Design and Evaluation of Mobile Interfaces for an Aging Population

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Abstract—**The design and evaluation of mobile interfaces for older adults are becoming more important as the population ages and their use of technology increases. Current design strategies, which are used to guide the design of mobile interfaces, are either not primarily developed for mobile platforms or are not focused on the aging population with diverse limitations. Adaptation and integration of the existing strategies were necessary to create an inclusive and comprehensive set of guidelines for interactive mobile interfaces for older adults. The paper presents an overview of the Universal Design Mobile Interface Guidelines (UDMIG) and the related evaluation checklist. UDMIG v.2.1 and the evaluation checklist were developed to ensure usability of future mobile technologies by older adults through a universal design strategy that accommodates all users to the greatest extent possible. This paper contributes to human-computer interaction research by including this population of users and advancing the technology uses for the mobile touchscreen interfaces for aging population.**

Keywords-aging; design; evaluation; mobile interfaces.

I. INTRODUCTION

Older adults encounter many barriers associated with aging while interacting with mobile applications [1]-[4]. Lack of physical space (e.g., small touch and physical buttons), confusion with their location within the context, use of menus that require precise movements, use of small fonts, content placement, and use of large contents that require memory recall, are some of the barriers that lead to longer and less successful task completion [5][6].

The design and evaluation of mobile interfaces for older adults is becoming more important as the population ages and their use of technology increases. Current design strategies that guide the design of user interfaces are either not primarily developed for mobile platforms or are not focused on the aging population with diverse limitations. Moreover, there is a lack of evaluation tools for mobile applications designed for older adults. Four established design strategies for desktop and mobile user interfaces for the general and aging population were analyzed: Universal Design (UD), Design for Aging (DfA), Universal Usability (UU), and Guidelines for Handheld Mobile Device Interface Design (MID). Adaptation and integration of the existing strategies were necessary to create an inclusive and comprehensive set of guidelines for interactive mobile interfaces for older adults. In addition, the evaluation checklist was created to support the user testing of mobile applications designed for an aging population.

The research paper presents an overview of the Universal Design Mobile Interface Guidelines, UDMIG v.2.1, and the related evaluation checklist. UDMIG v.2.1 and the evaluation checklist were developed to ensure usability of future mobile technologies by older adults through a universal design strategy that accommodates all users to the greatest extent possible.

This paper is organized into five sections. Section II describes the related work that covers four sets of design guidelines used to develop the resulting UDMIG. Section III describes the final version of the design guidelines. Section IV addresses the related evaluation checklist. Section V summarizes the paper and proposes future work.

II. RELATED WORK

The purpose of UD is to design for everyone and by doing so, to overcome the barriers to usability that come with aging [7][8]. It consists of seven principles of universal design and twenty-nine guidelines. In contrast to UD, DfA [9] focuses on specific limitations of older adults. DfA is a strategy that explores the factors that constrain the use of products and user interfaces by older adults, as well as aspects of human-computer interface design that accommodate older users with age-associated disabilities and limitations [10]. It has fifty-two design guidelines grouped into six categories that cover design of visual, auditory, and haptic presentation of information, input and output devices, and effective interface design.

Based on UD, which initially covered the design of physical environments (e.g., buildings, spaces, products, graphics), UU was developed to support usability, inclusivity, and utility of information and communication technology [11]. It contains eight guidelines, called the Eight Golden Rules of Interface Design. Guidelines for Handheld Mobile Device Interface Design [12] were based on UU, modifying its eight design guidelines and adding the guidelines applicable to mobile and touchscreen platforms.

While UD, DfA, UU, and MID represent design strategies that are currently used to guide the design of mobile interfaces, none are sufficiently comprehensive to ensure that mobile user interfaces will be usable by older adults. UU, DfA, and UD guidelines were not originally developed for mobile interfaces, although UD has recently included this platform to a certain extent. MID fails to

acknowledge diversity and the ranges of limitations that the aging population faces.

Moreover, there is a lack of relevant and comprehensive evaluation tools that support usability and equitability assessment of mobile touchscreen interfaces for an aging population. The existing assessment tools are either designed for other environments (e.g., products, services, spaces, buildings) or developed to support the design of mobile interfaces for general population, thus failing to acknowledge the diversity of limitations of older adults.

