants, listed in Table I (i.e., one and two participants).

V. REFINEMENT OF MS ASSISTANT

All the design features and related characteristics that needed to be redesigned based on the results of both the UDMIG v.2.1 design criteria questionnaire and audio transcripts were summarized (Table I). The rationale for the design response was to make a design change if in agreement with UDMIG v.2.1, if at least two participants reported the problem, and if the suggestions were not already present in the prototype of MS Assistant. For the number of participants in Table 1, the larger number reported by either the analysis of audio files or the UDMIG v.2.1 checklist was used. This way, the total number of participants reporting a problem was listed.

Dark grey background on the instruction pages was changed into white to provide more contrast against the black and green (i.e., confirmation) text (Figure 3). "Education" was renamed into "Resources", "Emergency" into "Emergency Contacts" (Figure 4), "Energized" (in Mood) into "Excited", "Input" into "Speech Input", "Touch" into "Touch Input", "Output" into "Display and Sound", and "Speech" was replaced with "Voice".

Due to the lack of space on the top navigation bar, name of the app, MS Assistant, was taken out of the Home page and the icons for Profile and Settings were added (Figure 4). The color of the icons for the current state (e.g., Diary, Reports, etc.) was changed from black into the color of that function (e.g., Diary icon in green, Reports icon in blue, etc.). In this way, the icon and the header look like the part of the page background and not like the buttons (Figure 3).

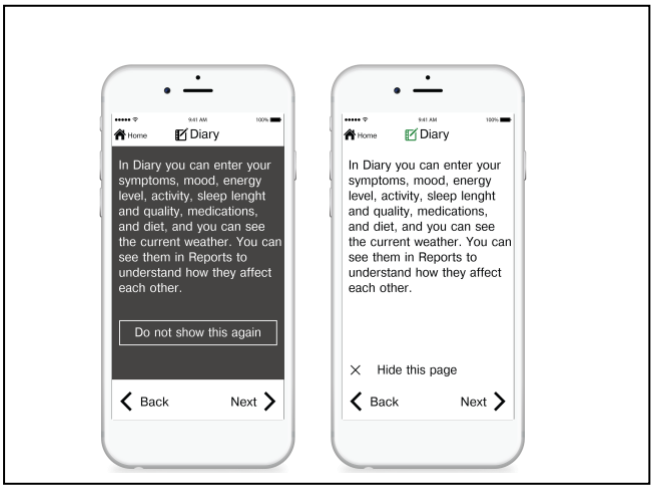

Figure 3. Before (left) and after (right) Diary Instruction page

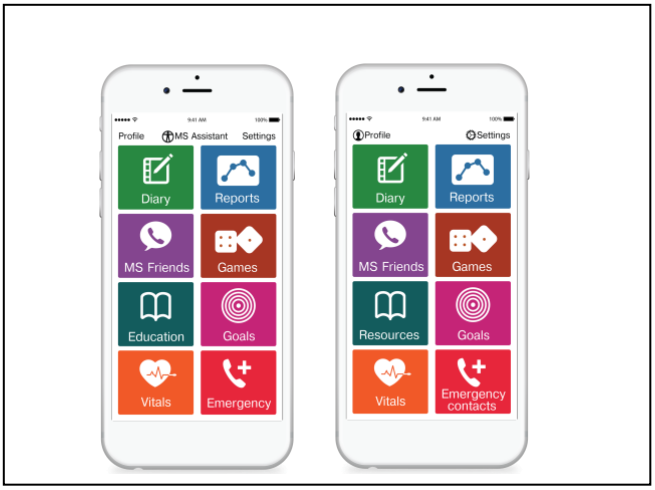

Figure 4. Before (left) and after (right) Home page

TABLE I. DESIGN CHANGES BASED ON THE IDENTIFIED PROBLEMS WITH THE DESIGN FEATURES AND CHARACTERISTICS THROUGH BOTH THE UDMIG V.2.1 DESIGN CRITERIA QUESTIONNAIRE AND AUDIO TRANSCRIPTS

