Grounded Theory for Designing Mobile User Interfaces-Based on Space Retrieval Therapy

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Abstract—Technology plays a major role in our daily lives. In healthcare, technology assists in treating and detecting diseases and can improve patients' quality of life. Alzheimer's disease patients are generally elderly people who suffer from disabilities in vision, hearing, speech, and movement. The disease is one of the most common types of dementia. This paper proposes a design for a mobile application with an adaptive user interface for Alzheimer's patients based on an elderly model developed using grounded theory. The application aims to improve the patients' quality of life and allow them to remain engaged in society. The design of the application is based on spaced retrieval therapy (SRT), a method that helps Alzheimer's patients to recall specific pieces of important information. User-centered design method was used to design and build this application. In the requirements phase, a user model for elderly people was elicited based on a classification developed through grounded theory. The prototype for the proposed model was designed and developed considering the default user interfaces and the adaptive user interfaces. A test was conducted with 15 elderly Arab users. The participants were 50–74 years old with varying levels of education and experience with technology. The authors proposed a user model for elderly people containing all the design implications in terms of physical and cognitive changes. The results of testing with elderly Arab users supported the proposed user model in terms of colors, fonts, pictures, and symbols. However, there were problems with the menu design and color preferences.

Keywords—Grounded theory, adaptive user interface, designing user interface, spaced retrieval therapy (SRT), elderly people, Alzheimer's disease, elderly model

1 Introduction

Technology plays a major role in our daily lives. It contributes to many fields, including home care, government safety, security, education, privacy, mobility, social interaction, and healthcare. One of the most important governmental applications is tracking citizens for security purposes. While many techniques are available for tracking, such as fingerprinting, iris scanning technology is a more effective technique [1]. In the educational context, a set of online teaching platforms like Blackboard Learn and Google Classroom helped to continue the education process during the COVID-

19 pandemic [2]. Moreover, many applications that aim to educate children through playing are available [3]. In healthcare, technology assists in treating and detecting diseases and can improve patients' quality of life. For example, a set of games was developed to help patients perform physiotherapy after surgery [4]. Machine learning algorithms have been developed to detect different types of cancers quickly and accurately without surgery [5]. For elderly people with chronic diseases, a set of applications has been developed to improve nurse–patient communication and monitor health outcomes [6][7][8]. A set of applications is available for Alzheimer's patients to improve their cognitive functions and quality of life. One effective Alzheimer's application detects whether the patient has wandered and notifies the patient's caregivers [9].

The Saudi Alzheimer's Disease Association estimated that there were 130,000 patients with Alzheimer's disease in Saudi Arabia in 2017 [10]. The probability of getting Alzheimer's disease increases with age: 5% of people between 65 and 74 years old have the disease, while the percentage reaches 50% for those over 85 years old [10]. The Alzheimer's Association in the United States confirms that one in three elderly people dies with Alzheimer's disease or other dementia diseases and by the year 2050 the number of patients will double [10]. The global estimation for the peoples whom living with dementia is 47.5 million people [11]. The statistics expected that the number of patients will double every 20 years. By the year 2030 the number of patients will be 66 million and 115 million by 2050 [12]. Due to the increasing ratio of Alzheimer's disease, the costs of healthcare and the demand for caregivers are also increasing. New technology can help older adults improve their quality of life, maintain their independence, and remain engaged in society. Such technology also promises to lower healthcare costs and reduce the demand for caregiving services. In order to design a usable application for elderly people, a set of age-related changes must be considered. Visual impairment, hearing loss, arthritis, and declining cognitive abilities are all common among older adults [13]. Cognition is the combination of a set of continuous mental processes that vary from one person to another [14]. These processes are attention, perception, learning, memory, planning, decision-making, reasoning, problem-solving, speaking, listening, and reading [15].

Today, context awareness plays a major role in designing usable technology, especially for elderly users [13][16]. Since each older adult has different characteristics and experiences, it is best to create a user interface (UI) that adapts to their needs, matching their personality and interaction abilities [17]. Designing interfaces based on elderly people's characteristics and individual needs increases usability [18]. There are three ways to create a personalized adaptive user interface (AUI). First, a user profile that contains the user's characteristics can be created; this profile can be used at runtime to personalize and design the interface. Second, the user can be allowed to control the interface appearance manually. Finally, a new approach is to make real-time adaptations that adapt the interface to the current user's situation while they are using the application, which will use in this study [19][20].

Users' unique characteristics and experiences affect their ways of interacting with applications and products. To achieve real-time adaptation, it is necessary to use the interaction type that is most effective for older adults. The four main types of interaction are instructing, conversing, exploring, and manipulating [21]. In instruction interactions, the user gives the application instructions that can be accessed in different ways, like pressing buttons and selecting from menus. Conversing interactions are based on speech between the user and the system. Exploring interactions allow users to move in a virtual environment and are based on a set of sensors that detect user movements. Finally, manipulating interactions allow users to manipulate objects in the virtual or physical environment [21]. In the case of real-time adaptation for elderly people, the exploring interaction type can help to detect the current user situation by using various sensors in a simple, fast, and accurate way [20].

