Universal Access in the Information Society (2024) 23:871–888
https://doi.org/10.1007/s10209-023-00979-y

LONG PAPER

Senior-centered design for mobile medication adherence applications based on cognitive and technology attributes

Reem Alnanih[1] · **Amal Balabid**[1] · **Lina Bahmdean**[1]

Accepted: 10 February 2023 / Published online: 1 March 2023

Abstract

This paper aims to promote technology usage among older Saudi people by addressing the common problems they encounter around adhering to medication schedules and using mobile health applications. An interactive mobile user interface has been designed based on requirements determined using three inputs: (1) relevant existing research work, (2) interviews with medicine specialists, and (3) a survey of 602 older Saudis. The output from the first input is a set of updated guidelines adapted to the older Saudi population and reconstructed based on cognitive process attributes. The interview output identifies medication adherence issues and proposed solutions. The survey output produced a mobile technology model for older Saudis. The guidelines have been applied to a prototype and then tested in two phases: (1) pilot testing and (2) usability testing. In the testing phase, 50 older Saudi users provided insights into the effectiveness, error safety, and productivity factors of the solution developed, with the results confirming that designing mobile applications based on the model of older users and cognitive attributes improved effectiveness and reduced errors when performing mobile tasks, specifically around adherence to medications. For the productivity factor, the results align with the physical characteristics of the targeted older individuals, who typically require more time than younger people to perform certain tasks.

Keywords Cognitive attributes · mHealth · Saudi older people · Basic mobile usage · Advanced mobile usage · Adherence to medications · Cognitive designing guidelines · Empirical study · Usability testing

1 Introduction

Mobile health (mHealth) applications are an effective way to track health benefits for older people who need medical treatment. As technologies evolve and mature, they tend to be used by an increasingly diverse set of users, including older people. There is an urgent need for attention and focus on user experience (UX) because good experiences critically encourage the continued use of an application. In medical contexts, UX can sometimes mean the difference between life and death. Due to advances in ubiquitous computing in recent years, the scientific community has developed numerous technical systems across domains including healthcare [1], education [2], entertainment [3], and transportation [4]. These developments help older people to be more independent and improve their quality of life. However, older people still face barriers that prevent them from using technology effectively, with mobile applications often representing obstacles due to their lack of usability and inaccessible design [5]. Therefore, considering the characteristics of older people's cognitive abilities when designing for this population can help designers make the right decisions to improve UX, influence perceptions of user friendliness, and improve users' cognitive abilities.

Meanwhile, lack of medication adherence is a serious problem worldwide. Studies conducted in Saudi Arabia have found that rates of non-adherence to antihypertensive medications range from 54 to 72% [6]. In [7], the authors conducted a study in Saudi Arabia that revealed an extremely high (96.62%) rate of medication non-adherence among patients with chronic diseases. Therefore, improving medication adherence is critical, with several studies indicating

✉ Reem Alnanih
ralnanih@kau.edu.sa

Amal Balabid
abalabid0001@stu.kau.edu.sa

Lina Bahmdean
lbahmdean@stu.kau.edu.sa

[1] Computer Science Department, Faculty of Computing and Information Technology, King Abdulaziz University, Jeddah, Saudi Arabia

that technological interventions could represent a solution [8]. Technology interventions can improve medication adherence by allowing for timely monitoring and providing useful information about the patient's status and commitment to the healthcare provider [9]. However, there is scarce research on the design of applications suitable for use by older Arabs. To the best of the authors' knowledge, no Arabic-language applications exist that can help older people easily adhere to their medication regimens.

This paper aims to empirically investigate the effects of designing an interactive mobile user interface (UI) based on a conceptual model of older Saudis that can effectively improve their medication adherence and reduce errors. The paper contributes theory-driven guidelines and incorporates cognitive attributes and user preferences into a model that encourages further engagement with the developed solution. The objectives of this research are as follows:

- To analyze the existing guidelines for designing UIs for older Saudi people, classify them according to cognitive process attributes, and identify any contradictions between guidelines;
- To design an interactive medication adherence application suitable for older Saudis people by considering the characteristics of the Saudi population and the cognitive attributes of older people;
- To empirically validate the proposed design by testing the quality-in-use characteristics of the design in terms of effectiveness, error safety, and productivity;
- To validate the desirability of the design.

The remainder of the paper is structured as follows. Section 2 discusses related work concerning technology designed for older people. Section 3 presents the details of the research methodology used to collect and analyze the data. Section 4 proposes the application design. Section 5 evaluates the proposed application design. Section 6 summarizes the results. Section 7 discusses the findings, and Sect. 8 concludes the study and suggests directions for future research.

2 Related work

This section discusses related work in two areas: (1) medication adherence systems and (2) designing technological solutions for older people.

2.1 Medication adherence systems

Medication adherence systems have been reviewed in terms of hardware and software. Hardware concerns include existing pill containers and wearable devices. The software discussion considers the various software designs, applications, and features in the field.

2.1.1 Hardware devices

Various studies have proposed using a sensor-based approach to improve medicine intake and adherence monitoring by fixing sensors to pill boxes, pill bottles, or cabinets to collect data and assess medication-taking activity. Other studies have used wristband devices to detect hand gestures related to pill-taking to provide a medication-taking guarantee. Some of these studies have considered older people a target user group [10] [11] [12]. For example, Jia et al. [13] suggested a smart pillbox managed with a mobile application. However, one limitation is that the individual's smartphone must always be in the zone of the pillbox in order to access the stored data. If not, the connection will be lost, precluding access to the data. Wu et al., [14] used technology to record medication information directly using radio frequency identification (RFID). To serve people who depend on the senses of hearing and sight, [11, 13, 15, 16], and [17] designed a pillbox that reminds users to take their medication by showing lights and making sounds. Some systems have taken the approach of collecting data about users via sensors, with recording vital data [11] and collecting fine-grained data on user activity [18], requiring no user intervention when collecting data. The smart pillbox proposed by Shinde et al., [12] required users to enter the number of pills removed each time, which may be difficult for older users.

None of these studies or their solutions have been able to address the demands of medication adherence—these devices cannot confirm whether users have taken their medication. Moreover, only two studies have even considered this challenge, with Aldeer et al. [18] proposing an approach to validating medication intake based on detecting patient hand movement patterns while interacting with pill bottles. Shinde et al. [12] set the pillbox's alarm to continue until the patient pressed a button on the pillbox, validating medication intake via the patient's physical interaction with the pillbox. However, this result does not accurately measure the extent of medication adherence, with user efforts to stop the alarm or open the medicine bottle and retrieve the medication not necessarily meaning that the user has ingested the medication. Notably, SmartMATES [19], which comprises two sensors that are worn on the wrist and a mobile application, is not intrusive, meaning that if the system detects that the patient has not taken their medication for a certain period, a reminder alert is sent to the individual's mobile phone. Although wearable devices are characterized by accuracy, there are major limitations, with users often finding such devices intrusive, uncomfortable, and annoying.

Meanwhile, for older users, there are limitations pertaining to user acceptance [20] [21].

2.1.2 Software applications

Adherence applications are a novel approach to facilitating older people's medication adherence, with the rapid spread and increased accessibility of smartphones making such applications appealing to many. Gashu et al. [22] developed a web-based reminder system for tuberculosis treatments. The system reminds patients about medication scheduling and refills by sending short message service (SMS) messages, available for both basic and smartphones. The system is characterized by low-resource needs, which makes it suitable for regions that do not have extensive technologies infrastructure. Sherif et al. [23] contributed to improving older people's medication adherence using a LoRa-driven medical adherence system comprising an embedded hardware device with medication alerts for patient home use. However, the system can store and track only a limited number of medications. Furthermore, the alarms run only once, meaning that the system mostly performs monitoring functions and cannot follow up with the patient. Alsswey and Al-Samarraie [24] developed an mHealth user interface to keep older people aware of schedules, dosages, and directions for their medications. General information about illnesses in the Arab world was also included in the proposed mHealth app, and the application design was based on Arabic culture, language, customs, and values. Although the authors considered color, font size, and type, they did not focus on older people's cognitive processes or preferences regarding the use and acceptance of specific design features (e.g., color, language, style, images) from a cultural perspective. In 2016, Heldenbrand et al. [25] evaluated the features of medication adherence applications, their functionality, and level of health literacy. Their survey confirmed that 461 adherence applications were available, of which 367 were unique applications that were evaluated after eliminating "lite" or trial versions. They listed the features that should be included in a medication adherence application (option for languages other than English, ability to monitor whether a dose has been missed or taken, ability to "snooze" reminders, refill alerts, recognition of adverse effects, ability to order refills, and ability to work without Internet access). Later in 2016, Rizal Mohd et al. [26] reconstructed the findings of Heldenbrand et al. [25] by reviewing four of the main medication adherence applications. In addition, another adherence-related feature was introduced: verification of adherence, which requires patients to scan a QR code each time they take a medication as proof of adherence.

