Design Guidelines and Design Recommendations of Multi-Touch Interfaces for Elders

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***Abstract*— The usage of multi-touch interfaces on a tabletop device, has been very explored for elder users in several domains. This interaction technique is an alternative to reducing the obstacles that older adults face in the use of computer systems, e.g., handling of peripherals. Many design guidelines are proposed in the literature for a wide range of products and systems for elders, e.g. websites, TV user interfaces. However, there is a lack of set of design guidelines and design recommendations of multi-touch interfaces that matches elder's needs. This paper presents a set of design guidelines and design recommendations distilled and extracted from most relevant works on design of multi-touch interfaces for elders available in the literature. The results are a set of design guidelines, useful for designers, application developers, usability specialists and researchers.**

Keywords-Human-Computer Interaction; Natural User Interfaces; Multi-Touch Interfaces; Design Guidelines; Elderly

I. INTRODUCTION

Globally, we can verify that the population is aging [1]. Mamolo and Scherbov [2] revealed that overall population is decreasing with a substantial increase of the elderly population. The number of people aged over 65 years in the world is predicted to be about 1 billion by 2030, a significant growth in comparison with 420 million verified in 2000 [3], registering the largest number ever. Zaphiris et al. [4] referred that in 2030, one habitant out of four will have above the age of 65.

The growing number of elders makes evident the need of development of technologies for this user group [5][6] that accommodate their needs [4][7].

This user group presents own characteristics that differ from other user groups [8], part of them are age-related changes, e.g., physical and cognitive changes [9]. Nevertheless, there are in the literature several studies researching on age-related changes and how they influence the design of user interfaces [1][5][6][10][11] and others that focused the relationship of older adults with technologies [26][29].

The interaction through of traditional input devices, such as mouse and keyboard, is difficult for elders [7][12], and other interaction techniques have been explored to surpass these limitations [9], e.g., using multi-touch interfaces [7] [9][13] as a more natural user interface [14].

The design of a touch-based user interface should suit elder's needs [11] to be easily used [5], becoming an elder-friendly user interface.

A considerable amount of works has been published on design guidelines for older adults, e.g., for design of websites [4][15], design of mobile user interfaces [16][17], design of TV user interfaces [8][18]. These studies usually propose a list of guidelines for designing and evaluating the user interfaces. This is not verified in works with a list of design guidelines of multi-touch interfaces, which are scarce in the literature.

Although the design guidelines of other types of user interfaces can be used partly in the design of a multi-touch interface, some characteristic aspects are not addressed, e.g., the identification of the most suitable gestures for this target audience.

In that sense, this paper contains a set of design guidelines and design recommendations refined and extracted from most relevant works on design of multi-touch interfaces for elders existing in the literature.

The rest of the paper is structured as follows. Section II reviews the background of this work, including, age-related changes, multi-touch interfaces, as well as designing multi-touch interfaces for elders. Section III describes the methodology used. Section IV provides a review of design guidelines of multi-touch interfaces for elders. Section V presents the final set of design guidelines. Finally, Section VI concludes and presents future research directions of this paper.

II. BACKGROUND

In this section, we briefly outline the main concepts associated with this work, including, age-related changes, followed by an overview of suitable input devices and multi-touch interfaces for elders and concludes with considerations regarding the design of multi-touch interfaces for elders.

A. Age - Related Changes

The aging process is typically accompanied with physical changes (namely visual, auditory and motor changes) and cognitive changes (decline in memory and attention) [10][19][20][21].

Visual problems are noticed around the age of 40 [6]. The visual capabilities of a person are affected with aging, being the most significant changes observed in the visual

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acuity [22], presbyopia [21], peripheral vision [21] and dark adaptation [21][22].

Hearing loss is verified in approximately 50% of all men over the age of 65 and 30% of women [6]. The human ear can hear sounds from the range of frequencies from 20Hz to 20000Hz. Aging causes a decrease in hearing [21], resulting in a loss of the capability to detect tones in all the frequencies. However, this loss is more recognized in the high-pitched sounds [23], where some elders do not recognize sounds with frequencies higher than 2500Hz [24].

With respect to motor changes, these are caused by a loss of muscle mass and flexibility [6]. The main changes are specifically, gait disturbances (i.e., immobility), balance difficulties (i.e., instability), and certain motor control problems (i.e., tremor) [25] and arthritis [12].