The high cost of medical treatments for Alzheimer's disease and the dissatisfaction with such treatments have led to the appearance of non-pharmacological interventions. Studies have shown the positive effect of non-pharmacological therapies, such as reminiscence therapy, errorless learning therapy, and spaced retrieval therapy (SRT) [22]. SRT was introduced in 1990 [23]. This therapy helps Alzheimer's patients to recall specific information, such as family members' names or a caregiver's phone number [23]. In SRT, the patient is repeatedly asked to recall a specific target after an interval of time. If they answer correctly, the time interval doubles (from immediate recall to 30 seconds, 1 minute, 2 minutes, 4 minutes, and so on). If not, the patient is given the correct answer and the time interval remains the same. During these intervals, the patient engages in activities like reading, puzzles, games, or general conversation [23].

Today, Alzheimer's patients face expensive treatment options with dissatisfying results. In addition, it is necessary to reduce healthcare costs and the demand for caregiving services while improving patients' quality of life and information recall and fostering sustained independence and engagement in society. As most Alzheimer's patients are elderly, they may suffer from impaired vision, hearing, touch, fine motor skills, speech, movement, and cognitive abilities.

In this paper, the authors model the characteristics of elderly people by applying the grounded theory to understand the design implications of this group's requirements and limitations. The authors then applied the SRT to design an application that helps people with Alzheimer's disease recall important information and improve their lives. This paper's contribution is twofold: propose an elderly model classification based on grounded theory for designing UIs and then apply the SRT method in the design process.

The rest of the paper is organized as follows. Section 2 presents the most user-interface techniques for applications. Section 3 clarifies the methodology of the study. Section 4 illustrates the elderly model. Section 5 explains the application design. Section 6 clarifies the evaluation method and results. Section 7 discusses the study. Section 8 clarify the limitations. Finally, Section 9 concludes the study.

2 Literature Review

Recently, technologies have evolved ways to improve usability for elderly people, especially through improved interface design [20]. As each user has their own characteristics and needs, designing a single interface for all users does not account for variations between individuals. However, designing multiple interfaces for the same application is costly and requires a sophisticated feedback system because individuals' variations are difficult to determine in advance. AUIs may be able to solve these problems during runtime [20]. In order to illustrate the challenges of AUIs, Pierre et al. [24] applied Salehie and Tahvildari's [25] hierarchy of software systems' adaptability properties to explain the concept of AUIs (Figure 1).

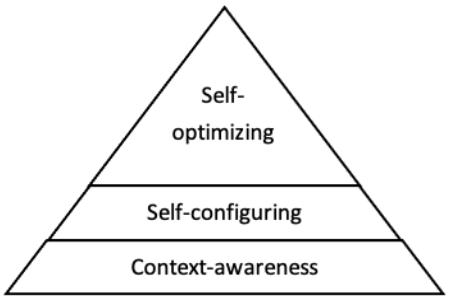


Fig. 1. Hierarchy of AUIs [24]

The hierarchy is divided into three main categories:

Context awareness: The UI should be able to improve usability by adapting to changes detected in the operating environment [26]. Many studies support this concept with some differences in target groups, platforms, and goals. Märtin et al. developed the SitAdapt architecture, which could be added to business applications to make them react to the current user's emotional state according to rules such as: when the faces' emotion is happy then prompt the offer [27]. Hanke et al. implemented a real-time, adaptive virtual assistant named CogniWin for people over 50 years old. This system recognized the needs of elderly people working on PCs through an intelligent mouse, Eyetracker, and Kinect One sensor. CogniWin detected abnormal behaviors and provided adaptive help (text, video, and audio) [28]. Another well-known project, called MyUI, was established by the European Commission to create real-time adaptive interfaces for iTV applications to help elderly people use email services, check the weather, and play games through their televisions. This project used sensors to detect users' situations and update their profiles. Once the user profile updated, the UI updated as well [29].

Self-configuring: The UI should be able to adapt to user feedback. For example, it should change when the user chooses a larger font size. This type of adaptation is used in many applications. One example, introduced by Ryu et al., featured a personalized adaptive smartphone for elderly people. The smartphone allowed each participant to manually set the keys to their preferred height, width, font size, and style [30].

Self-optimizing: The UI should be able to adapt to changes. For example, it should be able to adjust to changes to the window size based on the device size, rearranging the elements' locations and changing the font size.

3 Methodology

This study proposes a mobile UI design based on SRT to help Alzheimer's patients recall important information. The design reflects the age-based characteristics and preferences determined by the elderly model, which was created using the grounded theory method.