This literature review has recognized the importance of increasing medication adherence and validating medication intake by harnessing the potential different hardware and software setups (e.g., smart pillboxes, mobile and web-based applications, wearable devices) and summarized the most common features of medication adherence applications.

2.2 Cognitive design for older users

The human body undergoes age-related changes as a person gets older, including changes in visual, auditory, motor, and perception control [27]. Technology providers, such as designers, must consider these changes when designing a product or service for a community of older users. To overcome these obstacles, special applications must be designed that fulfill the needs of older people in terms of usability, one of the most significant factors in older people accepting new technology [28]. Usability is affected by many factors, including familiarity with technology [29] and geographical area [30]. Familiarity is obtained from prior experience with technology and concerns the relationship between an older person and a technology with which they have experience [31]. Knowledge of existing technologies helps older people become familiar with newly introduced technologies. Moreover, designing a usable interface for older people means designing an interface that matches their existing knowledge and competence. The heterogeneity in familiarity levels and cognitive abilities among older people makes it challenging to design for this population [29].

Several researchers have presented guidelines and principles for designing UIs suitable for older users. However, guidelines that focus on cognitive aging remain rare [32]. Design challenges associated with the physical limitations of users have generally been easier to address than those associated with cognitive limitations [33]. Alnanih [34] addressed the importance of considering a user's cognitive abilities when designing a UI and provided guidance for establishing design guidelines for UIs. The author mapped cognitive process attributes, including attention, thinking, memory, perception, learning, planning, and decision-making, to the capacity of cognitive UIs to plan in the context of uncertainty, supporting implications, learning based on experience, and autonomous adaptation to change. Sharp et al. [35] identified six categories of cognitive process attributes: attention; perception and recognition; memory; learning; reading, speaking, and listening; and problem-solving, planning, reasoning, and decision-making.

For this section, the authors reviewed studies concerning the cognitive guidance of mobile applications for older users. Upon reviewing 48 studies, the authors extracted 17 studies [32] [33] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] that could be analyzed to extract guidelines and recommendations. They classified these guidelines according to the aforementioned cognitive attribute taxonomy [35] in relation to designing UIs for older people. The 63 extracted guidelines are available at (https://gitfront.io/r/user-2924583/2fLh3Sracgsb/Design-guidelines/).

3 Research methodology

This study has adopted a top-down research methodology that begins with collecting data and analyzing the requirements, a step that is followed by the proposal of a prototype and then the testing and interpretation of the results. The following subsections detail each step.

3.1 Data collection

The following three data collection methods were used as inputs:

(1) Literature review: The authors extracted the features and cognitive design guidelines most suitable for consideration in the context of medication adherence applications for older people;
(2) Interviews with medical doctors: The authors conducted a face-to-face group interview with two expert Saudi medical doctors working at the College of Pharmacy at King Abdulaziz University (KAU). The interview took place after arranging a formal appointment with the participants at their office during business hours. The interview lasted approximately 30 min. A thorough set of questions concerning how older Saudi patients adhered to their medication regimens was prepared. Interviewing multiple doctors in a group setting provided several benefits to the process, including saving time, enabling explanations of the same ideas from different perspectives, and enabling explanations of the challenges of ensuring older people adhere to their medication regimens by presenting different scenarios to different participants;
(3) Questionnaire survey of older Saudis: The questionnaire was designed to be either self-completed or filled out by an older person's caregiver. The questionnaire was divided into three tracks, with Table 1 presenting the details of each track. The questionnaire was developed in English and translated into Arabic. According to World Meter's elaboration of the latest United Nations data, the current population of Saudi Arabia is 35,023,049 people [51], with older people 65 + age group comprising 2.8% of that total. The sample size was calculated with a 5% margin of error, 95% confidence interval, and 50% response distribution equivalent, giving 385 [52]. However, the survey ultimately exceeded that base requirement to reach 602 people.

3.2 Data analysis

This section analyzes the data obtained using both qualitative and quantitative methods.

3.2.1 Analysis of interviews with medical doctors

The researchers received substantial insight from the interviews with medical doctors regarding older Saudis' medication adherence:

- One of the most common mistakes among older Saudis was taking expired medicine. Thus, designers should consider expiration date as an essential field when adding medication information;
- The number of inputs should be reduced. There is no need to calculate the drug's position in the regimen each time; instead, the application should be designed to ask the user to enter the number of doses and the time of the first dose, after which the application can calculate the number of periods remaining;
- The side effects of drugs should be considered;
- Application designers should consider sending motivational phrases to users.

The analysis of interviews helps designers think and experience the world as users and better understand their needs in terms of medication adherence.

Table 1 Description of questionnaire tracks

Track	Description
T1. Demographic information	This track retrieved demographic information, including age group, gender, education level, employment status, and average monthly income
T2. Adherence to medication	This track determined participants' medication adherence level based on the 8-item Morisky medication adherence scale [53]
T3. Preferences for cognitive attributes	This track measured the preferences of older Saudis that reflected five cognitive process attributes (attention; perception; memory; learning; reading, speaking, and listening) [35]

3.2.2 Analysis of questionnaire survey

The three tracks have been analyzed and a statistical description provided.

3.2.2.1 Track 1: demographic information This track produced categorical variables classifying individuals into one of several groups. The data set for this section was first presented as frequencies and percentages (Table 2). The age group and average monthly income were chosen because, according to the Saudi Ministry of Health and the United Nations Population Fund, older age begins between the ages of 60 and 65 years [54] [55], and the average monthly income for Saudi families in 2021 was approximately 16,700 S.R. [56].

3.2.2.2 Track 2: adherence to medication The reliability of the eight-item scale in Track 2 was determined to be an acceptable level, with an alpha value of 0.7. Of the overall sample ($N = 602$), 476 participants (79%) were considered non-adherent (scores < 6), 112 (19%) were considered moderately adherent (scores of 6 or 7), and only 14 (2%) were considered highly adherent (score = 8) (Table 3).

3.2.2.3 Track 3: user preferences In the user preferences track, the results confirmed that target users demonstrated the following preferences, categorized in terms of the cognitive attributes reflected:

Table 2 Summary of participant demographics

Item	Item description	Number (n)	Percentage (%)
Age group	60–70 years	491	81.5
	Older than 70 years	111	18.4
Gender	Female	378	62.7
	Male	224	37.2
Education	Below primary education	178	29.5
	Primary education	88	14.6
	Intermediate education	44	7.3
	Secondary education	113	18.7
	Tertiary education	179	29.7
Occupation	Unemployed	303	50.3
	Retired	250	41.53
	Employed	49	8.14
Monthly income	Less than 10,000 S.R	323	53.65
	10,000–20,000 S.R	160	26.58
	20,000 S.R	119	19.77

Table 3 Adherence level

Adherence level	Low (%)	Medium (%)	High (%)
60–70	64	15	2
Over 70	15	3	0
Total	79	19	2

- Attention: Most users preferred the primary font color to be blue or red (38.2% and 36.5%, respectively) and the secondary font color to be pink (67%). The preferred primary background colors were blue (49.2%) and turquoise (45.7%);
- Perception: Most older Saudis recognized Sunday as the first day of the week (60.5%) rather than Saturday. Most users (over 95%) preferred redundant menu layouts (i.e., icons supported with text) over word-based (i.e., text-only) layouts;
- Memory: Most users preferred grid menu structures (85.9%) over vertical menu structures. This option is consistent with user choices pertaining to the perception attribute;
- Learning**:** Most participants (81%) preferred rectangles over circles. The former resemble the shape of pillboxes, which had been used by 40% of participants (although 61% did not use a pillbox to organize their medications at home);
- Reading, writing, and speaking: Most respondents preferred large font sizes (18 points) for reading on the UI (90%) and chose to hear reminder alarms that used a family member's voice (55.8%).

The researchers also investigated how respondents took their medications (Table 4):

75% (56% + 19%) depend on themselves to take their medication at the right time;

45% (21% + 24%) depend on other people living in the same home;

26% (17% + 9%) use mobile alarms to remind them when to take their medication;

10% depend on the medication's application.