UD checklist [13][14] is an evaluation tool, which assesses the design based on both UD principles and ranges of users' abilities (i.e., vision, hearing, speech, cognition, dexterity, communication, balance, stature, upper and lower body strength and mobility, life span) to indicate the degree to which the outcome met the criteria for each design principle and each type of ability, respectively. This tool only considers the architectural spaces, does not assess the specific design features and evaluates the proposed and not the actual designs. The Universal Design Performance Measures for Products [8] uses twenty-nine UD guidelines as performance measures, and the five-point rating scale from strongly disagree to strongly agree, with a choice of not applicable to identify strengths and weaknesses of a product. This assessment tool is intended to be used by experts on aging and disability to evaluate the usability of the products throughout the life cycle, develop usability testing and focus groups, and identify and promote UD features of products. It is limiting in the application to complex and integrated products. The second version of this tool called the Product Evaluation Countdown [15], was developed for use by end-users with their ranges and levels of abilities to test the actual demands of products. Universal Design Assessment Protocol (UDAP) [8][16] assesses UD principles by ability as well as across the range of abilities, evaluating design at the level of each UD guideline, thus providing a more precise analysis. However, the tool proved to be very complex and impractical to actually quantify UD with its six hundred and twelve-cell matrix. The Global Universal Design Commission, Inc. (GUDC) created GUDC Rating System that covers design process, site and building elements, customer service, and facilities management, which is building-type specific [8]. WCAG 2.0 checklist [17] was developed to design accessible web pages to users with disabilities. It is also used to primarily evaluate the accessibility of HTML content. However, neither one of these evaluation tools was developed for the usability evaluation of the mobile user interfaces.

Heuristic evaluation [18] is widely used for web and mobile interface usability assessment. This usability engineering method was made to be an easy, fast, and cheap way of evaluating user interface design during the project lifecycle. An evaluation framework for mobile interfaces [19] is developed to allow designers and users to quickly test the prototypes on the actual devices. A number of other evaluation checklists and frameworks for testing the usability of mobile applications for the general population have been proposed [20]-[22]. However, these usability assessment tools do not recognize a variety and ranges of limitations an aging population faces.

III. UNIVERSAL DESIGN MOBILE INTERFACE GUIDELINES, UDMIG

The first version of the guidelines, UDMIG v.1.0, which has been previously reported [23][24], was created by applying DfA, UU, and MIG to seven UD principles and related guidelines. This version relied too much on principles and guidelines of universal design, failed to incorporate person-environment interaction approach that was a unique contribution of DfA, contained inconsistent language and level of specificity, and needed further refinement. As a result, UDMIG v.2.0 [25] was developed within a framework based on the two organizing principles: the Person-Environment (P-E) Fit Model [26], and Guideline Approach (i.e., prescriptive- vs. performance-based).

The P-E Model [26] assessed the match or fit between a person's ability and the demands of the environment to promote healthy aging. Usability of mobile applications is achieved when there is a match between a person's ability and the design of the interface. In UDMIG v.2.0, the person component is a part of all the guidelines as it describes how to accommodate people with different abilities. The fit component includes those guidelines that describe the design of the touchscreen mobile interface as a whole (i.e., interface context), as well as those that guide the design of the specific design elements of the mobile interface with which users interact. The environment component recognizes the requirements of the overall space and context of use (e.g., lighting and glare). Only the fit component is addressed in this paper.

Guidelines were also categorized into prescriptive- vs. performance-based. Prescriptive guidelines focus on means and methods of achieving usability by dictating what must be done to achieve a usable outcome. This is largely achieved without specifying the design of the outcome. In contrast, performance guidelines focus on the product or results of the design process. Performance-based guidelines suggest what the usable outcome should be without regard to how that outcome is achieved. As a result, performance guidelines provide greater flexibility in design outcomes by providing opportunities for designers to rely on their own interpretation and creativity to achieve a usable outcome.

A. UDMIG v.2.1

UDMIG v.2.0 was refined and regrouped to better fit its organization into the interface context and design elements guidelines (See Table 1). Features guidelines were renamed into the design elements guidelines so that the resulting UDMIG v.2.1 precisely distinguish between the design characteristics and elements of the mobile interfaces. Design characteristics are specified based on the design elements guidelines and indicate clearly what exactly needs to be developed and designed for a usable outcome.

Interface context guidelines guide the design of the mobile touchscreen interface as a whole. For example, the mobile user interface needs to be designed in a way that the complexity is eliminated, and information arranged consistent with its importance to allow for natural use.

TABLE I.   UDMIG V.2.1

Design Elements Guidelines	Interface Context Guidelines
1. Choice in methods of use	1. Same means of use
2. Accuracy and precision	2. Design appealing to all
3. Minimization of hazards and unintended actions	3. Simple and natural use
4. Informative feedback	4. Consistency with expectations
5. Different modes of use	5. Internal locus of control
6. Simple error handling	6. Maximized "legibility" of essential information
7. Easy reversal of actions	7. Clear and understandable navigation structure
	8. Dialogs that yield closure
	9. Range of literacy and language skills
	10. Right-, left- or no-handed use
	11. Adaptation to users' pace
	12. Multiple and dynamic contexts
	13. Low physical effort
	14. Variations in hand and grip size
	15. Natural body position

Design elements guidelines cover the design of the specific elements within the mobile touchscreen interface that users interact with. For instance, a user interface is designed to provide the user with the option to change the color contrast (e.g., white on black vs. black on white).