This work follows the user-centered design (UCD) model developed by David Benyon to build and test the application [31]. UCD is an iterative model that aims to improve usability by involving the actual users in the design phase before developing the final product. We applied the phases of UCD as follows. To understand the context of use and gather the design requirements, we collected the necessary data through a systematic literature review and analysis, using grounded theory to create the elderly model. In the design phase, we designed the application's UIs considering SRT and built the prototype. Finally, in the evaluation phase, we tested the developed prototype. The following sections explain each step in detail.

4 Understanding the Context of Use and Gathering Requirements

To characterize a user model, the requirements for defining the model were collected through a systematic literature review [11, 13, 28–42]. Then, the authors analyzed these studies based on grounded theory [32].

Grounded theory aims to build a theory from the systematic analysis and interpretation of data. The theory contains categories suitable to the data. A coding process is used to identify the categories by extracting the categories and their properties and connecting them to their subcategories [32].

The contribution of this paper is illustrated by the proposed theory (classification) of a model of elderly people based on human–computer interaction (HCI; Figure 2). It contains two main subcategories: the age-related changes (personal aspect) that affect the participants and their design implications (technology aspect). The age-related changes are divided into two further subcategories: physical changes and cognitive changes. Finally, the design implications are divided into three subcategories: UI-related implications, cognitive implications, and general implications.

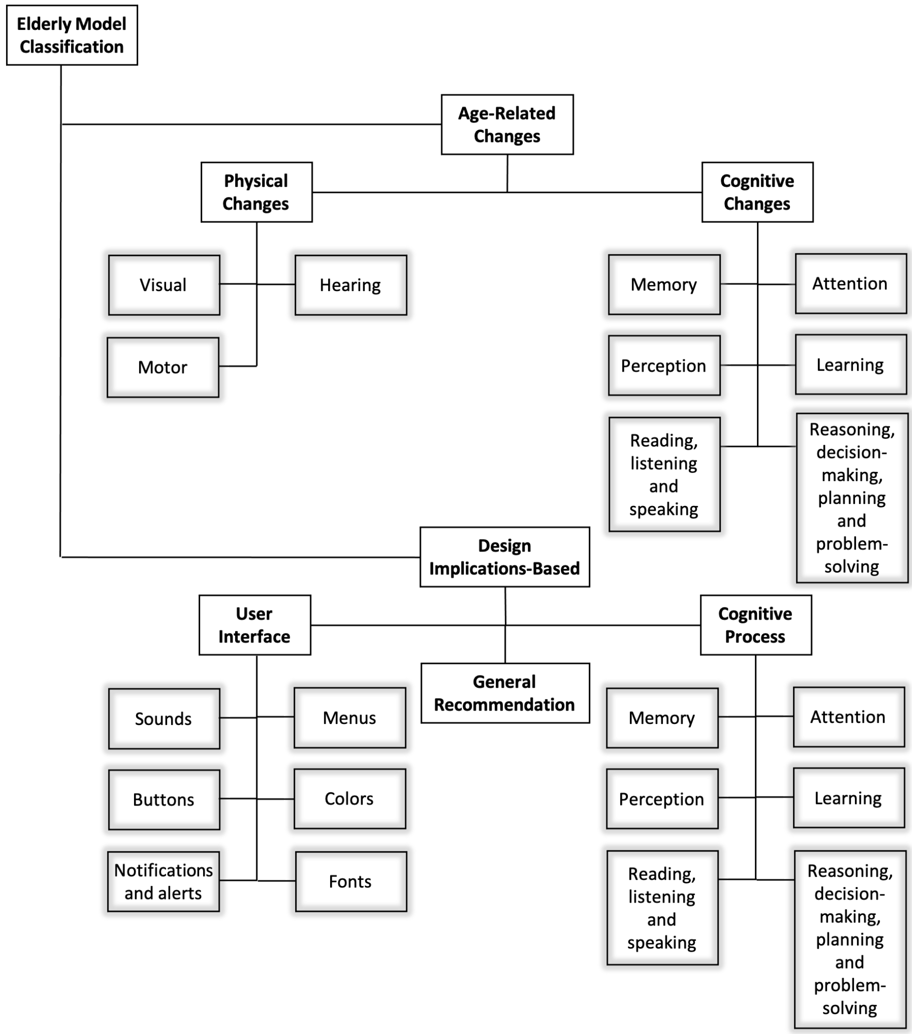


Fig. 2. Model classification of HCI for elderly people

4.1 Age-related changes

The first classification of the elderly model is defined in terms of physical and cognitive changes, as described in the following subsections.

Physical changes: Physical changes affect how elderly people interact with their environment. Changes to vision, hearing, and motor skills are all considered physical [13][33].