4 Design of proposed application

The main problem demonstrated in the data collected was non-adherence to medication: 79% of older Saudis did not adhere to their medication regimen (Track 2, Table 3). Recognition of this led the authors to consider the existing methods participants used to take medications, because 75% of those in our sample depended on themselves to take medication and 45% depended on caregivers (Table 4). Non-adherence among older people indicates

Table 4 Methods for adhering to medication regimens

	I depend on myself (%)	I depend on people who live with me (%)	I use a mobile alarm (%)	I use medication reminder apps (%)
Always	56	21	17	5
Usually	19	24	9	5
Sometimes	14	21	16	11
Rarely	5	16	26	20
Never	5	18	32	59

the ineffectiveness of these current approaches. Most older people can easily perform basic tasks but have difficulty performing advanced tasks. Based on the results of the data analysis (Sect. 3), participants were categorized into one of two classes:

Independent older people: Able to perform basic and advanced mobile tasks;

Dependent older people**:** Able to perform only basic mobile tasks and dependent on the assistance of a caregiver or other family member to perform more advanced tasks.

These two types of older people were considered in the design of the proposed application, Teryaq. For the dependent group, which represents most older Saudis, the researchers relied on basic functions to design the screens, with a caregiver connected to perform more advanced tasks. Meanwhile, for the independent group, the application screens have been designed with all the functionalities matched to their technical level, enabling individuals to use the application independently.

The conceptual model shown in Fig. 1 provides a general idea of the shift from the problem space to the solution space. The model distinguishes two cases that represent the two types of older people.

4.1 Design of proposed application

The design of the Teryaq application is based on outputs generated from the three data inputs detailed, namely, a literature review, a questionnaire survey of older Saudis, and an interview with medical specialists (see Sect. 3.1). The outputs from the analysis focused on two aspects: (1) Adherence to medication functionalities must be provided to serve this age group and map their familiarity with mobile technologies; (2) certain UI design elements must be considered to properly perform the functionalities of older people.

This section details these two aspects, with subSect. 4.1.1 explaining the application's functionalities and subSect. 4.1.2 describing the technical design guidelines.

4.1.1 Application functionalities

The functional requirements elicited represent the needs of older people and their caregivers. Older people, whether dependent or independent, can interact with the system and perform a set of basic tasks including showing their pillbox, checking their medications, and snoozing or skipping alarms. However, independent users can perform more tasks at the advanced level, including adding

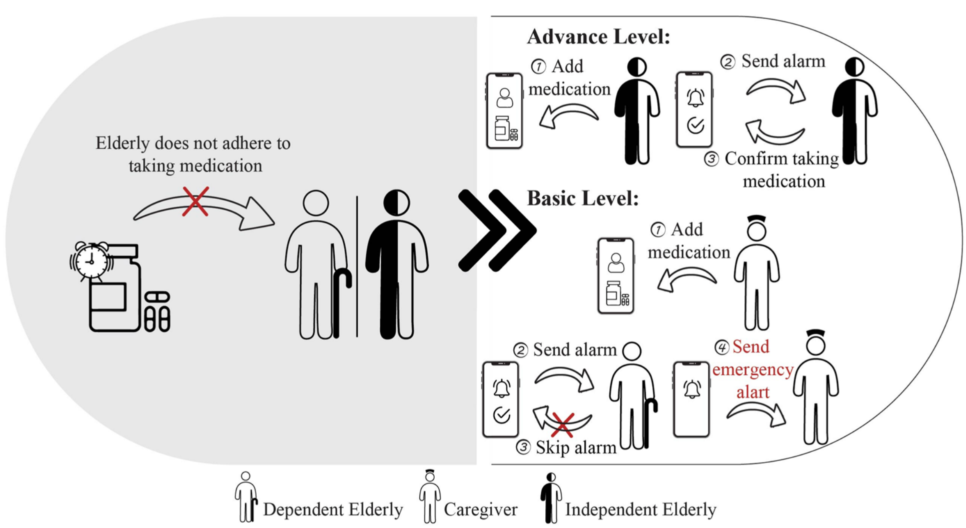

Fig. 1 Conceptual model for the classification of older people

medications and displaying daily and monthly reports, with dependent users requiring that a caregiver performs the advanced tasks for them.

4.1.2 Application interfaces

The design implications extracted from each input have enabled: (1) The application of design guidelines classified by authors based on cognitive attributes (Appendix A details the applied guidelines); (2) the study of older people's preferences from a design perspective to (a) resolve contradictions in the guidelines of previous studies and (b) determine older people's preferences in terms of designing certain elements (e.g., colors and tones) (see Appendix B describes all of the applied preferences); and (3) the consideration of the expertise of specialists in the field of medicine in the development of the design. Regarding the latter point, the experts interviewed mentioned an important aspect of supporting and motivating older users, namely, delivering motivational phrases to patients after they confirm that they have taken their medication.

The outputs in terms of design implications have been mapped to aspects of the design using mapping codes. The codes are divided into three segments: (1) Letters G, P, and S indicate guidelines, preferences, or specialist comments, respectively; (2) a number that refer to a cognitive attribute, under which design implications are classified; (3) a serial number. Figure 2 provides a visual demonstration of the mapping code format.

The final screen designs of the Teryaq prototype correspond to three user types (dependent older people, independent older people, and caregivers). Figure 3 shows tasks in the advanced-level screens, (a) medication screen and (b) new medication screen. Figure 4 shows tasks in the basic-level screens, (a) weekly pillbox screen, (b) daily pillbox screen, and (c) confirmation screen (Arabic).

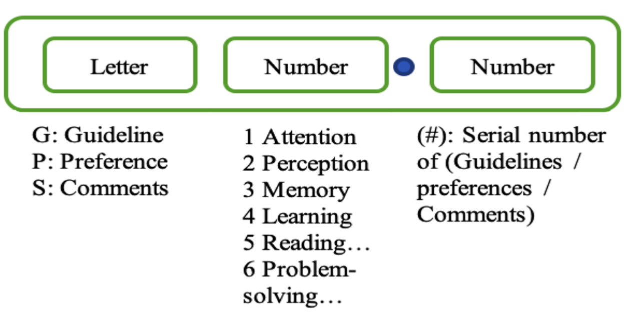

Fig. 2 Mapping codes

5 Design evaluation

As a preliminary step, pilot testing was conducted prior to the actual test to resolve design issues and ensure the clarity of the prototype and the task workflow. Table 5 lists the tasks mapped to the older people model, the level of functionality (basic or advanced), the guidelines considered in the design (Appendix A), and the cognitive attributes.

5.1 Pilot testing

The authors conducted pilot tests with three types of users: doctors, UX/UI experts, and older people. The feedback and results from this step were considered to improve the proposed Teryaq design before conducting actual usability testing.

5.1.1 Doctors

A 30-min pilot test was conducted in person with two doctors from the pharmacy college at KAU. Each doctor performed the tasks and identified existing errors. Most of the doctors' suggestions related to inputs, such as adding additional entries on the "Add medication" screen. The designers modified the prototype in response to these comments before pilot testing with UX/UI experts was conducted.

5.1.2 UX/UI experts

The pilot test was conducted online with four UX/UI experts (20 min per participant on average). The test moderator encouraged the UX experts to think aloud and ask questions if there was any confusion. During the test, the experts read the predefined tasks (basic and advanced) and then performed them. Expert comments were evaluated based on two factors: priority and severity. The high priority and high severity comments were acted upon.

5.1.3 Older users

The pilot test was conducted in person with a sample of four older users. According to [57], a sample of four to five participants is sufficient to identify 80% of usability flaws. The test took about five minutes for basic users and ten minutes for advanced users. Their levels were determined, and then the appropriate test was conducted. The test moderator observed the behavior of the older people during