Memory is a multi-component system that combines aspects of storage and processing [26]. Normal aging, produces different degrees of decline in the several forms of memory [20], namely short-term memory (i.e., working memory) used for example in learning and interacting with new devices and long-term memory (i.e., permanent memory) used to store information over a long period of time.

Finally, attention that consists in the ability to focus on the items needed to perform a certain task [20][22] is also affected by aging. Individuals over 60 years old, have a substantial difficulty in processing complex tasks [27], and have problems maintaining attention span for long periods of time [28].

The use of touchscreens through multi-touch interfaces can accommodate largely these age-related limitations [6]. We will briefly summarize the most appropriate input devices for elders.

B. Suitable Input Devices for Elders

Human-computer interaction enables the use of a wide variety of input devices, such as keyboards, mice, touchpads, touchscreens [10]. These input devices can be divided in two categories, direct and indirect input devices [29]. A direct input device is characterized by direct user input on a display [10], e.g., touchscreen. An indirect input device needs coordinate spatial information, hand-eye coordination, and finger dexterity to operate the device and interacting with the user interface [30], e.g., touchpad.

Touchscreen devices reduced cognitive and coordination demands [29], being referred by research community as appropriated and preferred for elder users [6]. However, these devices present some disadvantages, such as, users hands may obscure the screen, the risk of inadvertent activation, as well as difficulties in the precision tasks [31].

Several interaction techniques are possible in the touchscreens devices [30], e.g., single-touch or multi-touch interaction [32].

In the single-touch interaction, only a point of contact is recognized, e.g., using a finger. This way of interaction allows performing basic operations, e.g., open and close programs or pushing buttons. On the other hand, most recent devices enable multi-touch interaction, detecting multiple simultaneous touch points [33], e.g., using the fingers of a single hand or the both hands for interacting with the user interface, through of certain gestures on surface.

Comparisons of touchscreens with other input devices are often referred by the scientific community [29][34][35].

Wood et al. [29] analyzed the performance of older adults in simple drag-and-drop tasks, using four different input devices, namely, touchscreen, enlarged mouse (EZ Ball), mouse and touchpad. As performance measures was used accuracy and time to complete parts of a game. Additionally, it was held a set of measurements, to assess visual memory, visual perception, motor coordination, and motor dexterity of the users. The results showed that mouse was the device that demanded greater effort to accomplish the proposed tasks.

Findlater et al. [34] studied the psychomotor performance between young adults and older adults using desktops and touchscreens. The evaluated tasks were pointing, dragging, crossing and steering in both devices and pinch-to-zoom in the touchscreens. The results showed that older adults have slower performance than younger adults, however, the use of touchscreen reduced the time in comparison with desktop and mouse in the tasks performed by older adults.

Schneider et al. [35] presented a study to compare the performance of different input devices, namely, mouse, touchscreen, eye-gaze input, and a hybrid interface, composed by eye-gaze input with other input devices. The better results were achieved using touchscreen and worst results using mouse, in the group of the elder users.

In addition to comparisons with other input devices, the touchscreens allow innumerous interaction techniques that are also focused in the literature, e.g., Motti et al. [30] presented a review on interaction methods using touchscreens by older adults.

The multi-touch interaction capabilities of touchscreens enable the use of sophisticated multi-touch interfaces that will be addressed in next section.

C. Multi-Touch Interfaces for Elders

Natural User Interfaces (NUI) were formed to establish new natural ways of communication between users and computer systems [14]. The term NUI enables the manipulating of a user interface in natural and intuitive form for human being [9][36]. NUI can be developed using the natural capabilities of humans, such as, touch, gestures, speech, facial expressions, body language, eye-gazing, or combining several input modalities designated by multimodal interfaces.

Multi-touch interfaces are a type of NUI, in which multiple simultaneous touch points on a user interface are recognized [33], allowing direct mapping of the input in the user interface [13][37], considered ’natural’ and ’intuitive’ their use [6][7][14].

The use of multi-touch interfaces has been receiving an increasing attention in recent time, given the diversity of devices that supports multi-touch and gestural input [38], such as mobile devices [31], tablet devices [13], tabletop

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devices [39], becoming these type of interfaces very popular [7], promoting easier hand-eye coordination [6], and interesting to users of all ages [6].

Multi-touch interfaces using the fingers of one or two hands were evaluated through different gestures on touchscreen, e.g., tap, drag, rotate, resize [11][32][34][40].