- Visual impairment: Visual impairment can describe one or more common sight-based afflictions, such as visual acuity, dark adaptation, and peripheral vision impairments or presbyopia [13]. Visual acuity refers to detail recognition; a person's vision is considered impaired when their visual acuity reaches 20/40 or lower [34]. Dark adaptation describes reduced sensitivity following movement from a very light environment to a darker one [13]. Elderly people may take longer than others to adapt to dark environments [34]. Peripheral vision impairments involve difficulty seeing objects located outside one's central line of sight. Finally, presbyopia describes the inability to focus on nearby objects [13].
- Hearing impairment: Elderly people often have difficulty hearing pitches above 2,500 Hz [33]. Moreover, most elderly people over 65 years old have suffered hearing loss, which obstructs their social relationships [13].
- Motor impairment: Motor impairments include lengthy response times, arthritis, difficulty coordinating different movements, inaccurate movements, and swollen fingers. All of these symptoms affect tasks requiring fine motor skills, such as interaction with technology [13][33].

Cognitive changes: Cognitive changes include changes to memory, attention, perception, learning, reading, listening, speaking, reasoning, decision-making, planning, and problem-solving. These cognitive processes coordinate with each other to enable the performance of daily activities [13][15]. Changes due to aging's effect on the human brain can alter the performance of some or all of these processes [35].

- Memory is the process of recalling stored information and experiences [15]. Humans have two memory systems: working memory (also known as short-term memory) and long-term memory. Working memory is used to keep information available while it is being used, after which most of it is forgotten [36]. Long-term memory is used to store information and experiences permanently. The capacities of both systems decrease with age [36].
- Attention is the process of maintaining awareness of specific objects related to the task on which a person is working at a given time [15]. Elderly people may have difficulty shifting their attention quickly from one task to another and keeping their attention on desired information while ignoring extraneous information [36][37].
- Perception is the process of collecting environmental data through the five senses and transforming it into sensory experiences [15].
- Learning is the process of becoming knowledgeable about a given topic or becoming able to do something through instruction or trial and error [15].
- Reading, listening, and speaking are all processes related to natural language processing; difficulties vary depending on the elderly person's individual properties and skills [15].
- Reasoning, decision-making, planning, and problem-solving are all processes that involve reacting to an internal or external event. These processes demand high-level thinking to process various options and their associated consequences [15].

4.2 Design implications for elderly people

To build an application appropriate for elderly people, a set of design implications for this age group is recommended based on either UI or cognitive and general feedback [38][39]. Table 1 lists the UI-related implications based on physical changes in terms of sounds, menus, buttons, colors, notifications, and fonts.

Table 1. Design Implications for the UI

Attributes	Preferences
Sounds	Enable the user to adjust the volume because users' ability to hear pitches varies [13]. Ensure that sounds are intelligible by removing any background noise [33]. Put the volume controller in an easy-to-find place [13]. Sounds longer than 0.5 seconds should have an intensity of 60 dB [40]. The speech rate should be 140 words/minute or less [40].
Menus	Use a one-level (flat) structure due to the difficulty of understanding hierarchical menus [41][42][43]. Orient content in a grid instead of a list [43][44]. Use a multicolor background for menu items to decrease the item selection time [45].
Buttons	Place the buttons in a horizontal alignment (i.e., as a row) at the bottom of the interface to avoid hiding the screen behind the user's hands when clicking [41][46]. Make the buttons large enough for the user and avoid using 50 dp or less [33][40][42]. Use text labels with symbols to help the user remember the buttons' functions [33][42][43][45]. Distinguish the active button with a unique color [46].
Colors	Consider the contrast and brightness of the colors of all items. Red, green, yellow, blue, white, and black are recommended because it is easy to distinguish between them [33][40][42][45]. Use different colors to distinguish active buttons from other states. For example, use the traffic light metaphor: red for false cases and green for true cases [41][46].
Notifications and alerts	Use more than one method of notifying the user, such as sounds, vibrations, lights, blinking, and dialogue boxes [13][40][41]. Use sounds only for emergency statuses and at an appropriate pitch (i.e., 60 dB) [33]. Display alerts in a specific place on the interface to avoid confusing the user [33]. Do not use a technical term for alerts [42].
Fonts	The font size should be between 36 pt and 48 pt [41]. Use a simple and clear font, such as a sans serif, without any bold, underlined, or italicized text [40].

Table 2 lists the design implications of cognitive attributes in terms of memory, attention, perception, learning, reading, listening, speaking, reasoning, decision-making, planning, and problem-solving.

Table 2. Design Implications of Cognitive Attributes

Attributes	Preferences
Memory	Make tasks as simple as possible with a small number of steps [15]. Help the user recognize information easily by using menus and icons rather than requiring them to recall the information themselves [15].
Attention	Display information in an attractive way—for example, using animations or colors to draw attention [15]. Use attention-grabbing items sparsely [33]. Arrange items based on their importance [33]. Avoid displaying too much text and audio to avoid disturbing the user [13][33][15][40].
Perception	Use meaningful icons and symbols [15]. Display all menu items at once instead of requiring an additional action to explore more items [43]. Use borders and spaces to illustrate the different items in the interface [15][40].
Learning	Teach users to select the best course of action using aids like blinking or underlined words [15][40].
Reading, listening, and speaking	Use a human voice instead of an artificially generated voice [15]. Make the interface text as large as possible [15].
Reasoning, decision-making, planning, and problem-solving	Provide extra hidden information that appears when the user clicks on a link or button to help the user with reasoning and decision-making [15]. Use simple and clear words [40].