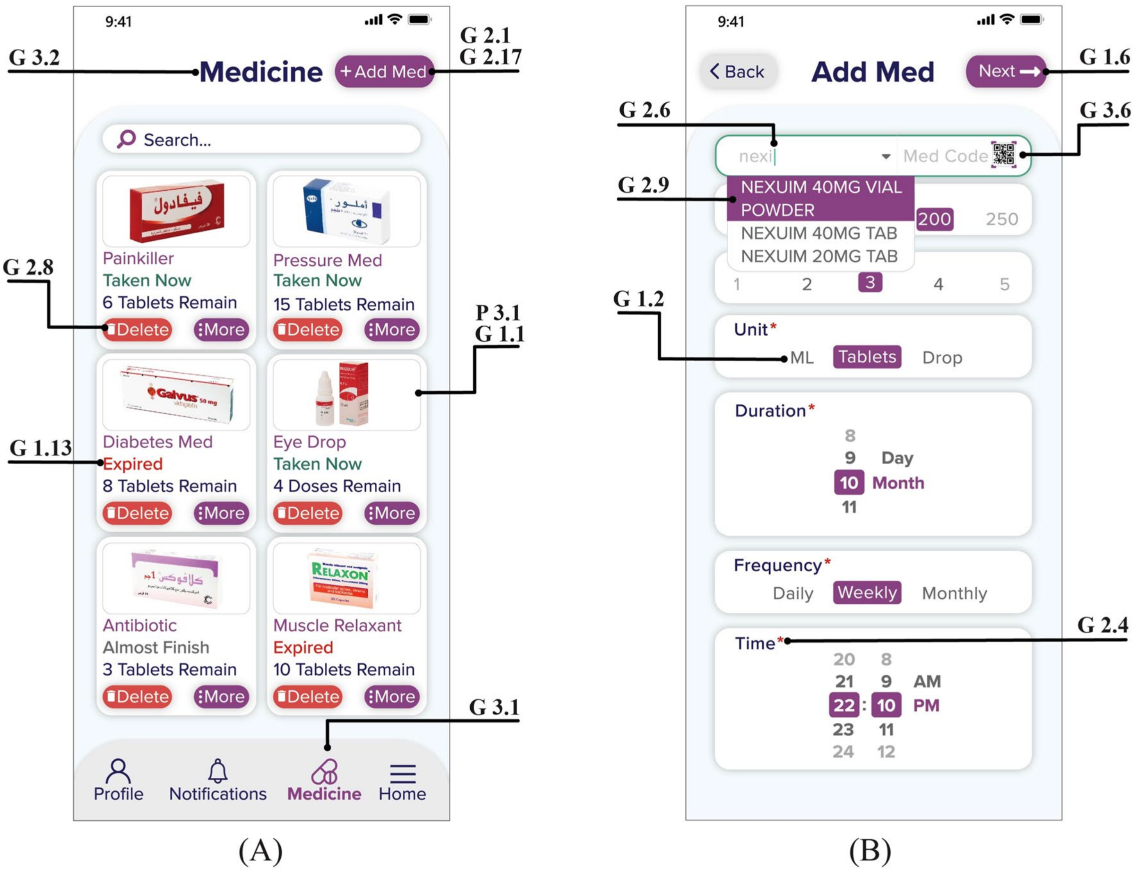

Fig. 3 Caregiver and independent older user screens

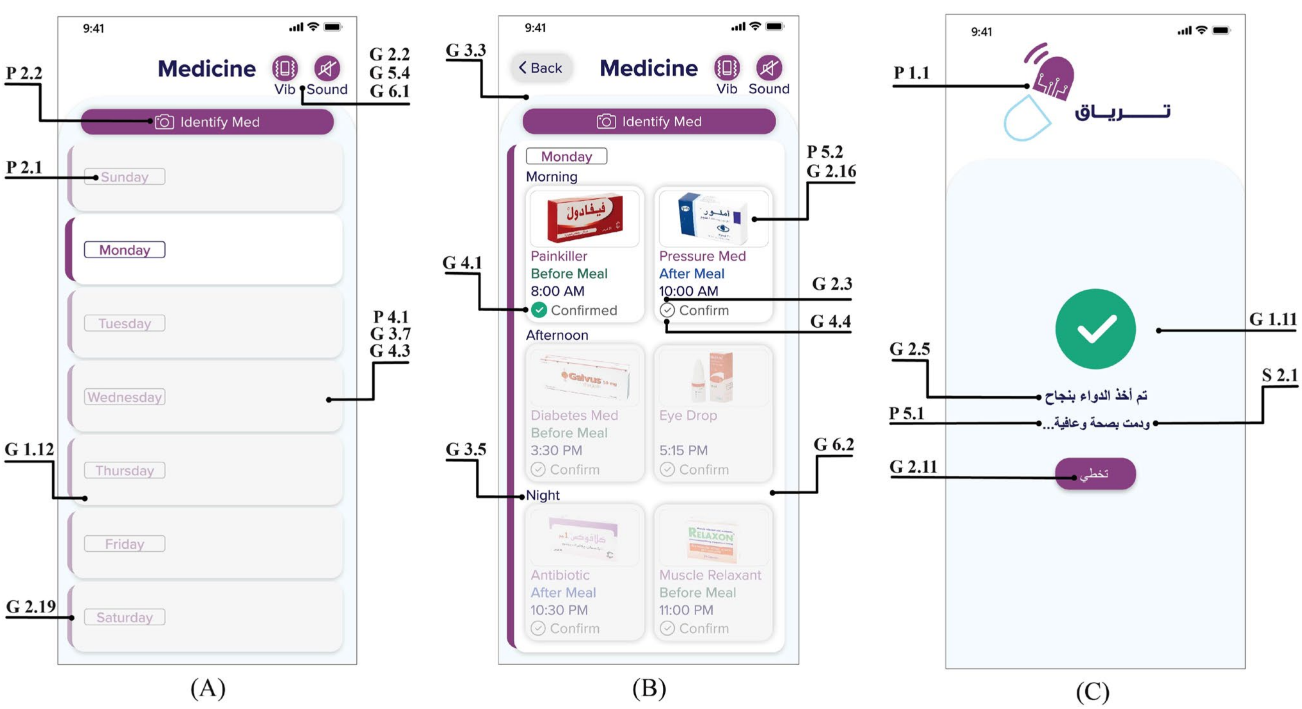

Fig. 4 Dependent older user screens

Table 5 Task list

Task functionality	Task scenario	Guidelines	Cognitive attributes
Basic level (dependent older user)			
1. Confirm taking medication	Suppose that today is Monday, and you did not hear the blood sugar medication alarm. After half an hour, you remember your medication before the application sends the second alarm. Please open Teryaq, take your medication, then confirm that you have taken the medication	1.9, 1.10, 2.2, 5.4, 6.1, 3.3, 4.1	All
2. Check medication	It is 6:29 now. At 6:30, Teryaq will remind you to take your blood pressure medication. Please check that you have the correct medication, take the medication, then confirm that you have taken it	1.1, 1.4, 1.6, 1.7, 1.9, 1.10, 1.12, 1.13, 2.2, 6.1, 2.19, 2.17, 2.19, 3.3, 3.5, 3.7, 4.3, 4.1, 5.4	All
3. Snooze reminder	Suppose you are outside your home and have forgotten to bring your medication with you. Teryaq reminds you to take your medication. Please snooze the alarm for 15 min until you are back home	1.9, 1.10, 3.3	Attention, memory
4. Skip reminder	Suppose you are expected to take your blood pressure medication now, and for some reason, you will not. Please skip the Teryaq alarm	1.9, 1.10, 3.3	Attention, memory
Advanced level (independent older user)			
1. Add medication	Your doctor has prescribed a new blood pressure medication for you. Please add the medication information to Teryaq so that the app can remind you to take the medication on time	1.1, 1.2, 1.3, 1.4, 1.6, 1.9, 1.10, 2.1, 2.4, 2.6, 2.9, 2.16, 2.17, 3.1, 3.5, 3.6, 6.2	Attention, perception, memory, problem-solving
2. Refill medications	Suppose your blood sugar medication is empty, but you have bought three new boxes. Please refill the blood sugar medication inside the application using the same information as before	1.1, 1.3, 1.9, 1.10, 2.4, 2.6, 3.1	Attention, perception, memory
3. Display daily report	Suppose that, at the end of the day, you want to check your medication adherence for the day. Please open Teryaq and display your daily report	1.1, 1.3, 1.4, 1.7, 1.9, 1.10, 3.1, 3.5	Attention, memory
4. Add side effects	Suppose you feel a sudden headache after taking a new blood pressure medication. Please open Teryaq and record this side effect so that you can inform your doctor about it at your next visit	1.1, 1.3, 1.9, 1.10, 2.4, 3.1	Attention, perception, memory

the test and then analyzed them based on their cognitive attributes to make the appropriate adjustments.

5.2 Case study testing

The effectiveness of designing a mobile UI was investigated based on cognitive attributes and the level of functionality of the proposed prototype in terms of improving older people's adherence to their medication regimens.

First, the proposed design was validated by evaluating older people's task performance using the quality-in-use characteristics of effectiveness, productivity, and error safety. Second, the proposed design was validated by whether participants expressed a desire to use the proposed design to adhere to their medication regimen. The application's functionality was tested based on a model involving two classes of older people:

- Dependent (basic level): To measure participant familiarity with performing the basic mobile application tasks required by the proposed design;
- Independent (advanced level): To measure participant familiarity with performing advanced mobile application tasks.