Design Feature and Related Characteristic		**Number of Participants, N**	**Design Response**	**Design Changes**
Background, Contrast		N=3	Increase contrast	Grey was changed into white with black and green text on instruction pages.
Next and Back buttons, Navigation		N=7	No change	No change was made due to the design criteria IC2d. (i.e., Have more than one way to go to different pages while keeping the consistency). Next and Back buttons are typical of linear navigation.
Buttons, Labeling	Education	N=7	Change labeling: Education	"Education" was renamed into "Resources".
	Emergency	N=7	Change labeling: Emergency	"Emergency" was renamed into "Emergency Contacts".
	Energized	N=2	Change labeling: Energized	"Energized" (in Mood) was changed into "Excited".
	Input, Output	N=7	Change labeling: Input, Output	"Input" was renamed into "Speech Input", "Touch" into "Touch Input", and "Output" into "Display and Sound".
	Speech	N=4	Change labeling: Speech	"Speech" was renamed into "Voice".
	News	N=1	No change	No change was made to "News" due to the inconsistency with other button labels within "Resources."
	Diary	N=1	No change	No change was made due to the small number of participnats reporting the problem.
	Do not show this again	N=1	No change	No change was made due to the small number of participnats reporting the problem.
UI elements, design (form and color)	Profile, Settings	N=5	Redesign Profile and Settings buttons	Name of the app, MS Assistant, was taken out of the Home page top navigation bar, and the icons for Profile and Settings were added.
	Header	N=3	Redesign header	Black color of the icons for the current state was changed into the color of that function (e.g., Diary icon in green, Reports icon in blue, etc.).
	Slider	N=5	Redesign slider	Numbers on the slider were placed on the top of it.
	Icons	N=3	Redesign icons	Speech icon was replaced with Output icon, and Input icon with Speech icon. Output icon and Seeing icon (in Difficulties) were redesigned.
	MS type	N=1	No change	No change was made due to problems that drop-down menu causes for people with limited dexterity, similar to the use of the picker.
Settings, Alternative voices		N=3	No change	No changes were made since this prototype included voices within the Settings.
Keyboard, spell check		N=1	Provide spell check w/keyboard	Spell check was provided within the keyboard.
Keyboard, Page scrolling		N=5	Add page scrolling w/keyboard	Page scrolling was added with the use of a keyboard.
Prompt, Content		N=3	Redesign prompt	Prompt was redesigned to inform about the missing data and to allow the navigation to the following page without having to fill out all information.
System, Navigation		N=2	Add text to the first instruction page	Text about the navigation and using Next and Back buttons was added to the first instruction page.
Text, font size		N=2	Increase font size	The font size of the MS News articles was increased.
Buttons, Layout		N=6	Change the layout	View Report button was moved above the Email Report button. Names of the VR games were shortened. The other changes were not made due to the inconsistencies.
Buttons, Haptic feedback		N=3	No change	iPhone 6 does not have the Taptic Engine that provides the vibration.
Buttons, Single tap		N=1	No change	No change was made due to the design criteria IC13a (i.e., Use a single tap throughout the app instead of double-clicking).
Button spacing, Layout		N=6	Increase spacing	Spacing between the top buttons and large buttons bellow was increased.
Feature, Feature request		N=6	Add information about a MS friend	Information about MS Friends was added on the calling page. No other changes were made due to the small number of participants reporting the specific problem (N=1 per problem).
Labels, Miscategorization		N=5	No change	No changes were made due to the small number of participnats reporting the specific problem (N=1 per problem).
Page layout, Lack of consistency		N=2	No change	No change was made to the second page of Reports due to the lack of page space.
Keyboard, On-screen verification		N=1	No change	No change was made since the on-screen verification exists within the input field.
Buttons and pages, Navigation		N=6	No change	No changes were made to the small number of participants reporting the specific problem (N=1 per problem).
Lack of confirmation of an activity, Navigation		N=1	No change	No change was made due to the small number of participants reporting the problem.

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Numbers on the slider were placed on the top of it. Speech icon was replaced with Output icon, and Input icon with Speech icon. Output icon and Seeing icon (in Difficulties) were redesigned. Even though only one participant reported that there was no spell check with the use of a keyboard, this general feature was implemented because it is present in a majority of the apps. Page scrolling was added with the use of a keyboard. A prompt was redesigned to inform about the missing data in a way that allows users to go to the following page without having to fill out all information (i.e., "Do you want to fill out the missing information?" with Yes that takes them back to the previous page, and No that takes them to the following page). Text about the navigation (i.e., linear navigation using Next and Back buttons) was added to the first instruction page. The font size of the MS News articles was increased. The layout of the buttons was changed (e.g., View Report button was moved above the Email Report button, and the names of the VR games were shortened). The other layout changes were not made due to the inconsistencies with the page layout. A spacing between the top buttons and large buttons bellow (e.g., Manual entry, and Week, Month, Year buttons) was increased. There was a number of feature requests. For example, additional information about MS Friends is added on the calling page (e.g., friend's interests, MS type, and other information the person wants to share). No changes were made to the other feature requests due to the small number of participants reporting the problem (N=1 per problem).

There were 7 participants reporting a problem with the navigation using Next and Back buttons. However, no change was made due to the design criteria IC2d. (i.e., Have more than one way to go to different pages while keeping the consistency). Next and Back buttons are typical of linear navigation and will be used in the novice user mode only. Additionally, 3 participants did not see that this prototype included alternative voices within the Settings and a problem with it. Similarly, 3 participants reported problems with the lack of the tactile feedback, which was not incorporated because iPhone 6 does not have the Taptic Engine that provides the vibration while tapping the buttons that was included in later versions. The total number of participants reporting the problems with the miscategorization of the labels was 5. However, no changes were made due to the small number of participants reporting the individual problem (N=1 per problem). No change was made to the second page of the Reports due to the lack of page space (N=2). Even though was there was a total of 6 participants who reported a problem with the navigation due to the design of the buttons and pages, no changes were made due to the small number of participants reporting the specific problem (N=1 per problem).

VI. Conclusion and Future Work

The goal of the reported study was to have expert reviewers assess the usability of MS Assistant. The results of the expert review study confirm that MS Assistant effectively implemented UDMIG v.2.1. Most of the participants favorably agreed that the guidelines were implemented appropriately. Ninety percent of the mean values of the participants' ratings were equal to 4 or higher. In addition, there was only a small number of recommendations related to the minor usability problems found in MS Assistant. These design changes were easily implemented in the MS Assistant. Future work will involve usability testing of this mHealth app with the individuals diagnosed with MS at least 5 years ago to understand the overall usability of this mHealth app to determine the effectiveness of UDMIG v.2.1 in producing a universally usable product. This study will help with the analysis of the user-specific differences and preferences towards the individual design features and resulting the design implications.

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