Table 3 lists general design guidelines for elderly people.

Table 3. General Design Implications

Attributes	Preferences
General guidelines	Use a slow animation speed [41]. Make the information area approximately one-third of the whole interface [41]. Provide haptic feedback, such as a sound or vibration, when the user clicks a button on a touch screen [33]. Avoid requiring double-clicking or drag-and-drop because the finger movement required will increase the error rate [36][40]. Avoid requiring text input as much as possible by providing options like selecting from menus [40]. Provide undo and return buttons [40]. Display the user name and picture in the user profile to personalize the application [13][47].

5 Design

Prototypes are an early version of the application in the development process that is used for the purposes of visualization. They are used for the early identification of problems with applications, saving time, cost, and effort [48]. Paper prototypes are low-fidelity prototypes that focus on the screen's layout. All interfaces in the paper prototype should be represented such that users can explore all possible tasks. In addition, interfaces should be represented at their actual size to be more realistic [49]. In this study, the prototype was created using Microsoft PowerPoint in order to be more interactive; the hyperlink feature was used to activate the buttons and connect the interfaces.

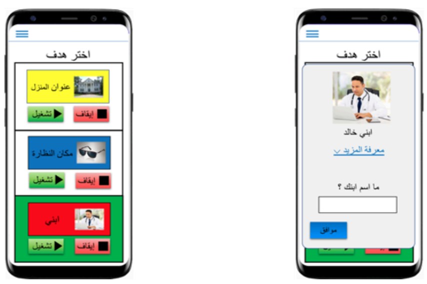
Figures 3 shows the proposed default user interfaces (DUIs) and Figure 4 shows the proposed design for an adaptive SRT application in the form of paper prototypes containing all possible interfaces. The application starts with a DUI designed to fit the generalized needs of elderly people. Then, if cognitive impairment is detected using an adaptive technique, the DUIs will be replaced by the AUIs, which are designed to fit individuals' needs and cognitive impairments. These designs consider all the design implications described in Tables 1–3.

To apply SRT, the application lists a set of personal information like name and phone number. The user chooses a goal to start the therapy. After that, the application repeatedly asks the user about the goal. If the user gives a wrong answer, they will be prompted with the question after the same interval of time. If they give the correct answer, the time interval will increase.

The clarifications of the two UI types are as follows:

1) Welcome interface. 2) Goals menu interface. 3) Goal detail and options interface. 4) Question prompt. 5) Question prompt in case of a wrong answer.

Fig. 3. The proposed DUIs



1) Goals menu interface. 2) Question prompt in case of a wrong answer.

Fig. 4. The proposed AUIs

5.1 Default User Interfaces (DUIs)

There are five DUIs (Figure 3). The descriptions of the designs of the five interfaces are as follows:

- DUI 1. Welcome interface

Given the importance of making the user feel that the application is personal, this interface presents the picture and name of the user. The background color and the font color contrast with one another in order to be easily distinguishable. The font is classic and a size appropriate for easy reading.

- DUI 2. Goal menu interface

This interface is a one-level grid-style menu with different background colors, which makes it easier to distinguish the menu items. The active goal is distinguished by a green color in accordance with the traffic light metaphor.

- DUI 3: Goal detail and options interface

This interface displays a large image of the goal, which acts as a visual cue to aid recognition and recall. This interface has three buttons. The two most important buttons are placed in a horizontal line at the bottom of the screen. These buttons are colored according to the traffic light metaphor, with green for "start" and red for "stop." The third button is placed in the top-left corner, which has a statistically lower error rate than the top-right corner during clicking.

- DUI 4. Question prompt

This interface is displayed after starting a goal process to periodically ask the user about their goal. The goal image is used as a visual cue. A button is placed at the bottom of the prompt. The alert sound and vibration occur when the prompt appears to ensure the user notices it.

- DUI 5. Question prompt after a wrong answer

This interface is displayed when the user cannot remember their goal. As for the question prompt, the goal image is used as a visual cue. A button is placed at the bottom of the prompt. As in DUI 4, the prompt occurs with an alert sound and vibration.

5.2 Adaptive User Interfaces (AUIs)

The AUIs have four main interfaces. They are different from the default for two interfaces (Figure 4): The goal menu interface and the question prompt after a wrong answer.

The goal detail and options interface was omitted because in the case of cognitive impairment, it is important to require fewer steps to complete tasks, and the UI must contain as few items and as little text as possible; extraneous buttons and text must be deleted. For these reasons, the goal detail and options interface was merged with the goal menu interface, and the goals' extra details were omitted. The font size was increased to make reading easier.