Pairs of hypotheses were formulated to meet the goal of the experimental design as follows:

- Null hypothesis: There is no significant difference in the average quality-in-use characteristics between the basic and advanced groups;
- Alternative hypothesis: There is a significant difference in the average quality-in-use characteristics between the basic and advanced groups.

5.2.1 Participants

A total of 50 Saudi citizens over the age of 60 years old were selected randomly. Participants were asked to sign consent forms, confirming that the collected information would be used for research purposes only. Control of subject selection methods involved assigning participants with similar levels of background knowledge to one of the two cohorts (basic or advanced) based on an initial examination comprising a set of items covering both basic and advanced mobile functionalities. Older users were considered advanced if they were able to perform 60% or more of the tasks on the advanced tasks list or 80% of those on the total list (basic and advanced). After the assessment, participants were divided into two groups: 36 in the basic group and 14 in the advanced group.

5.2.2 Testing procedure

Each participant was given a pre-test questionnaire to collect demographic information. Then, a usability test was conducted by briefing the participant on the application concept and the tasks. Two methods were used to collect data during the test: interviews and observations. The experiment evaluated each participant's ability to perform tasks sequentially on mobile devices using these methods. The basic group received four tasks related to the basic level, and the advanced group received four tasks related to the advanced level of functionality. The researchers collected independent variables, such as time taken to complete each task, number of correct actions for each task, and number of incorrect actions for each task. A post-test questionnaire obtained participant feedback on the application via four items related to cognitive attributes and one item related to adherence to medication. Table 6 shows the post-test questionnaire statements.

6 Results

6.1 Step 1: pre-test questionnaire results

Table 7 summarizes participant information for both groups.

6.2 Step 2: usability testing results

To investigate the hypothesis posed in Sect. 5.2, the three characteristics of the new quality-in-use model for each group were computed for each participant for all tasks based on the metrics presented in Table 8 [58]. After calculating descriptive statistics for all characteristics, the following steps were performed to verify the results. First, the normality of the data was checked. As Table 9 shows, the data are

Table 6 Post-test questionnaire

No	Cognitive attribute	Guideline	Item description	Agree	N/C	Disagree
1	Reading	G5.1	Font size is suitable			
2	Perception	G2.11	Layout colors are comfortable			
3	Memory	G3.3	Design is similar to other apps used			
4	Learning	G4.2	Tasks can be performed without assistance			
5	–	–	Improved adherence to medication			

Table 7 Demographic results

Item	Item details	Advanced group		Basic group	
		(*n*)	(%)	(*n*)	(%)
Age group (years)	60–70	14	100	34	94
	Over 70	–	–	2	6
Gender	Female	6	43	24	67
	Male	8	57	12	33
Education level	Below primary school	–	–	2	6
	Primary	–	–	9	25
	Intermediate	2	14	4	11
	Secondary	2	14	13	36
	Tertiary	10	71	8	22
Occupation	Employed	3	21	6	17
	Retired	9	64	11	31
	Unemployed	2	14	19	53
Monthly income (S.R.)	10,000 or less	3	21	19	53
	10,000–20,000	4	29	10	28
	20,000 or more	7	50	7	19

normal because the mean and median for all characteristics in both groups are almost identical.

Table 8 Quality-in-use factors, metrics, and interpretation

Quality-in-use characteristic	Metric	Interpretation
Effectiveness	Minimum number of correct actions/total number of actions per task	The closer to 1, the better
Productivity	Total number of actions/time	The greater the task productivity value, the better
Error safety	Incorrect number of actions per task/total number of actions per task	The closer to 1, the better

Table 9 indicates that the means of effectiveness and error safety are close to 1 in both groups. This means that older people in both groups perform well in terms of task effectiveness (i.e., selecting the minimum number of correct actions required) and safety (i.e., reducing the number of incorrect actions). The productivity levels of both groups were close to one another (0.29 and 0.27) and closer to 0 than a larger number, indicating that both groups took more time to complete the tasks successfully. Second, an *F*-test was performed to determine the variance between the two independent groups—whether different or equal—by verifying the following hypotheses: "The two population variances are equal" (null) and "The two population variances are not equal" (alternative). Because the *p*-values for effectiveness, productivity, and error were 0.08, 0.48, and 0.5, respectively, and none is smaller than 0.05, the null hypothesis cannot be rejected. As such, the two groups' variances are equal.

6.3 Step 3: user satisfaction results

The results of the post-test questionnaire revealed that both groups of older people gave the rating "agree" to all items, as Figs. 5 and 6 show. Statistically, after applying a two-sample *t*-test assuming equal variances, there were no differences between the two groups regarding agreement with all items. By comparing each item separately, it becomes clear that the advanced group demonstrated higher levels of agreement than the basic group for items 1, 2, and 4. However, for item 3 (familiarity of the design compared with other applications used), the basic group recorded higher levels of agreement than the advanced group. For the last item, both groups (94

Table 9 Mean and median of both groups of older users

	Basic group			Advanced group		
Characteristics	Effectiveness	Productivity	Error safety	Effectiveness	Productivity	Error safety
Mean	0.94	0.29	0.94	0.95	0.27	0.96
Median	0.95	0.29	0.95	1.00	0.26	1.00

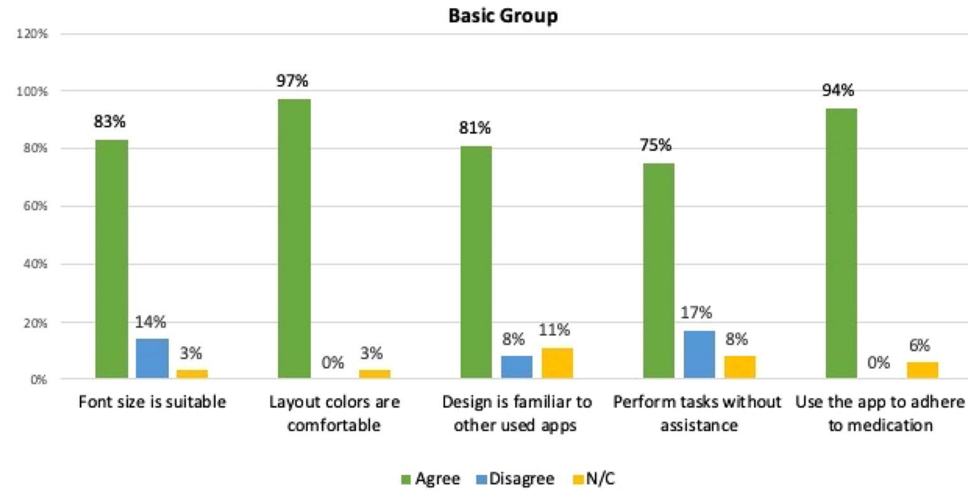

Fig. 5 Post-test questionnaire for the basic group

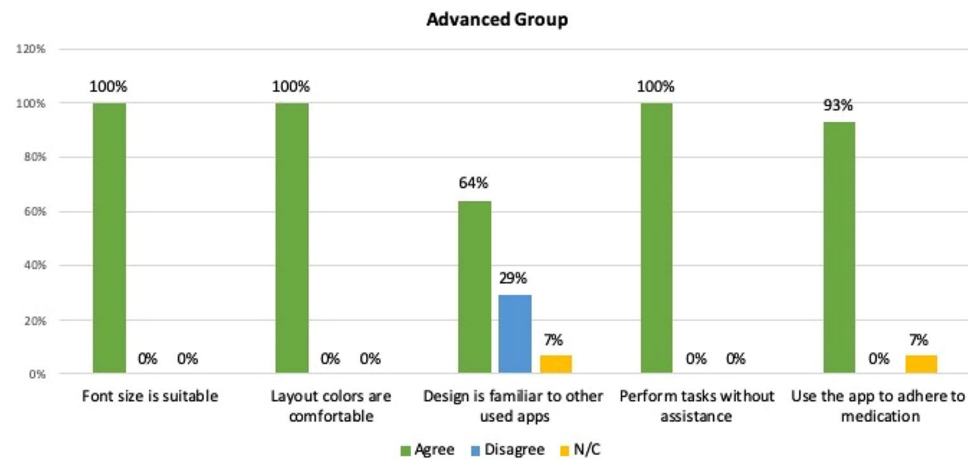

Fig. 6 Post-test questionnaire for the advanced group

and 93%) agreed to use the proposed design to improve their adherence to their medication regimens.

7 Discussion

The performances of basic and advanced older users were evaluated via direct assessment (a usability test) of their ability to achieve a set of tasks designed based on cognitive attributes and mapped to the developed model of older people (dependent vs. independent). In addition, an indirect assessment (a survey) was distributed to both groups after they performed the tasks to obtain their impressions regarding using the proposed design.