Piper et al. [40] showed that older adults are appropriate to performing multi-touch gestures, however, with difficulty in gestures that involve fine motor movements, i.e., gestures involving two or more fingers, e.g., rotate gesture. Leonardi et al. [11] mentioned that tap gestures using a single finger, are easy to understand and remember by older adults but with difficulties in drag gesture, due to lack of constant pressure. Findlater et al. [34] verified the presence of some errors in the "zoom out" gesture and the absence of errors in the "zoom in" gesture. Stößel et al. [31], referred that older adults are slower than young adults in multi-touch interaction, but with similar error-prone.

Tabletop devices are a type of touchscreens, very appropriate for elder's, making use of a large interaction area and with multi-user support [37][39], a playful way for promoting their face-to-face social interaction, like their daily activities, e.g., playing board games.

Gaming is an interesting domain for multi-touch interfaces. An illustrative example is [37], that explored multi-touch interfaces as a gaming platform for older adults.

The designing of multi-touch interfaces for elders requires the consideration of a diversity of aspects that will be addressed in the next section.

D. Designing of Multi-Touch Interfaces for Elders

As mentioned before, tabletop devices are appropriate for elder users, and the designing of multi-touch interfaces for this type of devices will now be described.

It is well known that aging inevitably brings changes to the physical and cognitive abilities of humans [41] and consequently the design of a user interface should accommodate the limitations caused by these changes [7], stimulating the development of technologies more usable by older adults [6].

Lists of design guidelines of multi-touch interfaces for elders are not abundant in the literature, however, Boustani [7] presented a set of touch-based design guidelines for elders, that is a good starting point for designing of multi-touch interfaces for elders, however some important aspects are missing, e.g., the reference of gestures desirable and avoidable by this type of users and guidelines to help the interface testing.

Although, in multi-touch interface design be possible the use of guidelines of other types of user interfaces, e.g., web design guidelines, given that, some guidelines are similar in both user interfaces, such as content layout design, text design, use of colors. However, specific aspects of multi-touch interfaces, e.g., the adequacy of gestures, ideal display size and feedback are not covered and are crucial in the design of an elder-friendly multi-touch interface. Designing of multi-touch interfaces for elders should aim at attenuating the limitations caused by aging. To this end, some practical guidelines will be mentioned according to age-related change:

- Visual changes - is suggested that the user interface should have an appropriate size of design elements and text [6][13], making use of high contrast colors [1] [6][7][8][18];
- Hearing changes - is recommended the presence of a control to adjust audio [1][6][8][20][21];
- Motor changes - the design of user interface should contains large targets for accurate selections [6][7] [8], avoid the use of scrolling [6][7][8][18] and exhibit slower response times [6][40];
- Memory changes - the interface should have appropriate feedback [1][42], including the current location in the system [7][8][18] and the use of meaningful icons [1][7][8][18];
- Attention changes - potential distracting elements should be avoided, such as, animations [7][8] and irrelevant informations [6][7][8][18].

In addition to the last practical guidelines mentioned, other considerations should be taken into account, e.g., tap gestures are easy to understand and remember being appreciated by elderly people, as well as iconic gestures [11]; positioning at the surface is critical, the user should be able to reach the entire interface and tactile user feedback and natural affordances are also needed [42].

The reviewing of works on design guidelines of multi-touch interfaces for elders is more detailed in Section IV.

III. METHODOLOGY

The list of design guidelines was reached using the methodology described in the following steps.

1) Selection of relevant works on design guidelines of multi-touch interfaces for elders: From literature were selected a set of most relevant works that focused on design guidelines of multi-touch interfaces for older adults.

2) Creation of an initial set of design guidelines: From the analysis of the works identified in step 1, it was created an initial set of 138 design guidelines.

3) Review, grouping and organization of the initial set of design guidelines: The initial set of design guidelines was reviewed, in order to: discover and associate identical guidelines, detect and resolve the guidelines that are in divergence and rewrite indistinct guidelines. After reviewing guidelines, 10 meaningful groups of guidelines were created, associating each guideline with a group, originating the final list of design guidelines.

4) Completing data of each design guideline: For each design guideline were filled the following fields: guideline number, guideline title, guideline group, guideline description, an illustrative example, the works that referred the guideline denominated guideline source and a set of tags that classifies the guideline.

5) Final set of design guidelines: The final set of design guidelines consists of a list of 113 grouped design

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guidelines, focusing the essential aspects on design of multi-touch interfaces for elders. The goal is to be a useful resource for designers, application developers, usability specialists and researchers.