- AUI 2. Goal menu interface

The menu style changes from grid style to list style. This is more effective for cognitively impaired users because it includes start and stop buttons with menu items to make the tasks as simple as possible and with fewer steps. Borders are used to illustrate the different menu items. The picture and button dimensions are increased.

- AUI 5. Question prompt after a wrong answer

This version is more effective for cognitively impaired users because extra information is hidden but still reachable, keeping the user's attention on important items.

6 Design Evaluation

The aim of this step is to examine the classification of the proposed model of HCI for elderly people (in terms of colors, the size of icons and buttons, menus, symbols, and selection time) to determine the effect of considering cognitive changes on the adaptive design.

6.1 Participants

Since most Alzheimer's patients are elderly [10], this prototype was evaluated with the participation of 15 elderly people (13 women and two men). The participants were 50–74 years of age with an average age of 56 years. They came from various educational backgrounds (six university graduates, four secondary-stage graduates, two who had completed the intermediate stage, two with only elementary education, and one illiterate participant). All the users except one had experience using technology and had sufficient reading skills. Twelve had vision problems, but only five wore glasses during testing. Testing took place at the participants' homes and at King Abdulaziz University (KAU). All the tests were performed by the same examiner following the same procedure.

6.2 Test procedure

First, the examiner completed a survey about each participant by asking them to draw a picture describing their demographic information. The survey recorded their sex, age group, education level, experience with technology, vision impairment, and whether they wore glasses.

Then, the participants were asked to perform the same tasks for each of the DUIs and AUIs (three for each type), which required different steps because of their differences in design. These tasks were related to the clarity of layouts, colors, symbols, and fonts, as well as the ease of navigating from one interface to another. Finally, the examiner asked the participants about their opinion on the design and their comments.

Table 4 shows the details of each task and its aim. The participants performed the tasks first on the DUIs and then on the AUIs.

The experiment was conducted face-to-face in comfortable environments such as participants' homes and at the KAU campus. An appointment was arranged before testing. The test was performed using a prototype to present the design of UIs and a paper log-in form for each participant (completed by the examiner) containing an empty table with different attributes to record the observation data for each task (such as the time and the number of mistakes).

To measure the usability of the proposed design for UI-based SRT, three attributes were collected for each task during each participant's test: the total number of actions per screen, the number of incorrect clicks per task, and the time (in seconds) to complete each task successfully. In addition, a comment from each participant was recorded.

Table 4. Task List for DUIs and AUIs

Task #	Description	Goal
Default 1	Find the active goal in the goal menu	To measure the effectiveness of using green color as a sign for the active goal and the ease of use of the grid-style menu
Default 2	Select the active goal, stop it, and return to the goal menu	To measure the ease of navigating between the interfaces, stopping undesired goals, and returning to the goal menu, as well as the clarity of the button fonts, colors, places, and symbols
Default 3	Select the "son" goal, and run it	To measure the ease of navigating between the interfaces and activating the desired goal, as well as the clarity of the button fonts, colors, places, and symbols
Adaptive 1	Find the active goal in the goal menu	To measure the effectiveness of using green color for the active goal and the ease of use of the list-style menu
Adaptive 2	Stop the active goal	To measure the ease of deactivating the undesired goal in the list-style menu and the clarity of the button fonts, colors, places, and symbols
Adaptive 3	Run the "son" goal	To measure the ease of activating the desired goal in the list-style menu and the clarity of the button fonts, colors, places, and symbols

7 Results

Table 5 summarizes the testing results. Six participants successfully completed all six tasks, while the other nine faced difficulties in various tasks.

In the DUIs, the most common mistakes were in Task 1, finding the active goal using DUI 2. In Task 2, five of the participants failed to return to the goal menu using DUI 3, having overlooked the 'back' button because of its place (upper left corner). All participants succeeded in Task 3, selecting a goal and running it using DUI 2 and DUI 3.

In the AUIs, in Task 1, one participant failed to find the active goal using AUI 2. In Task 2, all the participants succeeded in stopping the active goal using AUI 2. In Task 3, one participant failed to run the desired goal using AUI 2.

When asked, 13 of the participants agreed that it was easy to use the list-style menu, while nine agreed that the grid-style menu was clear because of the limited number of elements on the interface.

Table 5. Testing Results

Task	Task completion (number of participants)	Number of incorrect actions	Time (average)	Users' comments
Default 1	9 of 15	8	20.8 sec	Difficulty anticipating what the active goal would look like—the colored items confused them, leading them to incorrectly anticipate which was active, red being the most attractive color.
Default 2	10 of 15	5	24.4 sec	The color red and the symbols helped participants to understand the button's function, although the return button was not noticed because they expected to find it at the bottom with the rest of the buttons.
Default 3	15 of 15	0	12.8 sec	The item pictures helped participants decide on the desired goal, and the color green helped to distinguish the "run" button's function.
Adaptive 1	14 of 15	1	6.2 sec	Difficulty understanding the metaphor between activation and the color green.
Adaptive 2	15 of 15	0	6.4 sec	Red helped participants understand the button's function, and the list style was easier to use than the grid style.
Adaptive 3	14 of 15	2	8.5 sec	Users expected to click any place on an item to start it, not specifically on the run button.