The usability test results make clear that both groups performed all the tasks included in the design prototype. The average effectiveness levels for the basic and advanced groups were 0.94 and 0.95, respectively. This result is considered excellent because it is close to 1 according to the interpretation (Table 8). Meanwhile, average error safety levels were 0.94 and 0.96 for the basic and advanced groups. This result is also considered excellent. Thus, both groups achieved the tasks effectively and with few errors.

Regarding the productivity factor, the averages were 0.29 and 0.27, respectively, for the basic and advanced groups. To interpret this result, the authors decided to compare the task performances of the two groups of older users with the performance of a sample of expert users who are familiar with mobile technology, namely, young people and users with a computer science background.

Table 10 Establishing baseline attributes for tasks (quality benchmarks)

T1. Confirm taking medication	Excellent	Acceptable	Unacceptable
Time (seconds)	< 7	7–10	> 10
Number of correct actions	4	5–6	> 6
Number of incorrect actions	0	1–2	> 2

Table 11 Average results of expert users for basic and advanced tasks

Groups	Effectiveness	Productivity	Safety
Basic tasks	1	0.85	1
Advanced tasks	1	0.86	1

Table 12 Baseline range for quality factors

Factors	Excellent	Acceptable	Unacceptable
Effectiveness	0.67–1	0.34–0.66	0–0.33
Productivity	> 0.65	0.45–0.65	< 0.45
Error safety	0.67–1	0.34–0.66	0–0.33

This sample's six expert user was given all the tasks (basic and advanced). Then, their average was calculated for the three quality-in-use factors. Based on the technique suggested by [59], the performance of the six experienced users was adopted as the baseline for judging the study participants. The average performance of the six expert users for the three factors was considered excellent, with instances of needing more time, correct actions, and incorrect actions considered acceptable and instances of needing substantially more time considered unacceptable. Table 10 shows an example of the attributes collected for task 1 ("Confirm taking medication") from the expert users.

Each task was measured for each expert, and the mean of all tasks for each factor was then computed. Table 11 shows the average results of the expert users for the three factors for both the basic and advanced tasks. According to [59], the limits of the acceptable and unacceptable ranges are 0.66 and 0.33 for effectiveness and error safety and 0.65 and 0.45 for productivity. The indicative baseline range appears in Table 12.

The results of the participating older users were compared with the baseline ranges documented in Table 12, which classify user performance as either excellent, acceptable, and unacceptable. The results show that the performance of both groups of older users was excellent for the effectiveness and error safety factors, meaning that designing an application for older people that considers their cognitive attributes based on the proposed model allowed them to perform tasks with the minimum number of correct actions and fewer incorrect actions. For the productivity factor, older users recorded scores of 0.29 and 0.27, respectively; as Table 12 shows, this is unacceptable. However, this result aligns with the physical characteristics of older users, who require more time than younger people to perform tasks due to the physical effects of aging.

8 Conclusion

This paper aimed to reduce the distance between older people and technology by understanding older users' cognitive attributes and adapting UI design accordingly. This paper has presented novel design guidelines based on the cognitive attributes that promote older people's adherence to their medication regimens. The study developed a model including two classes of older people based on mobile technology capability: (1) a dependent class, which maps to the basic level of mobile capability, and (2) an independent class, which maps to both the basic and advanced levels of mobile capability. The usability testing results confirmed that designing the mobile app based on the proposed model of older people and cognitive attributes improved effectiveness and error safety in the context of performing mobile tasks and promoted adherence to medications as a proof of concept. Regarding productivity, the results align with the physical characteristics of older people, who require more time than younger people to perform tasks demanding motor skills. In future work, the authors aim to add doctors as another user type and develop all features that relate to this type to improve communication between doctors and patients.

Appendix A: Description of applied guidelines

Guideline	Cognitive attribute guidelines
Attention	
G1.1	Content-oriented navigation is used in the form of a grid menu (based on preference P3.1) for the medication screen. However, a navigation bar (which supports G1.3) is implemented for the caregiver and independent screens, because these users are expected to have more advanced technical expertise
G1.2	All the options on the "add medication" screen are visible to the user
G1.6	The use of scrolling was avoided on all screens to the extent possible. For example, on the "add medication" screen, the entries are divided into two screens and separated by the "Next" button to avoid scrolling. Scrolling is only used if the number of medications increases
G1.7	On the "medication follow-up" screen, a back-to-top button has been added to enable the user to instantly jump to the screen's home position

Guideline	Cognitive attribute guidelines
G1.9	Consistency was considered for all of the application's visual elements: - Font (Proxima Nova and Arial) - Color (three colors were used) - Size (standardized) - Style of icons and menus
G1.10	The application does not contain ads and uses a plain background to avoid distractions
G1.11	Pop-up windows are never used, with designers replacing them with other design items
G1.12	The movement of opening the pillbox is not simulated to avoid animation
G1.13	Different information is categorized using different colors on the medication screen: - Red for expired medications - Green for full medications - Gray for medications that are nearly empty
Perception and recognition	
G2.1	Simple and descriptive language has been used to make it easier for older people to understand. For example, "Identify medication" instead of "Identify," "Edit profile" instead of "Edit," and "Add medication" instead of "Add."
G2.2, G5.4, G6.1	There are options on user screens to control volume and vibration
G2.3	Arabic numerals were used for all application screens
G2.4	Mandatory fields are marked with a red asterisk, and the entire entry header is marked with red in case the user has not filled it in
G2.5	Continuous and consistent feedback is provided in all application screens: - Confirmation operations messages, such as confirming the addition of an older person (readable feedback); - Changing the color of a button to green after users confirm that they have taken a medication (visual feedback); - Reading the name of a medication when pressed (audio feedback)
G2.6	When entering information, the cursor that appears inside the field in green
G2.8	Confirmation messages are shown to the user after completing any task, such as registering or adding medication, and before critical operations, such as deleting medications
G2.9	Entries are minimized to the extent possible. An SFDA database has been employed to support the entry process
G2.11	The color contrast has been considered in developing the application's screens, leading to difference ratios between the backgrounds and text ranging from 4.95 to 13.74, achieving AAA or AA level, according to WCAG 2.0 [60] [61]
G2.16	Inside the pillbox, the user can hear the name of any medicine by pressing it
G2.17	The essential buttons are provided at the top of the screen. These include the "Identify Medication" and "Add Medication" buttons
G2.19	According to this guideline and the questionnaire results, which emphasize older people's abilities to distinguish between active and disabled buttons, user options (inside the pillbox) are restricted as follows: - The week's days are disabled except for the current day - The process of confirming having taken the medication is disabled if it is the wrong time - The current day appears in a different color
Memory	
G3.1	The bar at the bottom of the screen allows the user to know their current location, because the current screen icon appears in a different color
G3.2	All screens have titles (e.g., Medication, Notifications, and Daily Report)
G3.3	Navigation and steps have been reduced in all screens. For example, on the pillbox screen, the user can perform many tasks (such as confirming taking the medication, checking the medication, and hearing the name of the medication) on one screen

Guideline	Cognitive attribute guidelines
G3.4	The amount of information required to complete the registration process has been reduced. It is limited to name, age, mobile phone number, and caregiver's password and name
G3.5	Medications are divided and grouped according to time of day
G3.6	The automatic entry feature has been implemented in the form of using the QR code on the "Add Medication" screen and using the QR code to link the older person's account with the caregiver's account without needing to enter the user ID
G3.7 and G4.3	The pillbox has been used as a metaphor to generate an idea about how to interact with the application screens, because older people are familiar with pillboxes
G4.1	A medication confirmation feature has been added that uses the camera. This is an existing feature of the WhatsApp application, and WhatsApp is a familiar application for older people
G4.4	The undo feature is provided for some operations. For example, if users accidentally confirm that they have taken a medication, they can undo it
G4.5 and G4.6	The registration process for older users is facilitated by enabling the process's completion by solely scanning the caregiver's QR code. Additionally, tutorials have been added to support and facilitate the use of the application
Reading, speaking, and listening	
G5.3	The actions used to operate the application have been minimized, with all application screens depending on two types of actions (click and drag)
G5.6	Proxima Nova (a sans-serif font) is used for all English- and French-language screens, with Arial used for all Arabic-language screens
Problem-solving, planning, reasoning, and decision-making	
G6.2	Hierarchical levels have been minimized, with less information required at lower levels. However, note the following: - On the "Add Medication" and login screens, three hierarchical levels are used - On the pillbox screen, two hierarchical levels are used