IV. Review of Design Guidelines of Multi-Touch Interfaces for Elders

In this section, a selection of the most relevant works on design guidelines of multi-touch interfaces for elders available in the literature, will be presented and summarized.

Leonardi et al. [11] conducted a preliminary study on a touch-based gestural interface (Mobitable), to assist elders in the use of social networking. The study verified the appropriateness of this type of interfaces, mentioning some considerations on design, e.g., tilted or adjustable display, can ease the interface visualization.

Apted et al. [39] described the design of SharePic - a collaborative digital photograph sharing application. An easy to learn and remember multi-touch and gestural application used by multiple users on a tabletop. An evaluation was conducted, with young and older adults, verifying difficulty in two-handed gestures, performed by older adults. Design guidelines were pointed, e.g., should be possible to enlarge the interface elements and the interactivity should be focused on learnability and memorability.

Kin et al. [43] studied the performance in multiple target selection using a mouse, a multi-touch workstation, with a single finger, two fingers (one of each hand) and multiple fingers interaction. The results revealed greater speed with the use of multi-touch interaction, independently of the number of targets. Moreover, it was mentioned some design considerations of applications whose target selection is the primary task, e.g., the use of two-fingers in the multi-touch interaction does not provide any performance improvement in the multi-target selection.

Piper et al. [40] examined accessibility issues in the use of surface computing by older adults and investigated the appeal of this interaction technique for health care support. A study that involved the performing of set of tasks by older adults was done. The results showed that participants had difficulty with gestures involving two or more fingers, e.g., resize and rotate. Additionally, it was referred some design guidelines, such as, provide cues for interaction and the display size may be intimidating.

Silva and Nunes [5] conducted usability tests with older adults in the context of the European project Enhanced Complete Ambient Assisted Living Experiment (eCAALYX). From their experience a set of guidelines of usability tests for older adults was presented. These include guidelines, such as informing the older adult of the goal of the project beforehand, talk to privileged informers, and make it clear that they are not being tested.

Bachl et al. [42] discussed eight challenges in designing multi-touch interfaces, grouped in three categories, specifically, screen-based, user-based and input-based challenges. Some examples of challenges debated were: the necessity of tactile user feedback during the interaction, individual differences of the users, for instance hand size are relevant in designing of multi-touch interfaces and distinguishing and identifying users in the multi-user support.

Nunes [8] presented a set of design guidelines to guide the design and planning of usability tests of TV-based user interfaces for older adults, derived from the knowledge of the analysis, design and evaluation of a TV system for the European project eCAALYX [18]. Guidelines, such as, give them time to learn, use simple phrasing, use a very large font type, remove sound distractions and provide a good navigation are examples included in this collection.

Caseiro [13] created an Android tablet gaming platform to provide cognitive games. User management and the cognitive performance of players were the main features of this platform. Design considerations highlighted, use of big button size; use of colors with good contrast; use a suitable text size, among others.

Banovic et al. [44] explored the efficient design of context menus manipulated by a single hand on multi-touch surface. A context menu design for a horizontal tabletop surfaces was proposed, as well as, design guidelines for single hand multi-target selection using multi-touch interactions, e.g., interfaces should encourage users to approach from south (S), southeast (SE), or east (E) to the primary target and the use of index finger (index-anchored) or the thumb (thumb-anchored) to select the primary target does not influence the performance.

Boustani [7] presented a list of twenty nine guidelines distributed by ten groups of touch-based interfaces design guidelines for the elderly people, derived from a set of related works available in the literature. Examples of guidelines referred, irrelevant information on the screen should be avoided and blue and yellow or red and green tones should not be used. The identified guidelines were used in the design of application Keep in Touch (Kit) a platform easy to learn and understand in the communication between older adults.

Caprani et al. [6] investigated the use of touchscreen technology for elders. The research was focused on several aspects, such as, study of main characteristics of the older user, use of technology by older adults, comparison of touchscreens with other pointing devices, design guidelines for touch-screen devices, among others. Examples of referenced guidelines in this work: use high contrast between the elements of the user interface, use of buttons with big size and scrolling should be avoided.

Farage et al. [1] summarized the main age-related changes, addressing specifically, changes in the visual function; hearing; touch and temperature perception, mobility, and balance; memory and cognition. For each one age-related change were suggested concrete design guidelines to attenuate these limitations, e.g., use colors with good contrast (visual changes), increase duration of sound signal (hearing changes) and use of icons along with labels (cognitive changes).