According to these results, in the default goal menu interface (DUI 2) and the adaptive goal menu interface (AUI 2), the users had difficulty finding the active goal. This indicates the necessity of finding an alternative way of illustrating the active goal. The color green was not enough to attract the participants' gaze in a colorful menu, especially given the presence of the color red. Using green for the active goal in a colorful menu was distracting, especially for older people, who often suffer from visual impairments. Other methods could be tested to find the best alternative, such as a unicolor menu with a green active goal or a colorful menu with a black border around the active goal.

Although the upper left corner was the best place for the buttons according to the user model, some elderly users found it difficult to find in DUI 3, especially those who did not have any experience with technology. Locating all the important data and buttons in one area—for example, the center—may help them the users to be more focused.

While most participants agreed about the ease of the list-style menu and the clarity of the grid-style menu, it may be better to merge these two types by making the menu in list style but without extra buttons, thus clarifying the menu for users.

The pictures of items in the goal menu (DUI 2 and AUI 2), the button colors (red for stop and green for start), and symbols (arrow for the back button) all helped participants understand the meaning and functions of the buttons, even without the ability to read (in the case of vision loss or illiteracy). The fonts were clear and large enough to be readable, even for participants who were not wearing glasses.

In order to determine the effect of the consideration of cognitive limitations in designing the AUIs, we compared the DUIs and AUIs (see Figures 5 and 6). The results show that the participants completed tasks more quickly using the AUIs than the DUIs. This is because there was no need to navigate between different interfaces. We consider it an advantage of the AUIs that the user can perform all functions from one interface. Additionally, the total number of mistakes was lower for the AUIs. In summary, the ease of performing tasks using the AUIs makes them more suitable for people with cognitive impairments.

The education level of users had a strong positive impact on the time required to complete the tasks and the number of mistakes. Figures 7 and 8 show that the number of mistakes and the task completion time decreased when the education level was higher. The educated users had the advantage of being more accustomed to new technologies and mobile devices, which reduced their time and number of mistakes compared to other users.