Appendix B: Description of applied preferences

Preference	Cognitive attribute preferences	Notes
Attention		
P1.1	Application views are based on the user's color preferences (blue, turquoise, or pink), and the choice of these three color tones is based on the need for high contrast, fulfilling G2.11	Older people prefer blue and pink for fonts and blue and turquoise for backgrounds
Perception		
P2.1	The days of the week are designed inside the pillbox, starting with Sunday	60.5% of older people consider the start of the week to be on Sunday
P2.2	Redundant (i.e., text with icon) interfaces have been used	
*Solves the contradiction between G2.12 and G2.13	95.3% of older people prefer redundant interfaces, with 4.7% preferring word-based interfaces	
Memory		
P3.1	Grid menus have been used instead of vertical menus	
*Resolves the contradiction between G3.8 and G3.9	85.9% of older people prefer a grid menu over a vertical menu	
Learning		

Preference	Cognitive attribute preferences	Notes
P4.1	A rectangular rather than a circular shape has been adopted for the pillbox	80.9% of older people prefer the rectangular shape
Reading, speaking, and listening		
P5.1	An 18-point font size has been adopted as the smallest font used in the application	Font sizes suggested in previous studies varied from 12 to 18 pt. According to the data collected, 90.7% of older users prefer a font size of 18 pt. Therefore, this font size has been adopted as the smallest font
P5.2	A family member's voice is used to deliver reminder messages *Resolves the contradiction between G5.8 and G5.9	One study suggested using male voices [38], and another study suggested using a voice of the same sex as the user [32]. However, following this paper's suggestion of using a family member's voice, as expected, 55.8% of older people preferred this approach

Acknowledgements The authors would like to thank all participants for contributing their time to this study.

Author contributions All authors contributed to the study conception and design, material preparation, and data collection and analysis. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding The authors did not receive support from any organization for the submitted work.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Durán-Vega, L.A., Santana-Mancilla, P.C., Buenrostro-Mariscal, R., Contreras-Castillo, J., Anido-Rifón, L.E., García-Ruiz, M.A., Montesinos-López, O.A., Estrada-González, F.: An iot system for remote health monitoring in elderly adults through a wearable device and mobile application. Geriatrics **4**(2), 34 (2019). https://doi.org/10.3390/geriatrics4020034
2. Shin, K.O., Yeom, N.-G., Park, H.-S.: Customer happiness and open innovation in the esthetics education for the elderly generation. J. Open Innov. Technol. Mark. Complex. **5**(4), 86 (2019). https://doi.org/10.3390/joitmc5040086
3. Gomes, C. A., Ferreira, S., Sousa, B.: Older Adults' participation in VIAS' mobile app design. In: International Conference on Human-Computer Interaction, Cham. (2020). https://doi.org/10.1007/978-3-030-50252-2_1
4. Concepción-Sánchez, J. Á., Caballero-Gil, P., Suárez-Armas, J., Álvarez-Díaz, N.: Mobile application for elderly assistance in public transport. In: Proceedings of the 1st International Conference on Internet of Things and Machine Learning, (2017). https://doi.org/10.1145/3109761.3158387
5. Alnanih, R.: Usability issues and design guidelines for user interfaces for elderly users. Int. J. Adv. Sci. Technol. **28**(13), 138–148 (2019)
6. Alsolami, F., Hou, X.Y., Ignacio, C.-V.: Factors affecting antihypertensive medications adherence among hypertensive patients in Saudi Arabia. Hypertension **34**, 34–52 (2016)
7. Kurdi, S., Albannay, R., Alsinan, Z., Islam, A.: Evaluation of medication adherence among patients with chronic diseases in Saudi Arabia. Int. J. Clin. Pract. **75**(7), e14253 (2021). https://doi.org/10.1111/ijcp.14253
8. Kini, V., Ho, P.M.: Interventions to improve medication adherence: a review. Am. Med. Assoc. **320**(23), 2461–2473 (2018). https://doi.org/10.1001/jama.2018.19271
9. Diemert, S., Weber, J., Price, M.: Computable adherence. In: International Conference on Healthcare Informatics (ICHI), (2017). https://doi.org/10.1109/ICHI.2017.96
10. Huang, S. C., Chang, H.-Y., Jhu, Y.-C., Chen, G.-Y.: The intelligent pill box — design and implementation. In: International Conference on Consumer Electronics, Taiwan, (2014). https://doi.org/10.1109/ICCE-TW.2014.6904076
11. Bhavya, K., Ragini, B., Anandhapadmanaban, S., Ashifa, A., Kumar, S.S., Suryalakshmi, R.: A smart medicine box for medication Management using IoT. J. Xi'an Univ. Archit. Technol. **12**(5), 1169–1174 (2020)
12. Shinde, S., Kadaskar, T., Patil, P., Barathe, R.: A smart pill box with remind and consumption using IOT. Int. Res. J. Eng. Technol. **4**(12), 152–154 (2017)
13. Jia, J., Yu, J., Hanumesh, R.S., Xia, S., Wei, P., Choi, H., Jiang, X.: Intelligent and privacy-preserving medication adherence system. Smart Health **9–10**, 250–264 (2018). https://doi.org/10.1016/j.smhl.2018.07.012
14. Wu, Q., Zeng, Z., Lin, J., Chen, Y.: AI empowered context-aware smart system for medication adherence. Int. J. Crowd Sci. **1**(2), 102–109 (2017). https://doi.org/10.1108/IJCS-07-2017-0006
15. Minaam, D.S.A., Abd-ELfattah, M.: Smart drugs: improving healthcare using smart pill box for medicine reminder and monitoring system. Future Comput. Inform. J. **3**(2), 443–456 (2018). https://doi.org/10.1016/j.fcij.2018.11.008
16. Bhati, S., Soni, H., Zala, V., Vyas, P., Sharma, Y.: Smart medicine reminder box. IJSTE Int. J. Sci. Technol. Eng. **3**(10), 172–177 (2017)
17. Debevc, M., Kosec, P., Holzinger, A.: Improving multimodal web accessibility for deaf people: sign language interpreter module. Multimed. Tools Appl. **54**, 181–199 (2011)
18. Aldeer, M., Alaziz, M., Ortiz, J., Howard, R. E., Martin, R. P.: A sensing-based framework for medication compliance monitoring. In: Proceedings of the 1st ACM International Workshop on Device-free Human Sensing, New York, NY, USA, (2019). https://doi.org/10.1145/3360773.3360886
19. Abdullah, A., Lim, T.: Smartmates for medication adherence using non-intrusive wearable sensors. In International Conference on Wireless Mobile Communication and Healthcare, Cham, (2017). https://doi.org/10.1007/978-3-319-58877-3_8