Jin et al. [45] investigated the spacing and size of buttons in a touchscreen user interface used by older adults. During the experiments it was measured the reaction time,

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accuracy and user preferences. The results of this research showed that large button have shorter reaction times and larger space between buttons does not improve performance.

Nunes et al. [18] presented a set of thirteen recommendations for designing TV user interfaces for older adults. These recommendations were based on design, testing, and development of a TV-based health system. Use consistency to facilitate recognition, show the current selection clearly and give users time to read, are examples of recommendations suggested.

All works detailed here were used to form the list of design guidelines, presented in the next section.

V. FINAL DESIGN GUIDELINES

The final design guidelines are composed by 113 distinct guidelines, grouped under 10 distinct category headings, as illustrated in Figure 1. The categories used in the grouping of guidelines was based on classification used by Boustani [7] and Kurniawan and Zaphiris [46]. Some selected examples of each category are listed below.

Figure 1. Guidelines Categories [47]

G1 - Target Design

- Ensure the user can easily make interface elements larger (adjustable);
- Different physical properties have to be considered while designing the interface (e.g. size of buttons);
- Provide a cursor showing clearly the selected target. It should be obvious to older adults what can be selected and what cannot.

G2 - Use of Graphics

- Use icons along with labels. Icons should be simple and meaningful; text incorporated with the icon when possible;
- Use high contrast between the elements of the user interface. A high contrast between the foreground and background should exist;
- Blue and yellow or red and green tones should be avoided. Warm colors are the most suitable.

G3 - Navigation and Errors

- Provide a good navigation;
- Show the current location clearly;
- Design error messages that make it clear that the user is not the cause of the error;
- Make it easy for user to correct input errors.

G4 - Content Layout Design

- Concentrate information on the center of the screen;
- Avoid the use of scroll;
- Maintain consistency in the user interface. Screen layout, navigation and terminology used should be simple, clear and consistent;
- Remove user interface elements calling attention as soon as they are not needed.

G5 - User Cognitive Design

- Be prepared for older adults that refuse to learn;
- Make use of behaviors developed by older adults to cope with memory loss;
- Give them time to read. Older adults usually read more slowly (than younger adults);
- Avoid forcing users to read at very close distances.

G6 - Audio

- Enable older adults to adjust the volume at their will;
- Increase duration of sound signals;
- Use male voices for delivering auditory information;
- Remove sound distractions.

G7 - Text Design

- Use a very large font type;
- Use left-aligned text;
- Use an easy to read font family;
- Use medium or bold face type, e.g., Sans Serif type font, i.e., Helvetica, Arial. Avoid other fancy font types.

G8 - User Feedback and Support

- Accessibility issues should be taken into account, for example giving tools to allow the use by blind people;
- The lack of tactile user feedback also affects the user experience of data input on multi-touch interfaces;
- Use supporting peripherals if needed.

G9 - Multi-Touch Interaction

- Tap gestures (when applied to well recognized objects) are the easiest ones to understand and remember;
- Iconic gestures are very engaging;
- Provide cues for interaction for initial learning and sub- sequent use of the technology;

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- Positioning at the surface is critical; the user should be able easily reach the interface corners.

G10- Interface Testing

- Inform the older adult of the goal of the project beforehand;
- Keep the test short and make use of breaks;
- Respect the opinions of the test participants.

Due to space restrictions for this paper, certain guidelines were omitted, as well as, descriptive data, including, guideline description, works that cited the guideline, illustrative examples, etc. The complete list of design guidelines can be obtained from [47].

VI. CONCLUSION AND FUTURE WORK

In this paper, we presented a properly organized set of design guidelines of multi-touch interfaces for elders, refined and extracted from most relevant works presented in the literature. This set of design guidelines was structured in a very detailed and comprehensive way, covering the main age-related changes that might affect the usability of the interactivity in the multi-touch interfaces, becoming an important resource for designers, application developers, usability specialists and researchers to guiding and evaluating the design of this type of user interfaces for elder users.

As future work, we are considering the possibility of incorporating the design guidelines in an automatic detection system that identifies and suggests guidelines during the testing of a multi-touch interface; increasing the list of design guidelines with inclusion of other design guidelines; the reviewing and rating of the design guidelines by experts, in order to validate their usefulness, as well as a comparison of the design of a multi-touch interface for elders with and without the use of proposed guidelines to verify its impact on usability.

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