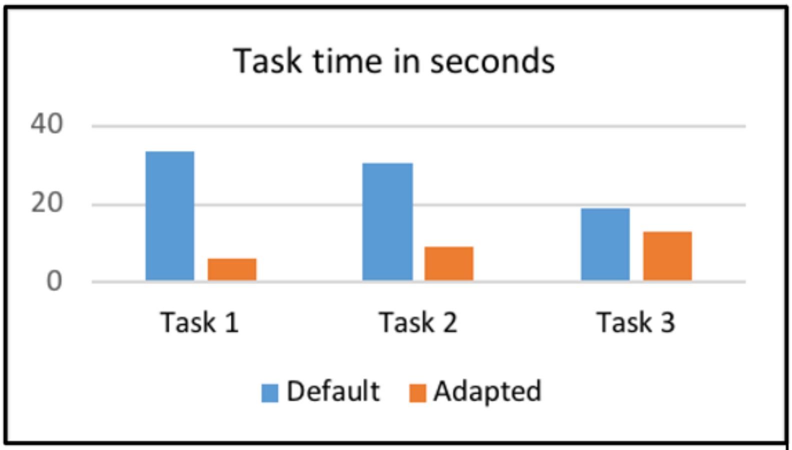


Fig. 5. Time consumed in DUIs and AUIs

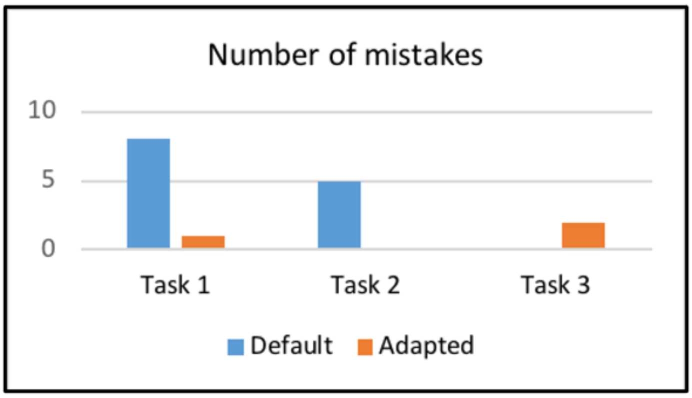


Fig. 6. Number of mistakes in DUIs and AUIs

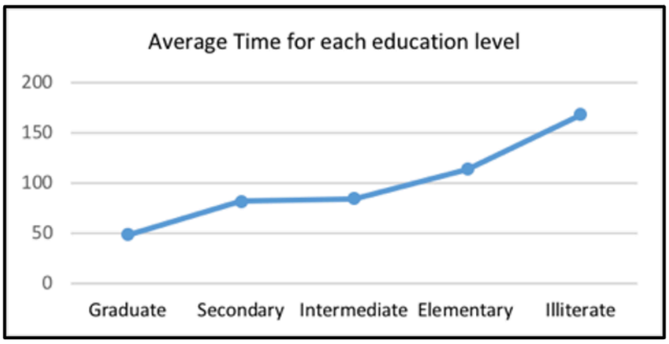


Fig. 7. Relationship between education level and task time

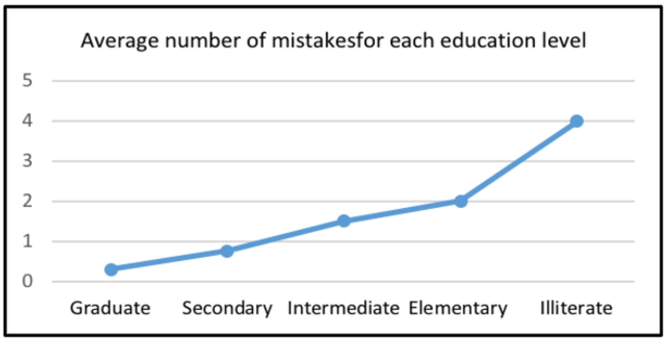


Fig. 8. Relationship between education level and task time

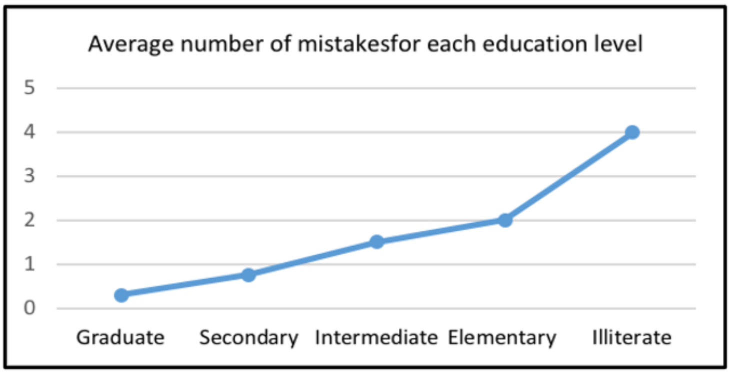


Fig. 9. Relationship between education level and number of mistakes

8 Discussion

This study proposed an elderly model classification based on grounded theory for designing a mobile UI considering SRT. The application aims to use SRT to help Alzheimer's patients recall important information. The proposed user model classifies the design implications into two main parts. The first part is related to physical changes and the second to cognitive changes. Due to the importance of context awareness in making the applications more acceptable, this application had two types of interfaces: DUIs, which focused on physical changes, and AUIs, which focused on cognitive changes.

Seventeen studies were used to build the user model [11,13, 28–42]. Just one of these studies was based on Arab participants. Although all these studies agree in most implications, the Arabic study mentioned the effect of Arab cultures on users' preferences. The testing results show some differences in colors and menus, which may be due to cultural factors.

In the application testing results, education level had a clear positive effect on usability. It may be better to categorize the participants into groups based on their demographic information before testing the user model. Such groups would help to find the relationship between age, education level, and level of experience with technology for this user model.

9 Limitations

This study's limitation was difficulty finding a large number of elderly participants face to face to evaluate the proposed UIs due to the COVID-19 pandemic.

10 Conclusion

This paper focused on the design of an AUI for elderly people with Alzheimer's to help them recall specific pieces of important information. In this paper, the authors explored existing adaptation techniques. A systematic review was performed for elderly people in HCI, and a classification system for elderly people based on grounded theory was used to create an elderly model. The model contained two main subcategories: age-related changes and design implications. The user model was used to design an AUI for elderly people with Alzheimer's disease by implementing SRT.

The authors evaluated the DUIs and AUIs with 15 elderly people. The results showed that the model was appropriate for elderly people with the exception of the menu design, whose colorful menu items were confusing. Participants had difficulty finding the active goal using DUI 2 and AUI 2 because the color green was not sufficient to indicate the active goal. The top-left corner did not constitute a noticeable place for the elderly participants, and so it should not feature any buttons.

The AUIs were easier to use, requiring less time and resulting in fewer mistakes, making them more suitable for people with cognitive impairments. In addition, there was a inverse relationship between the education level of users and the number of mistakes and time consumed completing tasks.

In future research (after the COVID-19 situation improves and movement becomes easier) the authors will resolve the current design problem by interviewing elderly people to find the best options and then updating the user model. The application will be redesigned and tested again. After testing, the application will be built and tested with Alzheimer's patients to prove its therapeutic effectiveness and efficiency. Extra hardware will be used with this application to decide when the elderly have a cognitive impairment; in such cases, the application interface will switch from the DUIs to the AUIs.

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