20. Kalantarian, H., Alshurafa, N., Sarrafzadeh, M.: A survey of diet monitoring technology. IEEE Pervasive Comput. **16**(1), 57–65 (2017). https://doi.org/10.1109/MPRV.2017.1
21. Holzinger, A., Schaupp, K., Eder-Halbedl, W.: An investigation on acceptance of ubiquitous devices for the elderly in a geriatric hospital environment: using the example of person tracking. In: Miesenberger, K., Klaus, J., Zagler, W., Karshmer, A. (eds.) Computers Helping People with Special Needs. ICCHP 2008. Lecture Notes in Computer Science. Springer, Berlin, Heidelberg (2008)
22. Gashu, K.D., Nurhussien, F., Mamuye, A., Gelaye, K.A., Tilahun, B.: Developing and piloting TB medication and refilling reminder system in Ethiopia. Stud. Health Technol. Inform. **270**, 1251–1252 (2020). https://doi.org/10.3233/SHTI200387
23. Sherif, S., Tan, W.H., Ooi, C.P., Sherif, A., Mansor, S.: LoRa driven medical adherence system. Bull. Electr. Eng. Inform. **9**(6), 2294–2301 (2020). https://doi.org/10.11591/eei.v9i6.2195
24. Alsswey, A., Al-Samarraie, H.: Elderly users' acceptance of mHealth user interface (UI) design-based culture: the moderator role of age. J. Multimodal User Interfaces **14**(1), 49–59 (2020). https://doi.org/10.1007/s12193-019-00307-w
25. Heldenbrand, S., Martin, B.C., Gubbins, P.O., Hadden, K., Renna, C., Shilling, R., Dayer, L.: Assessment of medication adherence app features, functionality, and health literacy level and the creation of a searchable Web-based adherence app resource for health care professionals and patients. J. Am. Pharm. Assoc. **56**(3), 293–302 (2016). https://doi.org/10.1016/j.japh.2015.12.014
26. Nor, R. M., Mohamadali, N. A., Azmi, K., Marzuki, A., Nor, L. M., Yusof, M.: ScanMed: a mobile medicine adherence application with intake validation using QR code. In: 2016 6th International Conference on Information and Communication Technology for The Muslim World (ICT4M), Jakarta, Indonesia, (2016). https://doi.org/10.1109/ICT4M.2016.033
27. LeRouge, C., Ma, J., Sneha, S., Tolle, K.: User profiles and personas in the design and development of consumer health technologies. Int. J. Med. Inform. **82**(11), e251–e268 (2013). https://doi.org/10.1016/j.ijmedinf.2011.03.006
28. Lee, C., Coughlin, J.F.: PERSPECTIVE: older adults' adoption of technology: an integrated approach to identifying determinants and barriers. J. Prod. Innov. Manag. **32**(5), 747–759 (2015). https://doi.org/10.1111/jpim.12176
29. Reddy, G.R., Blackler, A., Popovic, V.: Adaptable interface framework for intuitively learnable product interfaces for people with diverse capabilities. In: Intuitive Interaction, pp. 113–127. CRC Press, Boca Raton (2018)
30. Sharma, R., Nah, F. F.-H., Sharma, K., Katta, T. S. S. S., Pang, N., Yong, A.: Smart living for elderly: design and human-computer interaction considerations. In: International conference on human aspects of IT for the aged population, (2016). https://doi.org/10.1007/978-3-319-39949-2_11
31. Zhang, H., Shen, Z., Lin, J., Chen, Y., Miao, Y.: Familiarity design in exercise games for elderly. Int. J. Inf. Technol. **22**(2), 1–19 (2016)
32. Chirayus, K., Nanthaamornphong, A.: Cognitive mobile design guidelines for the elderly: a preliminary study. In: 2020 17th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), Phuket, Thailand, (2020). https://doi.org/10.1109/ecti-con49241.2020.9157905
33. Chang, J. J., Binti Zahari, N. S. H., Chew, Y. H.: The design of social media mobile application interface for the elderly. In: 2018 IEEE Conference on Open Systems (ICOS), Langkawi, Malaysia, (2018). https://doi.org/10.1109/ICOS.2018.8632701
34. Alnanih, R.: Cognitive process-based design implications for mobile user interfaces. Int. J. Emerg. Trends Eng. Res. **7**, 523–529 (2019)
35. Sharp, H., Preece, J., Rogers, Y.: Interaction Design: Beyond Human-Computer Interaction, pp. 65–85. Wiley, New York (2015)
36. Darvishy, A., Hutter, H.-P.: Recommendations for age-appropriate mobile application design. In: International Conference on Applied Human Factors and Ergonomics, (2017). https://doi.org/10.1007/978-3-319-60597-5_22
37. Li, Q., Luximon, Y.: Older adults' use of mobile device: usability challenges while navigating various interfaces. Behav. Inf. Technol. **39**(8), 837–861 (2020). https://doi.org/10.1080/0144929X.2019.1622786
38. Ghorbel, F., Metais, E., Ellouze, N., Hamdi, F., Gargouri, F.: Towards accessibility guidelines of interaction and user interface design for alzheimer's disease patients. In: ACHI 2017. The Tenth International Conference on Advances in Computer-Human Interactions, Nice, France, (2017). https://hal.archives-ouvertes.fr/hal-03238198
39. Yin, T., Ali, N.M., Noah, S.A.M.: Interface design guidelines of nutritional information application for the elderly. J. Teknol Mklm dan Multimed Asia Pasifik **5**(1), 1–13 (2016)
40. Muskens, L., van Lent, R., Vijfvinkel, A., van Cann, P., Shahid, S.: Never too old to use a tablet: designing tablet applications for the cognitively and physically impaired elderly. In: International Conference on Computers for Handicapped Persons, (2014). https://doi.org/10.1007/978-3-319-08596-8_60
41. Hollinworth N., Hwang, F.: Investigating familiar interactions to help older adults learn computer applications more easily. In: Proceedings of HCI 2011 The 25th BCS Conference on Human Computer Interaction 25, (2011). https://doi.org/10.14236/ewic/HCI2011.79
42. Mi, N., Cavuoto, L.A., Benson, K., Smith-Jackson, T., Nussbaum, M.A.: A heuristic checklist for an accessible smartphone interface design. Univ. Access Inf. Soc. **13**(4), 351–365 (2014). https://doi.org/10.1007/s10209-013-0321-4
43. Salman, H.M., Ahmad, W.F.W., Sulaiman, S.: Usability evaluation of the smartphone user interface in supporting elderly users from experts' perspective. IEEE Access **6**, 22578–22591 (2018). https://doi.org/10.1109/ACCESS.2018.2827358
44. Naumann, A.B., Wechsung, I., Hurtienne, J.: Multimodal interaction: A suitable strategy for including older users? Interact. Comput. **22**(6), 465–474 (2010). https://doi.org/10.1016/j.intcom.2010.08.005
45. Al-Razgan, M., Al-Khalifa, H.S.: Sahl: a touchscreen mobile launcher for arab elderly. J. Mobile Multimed. **13**(1–2), 75–99 (2017)
46. Reddy, G.R., Blackler, A., Popovic, V., Thompson, M.H., Mahar, D.: The effects of redundancy in user-interface design on older users. Int. J. Human Comput. Stud. **137**, 102385 (2020). https://doi.org/10.1016/j.ijhcs.2019.102385
47. Restyandito, E.K., Widagdo, T.: Mobile application menu design for elderly in indonesia with cognitive consideration. J. Phys. Conf. Ser. **1196**(1), 012058 (2019). https://doi.org/10.1088/1742-6596/1196/1/012058
48. Baharum, A., Zain, N.M., Taharudin, A., Hanapi, R., Saudi, A., Alfred, R.: Guidelines of user interface design for elderly mobile applications: a preliminary study. Asian J. Inf. Technol. **16**(1), 38–44 (2017). https://doi.org/10.3923/ajit.2017.38.44
49. Sookhanaphibarn, K., Ketchaikosoal, V., Kanjanayothin, C.: Optimum button size and reading character size on mobile user interface for Thai elderly people. In: IEEE 6th Global Conference on Consumer Electronics (GCCE), (2017). https://doi.org/10.1109/GCCE.2017.8229479

50. Po-Chan, Y.: The influence of the interface button design of touch screens on operation and interpretation by elderly and middle-aged adults. Designs **3**(3), 35 (2019). https://doi.org/10.3390/designs3030035
51. World Population Review: Saudi Arabia population. (2020). Available: https://worldpopulationreview.com/countries/saudi-arabia-population
52. Select Statistical Services: Population proportion - sample size. Available: https://select-statistics.co.uk/calculators/sample-size-calculator-population-proportion/
53. Morisky, D.E., Ang, A., Krousel-Wood, M., Ward, H.J.: Predictive validity of a medication adherence measure in an outpatient setting. J. Clin. Hypertens. **10**(5), 348–354 (2008). https://doi.org/10.1111/j.1751-7176.2008.07572.x
54. Ministry of Health Saudi Arabia: What is aging? Elderly health. (2020). Available: https://www.moh.gov.sa/en/HealthAwareness/EducationalContent/Health-of-Older-Persons/Pages/What-Is-Aging.aspx
55. United Nations Population Fund (UNFPA): Ageing. (2020). Available: https://www.unfpa.org/ageing
56. Salary Explorer: Average salary in Saudi Arabia, (2021). Available: http://www.salaryexplorer.com/salary-survey.php?loc=191&loctype=1
57. Nielsen, J.: How many test users in a usability study. Nielsen Norman Group **4**(6), 1–10 (2012)
58. Alnanih, R., Ormandjieva, O., Radhakrishnan, T.: A new quality-in-use model for mobile user interfaces. In: 2013 Joint Conference of the 23rd International Workshop on Software Measurement and the 8th International Conference on Software Process and Product Measurement, Ankara, Turkey, (2013)
59. Sauro, J.: A practical guide to measuring usability. Meas. Usabil. LLC Denver **12**, 10–20 (2010)
60. Kirkpatrick, A., Connor, J. O., Campbell, A., Cooper, M.: Web content accessibility guidelines (WCAG) 2.1. World Wide Web Consortium (W3C) Recommendation, (2018). Available: https://www.w3.org/TR/WCAG/#contrast-minimum
61. Verou, L.: Web content accessibility guidelines (WCAG) 2.1 on contrast ratio. W3C Recommendation, (2018). Available: https://contrast-ratio.com/

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.