IV.   UDMIG V.2.1 EVALUATION

Prescriptive design guidelines and standards are easy to interpret and to objectively test in the wild. Assessment of performance guidelines is multidimensional since it incorporates both activity and participation [8]. All performance-based guidelines are subject to interpretation by experts as well as end-users to a certain extent, which makes objective measurement slightly difficult. UDMIG v.2.1 Checklist rates all the design guidelines using the 5-point Likert scale. It is intended to be used by users as well as by the experts in the field to objectively assess usability and equitability of the mobile interfaces.

A.   UDMIG v.2.1 Checklist

The checklist rates agreement with each of the UDMIG v.2.1 guidelines. This evaluation sheet can help you think about your needs and those of other potential users when interacting with mobile applications.

1) Design Element Guidelines

1. This application provides alternate means of interaction such as speech input, hands-free, or eyes-free interaction.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

2. I am able to find the information I am looking for easily.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

3. The design of this application minimizes the occurrence of unintended actions (e.g., prompt messages, button placement, etc.).
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

4. A. This application provides informative feedback (e.g., a beep when pressing a key, an error message, etc.) that I am using it in the right way.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

    B. I am able to tell that I have successfully completed an action in this app.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

5. This application provides different modes of feedback such as audio, tactile, or visual feedback.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

6. The most important design elements in this application are readily available, and the app provides warnings of errors.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

7. I can easily reverse my actions if I make a mistake in using this application.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

B.   Interface Context Guidelines

1. I find this application useful and accessible.
    □1   □2   □3   □4   □5
    Strongly   Disagree   Neither   Agree   Strongly
    Disagree   Agree

2. The design of this app appeals to me.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

3. The interface of this application is easy to understand and not complex.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

4. Interaction in this app is consistent with my expectations and intuition.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

5. I am able to control the output of my actions when using this app.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

6. A. This application provides adequate contrast between background colors against the images and text.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

   B. Fonts and graphics are legible in this app.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

7. Navigation throughout this app is understandable, and I can easily find my way from one screen to the next.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

8. I am able to tell my status throughout the use of this app.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

9. I can easily understand the terms and language used throughout this app.
   □1 □2 □3 □4 □5
   Strongly Disagree Neither Agree Strongly
   Disagree Agree

10. The app provides right- or left-handed and single- or no-handed access and use.
    □1 □2 □3 □4 □5
    Strongly Disagree Neither Agree Strongly
    Disagree Agree

11. This application features an appropriate pace of interaction for me.
    □1 □2 □3 □4 □5
    Strongly Disagree Neither Agree Strongly
    Disagree Agree

12. I can configure output to my needs and preferences (e.g., text size, brightness).
    □1 □2 □3 □4 □5
    Strongly Disagree Neither Agree Strongly
    Disagree Agree

13. The amount of force required to perform actions in this app was adequate.
    □1 □2 □3 □4 □5
    Strongly Disagree Neither Agree Strongly
    Disagree Agree

14. Buttons, keys, and icons are large enough for me to select without error.
    □1 □2 □3 □4 □5
    Strongly Disagree Neither Agree Strongly
    Disagree Agree

15. I feel comfortable using this app regardless of my previous experience with mobile applications.
    □1 □2 □3 □4 □5
    Strongly Disagree Neither Agree Strongly
    Disagree Agree

UDMIG v.2.1 checklist is developed to be used by both experts in the field (e.g., designers, researchers, disability and gerontology experts) and older adults. The checklist is a usability and equitability evaluation instrument that can be used to identify usability problems during the design process as well as to test the final product.

V. CONCLUSION AND FUTURE WORK

UDMIG v.2.1 and related evaluation checklist were developed to ensure usability of future mobile applications by older adults. A universal design approach was used to accommodate all users to the greatest extent possible. Based on each UDMIG v.2.1 guideline, a representative statement with the 5-point Likert scale was created. The purpose of the checklist is to rate the agreement with each of the guideline. It was developed for end-users and usability experts to evaluate the usability and equitability of the mobile interfaces for an aging population.

The future work will require validation of the guidelines and the checklist through the application of UDMIG v.2.1 and evaluation of both the guidelines and the checklist with older adults and other users who represent variety and ranges of abilities. The planned work includes development and testing of an eHealth mobile application for individuals aging with Multiple Sclerosis (MS). People with MS represent an ideal user group for application and evaluation of UDMIG v.2.1 and the checklist. They are a diverse user group with symptoms

that vary widely from individual to individual and within an individual over time. UDMIG v.2.1 checklist will be evaluated with both experts in the field and individuals with MS.

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