Toward an Age-friendly Design of Smartphone Interfaces: The Usability Test of a Launcher for Older Adults

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Abstract
Smartphones are expected to play an important role in augmenting active and healthy ageing by integrating various assistive technologies (ATs). This paper outlines prior literature about design guidelines for smartphone user interfaces (UI) for older adults and reports on the results of usability testing of eight built-in features and ATs of *GoLivePhone* in an attempt to evaluate usability problems in the design of smartphone launchers with an adapted UI for older adults. The findings indicate a generally adequate performance of the *GoLivePhone* UI in terms of quantitative usability metrics, suggesting that the performance of a launcher UI is not determined by the type of service (basic features vs. ATs), but rather by the design of UI. In addition, the examination of participants' errors revealed two aspects of UI usability optimization for launchers. First, wrong-action errors often occur because of a non-optimal fit between mental models familiar to older adults and the structure of the UI. Second, multi-screen navigation can be beneficial for older adults only if the layout of the UI elements is applied consistently and multiple entry fields are avoided on the same screen.
Keywords: assistive technologies, older adults, smartphone launcher, usability.

Izvleček
Razvoj starejšim prijaznih uporabniških vmesnikov na pametnih telefonih: testiranje uporabnosti zaganjalnika za starejše
Za pametne telefone se pričakuje, da bodo imeli v prihodnosti osrednjo vlogo pri spodbujanju aktivnega in zdravega staranja zaradi možnosti integracije podpornih tehnologij. V članku izhajamo iz pregleda literature na področju smernic za oblikovanje uporabniških vmesnikov za starejše na pametnih telefonih in predstavimo rezultate testiranja uporabnosti osmih funkcionalnosti in podporne tehnologije zaganjalnika *GoLivePhone*. S tem skušamo ovrednotiti težave z uporabnostjo, ki se pojavljajo pri uporabi zaganjalnikov za pametne telefone z uporabniškimi vmesniki za starejše. Kvantitativne metrike uporabnosti nakazujejo sorazmerno ustrezno prilagojenost zaganjalnika *GoLivePhone*, pri čemer uporabnost vmesnika ni pogojena s tipom storitve (osnovna funkcionalnost proti podporni tehnologiji), marveč z njegovim dizajnom. Hkrati podrobnejši pregled napak med testi uporabnosti izpostavlja dve področji optimizacije uporabnosti vmesnikov na zaganjalnikih. Prvo predstavljajo napake zaradi napačnih dejanj, ki so posledica neustreznega ujemanja miselnih modelov starejših s strukturo uporabniškega vmesnika. Hkrati pa rezultati kažejo, da je večzaslonska navigacija za starejše koristna le, ko je videz vmesniških elementov konsistenten in se na istem zaslonu ne nahaja več vnosnih polj.
Ključne besede: podporne tehnologije, starejši, zaganjalniki za pametne telefone, uporabnost.

1 INTRODUCTION

The use of touch-based smartphones represents an opportunity for improving the active and healthy ageing of older adults (Plaza, Martín, Martin, & Medrano, 2011) by the potential integration of a range of assistive technologies (ATs), including various kinds of emergency services, health monitoring solutions, social communication platforms, fall detectors etc. (Lamonaca, Polimeni, Barbé, & Grimaldi, 2015). Many case studies have indicated positive outcomes of the adoption of mobile health applications (apps) (Arnhold, Quade, & Kirch, 2014; Joe & Demiris, 2013) and mobile ATs (Plaza et al., 2011) in field trials. Nevertheless, the overall adoption of smartphones among older adults is still low, with a persisting acceptance gap in comparison with younger generations (Smith, 2013).

As one possible reason for this lack of acceptance, researchers have underscored the scarce implementation of usability design guidelines for older adults (Balata, Mikovec, & Slavicek, 2015). For example, Arnhold et al. (2014) demonstrated that in spite of hundreds of smartphone apps for diabetics, their average performance in terms of adaptation to the declining cognitive, sensory and motor capabilities of older adults could be significantly improved with the optimisation of the user interface (UI). In addition, mobile ATs are mainly offered as third-party apps which demands that older adults be familiarised with the installation and operation procedures of generic smartphone operating systems (OSs) that also rarely consider their specific usability requirements (Leitão & Silva, 2012).

Very recently, smartphone launchers with an age-friendly UI for older adults have been proposed to address the usability problems of older adults (Al-Razgan, Al-Khalifa, & Al-Shahrani, 2014; Arab, Malik, & Abdulrazak, 2013; Balata et al., 2015). Launchers are specific apps programmed with the intent to reduce the complexity of a smartphone UI. They are part of the smartphone OS' UI that lets users customise the home screen and/or perform other tasks, such as launch apps on the smartphone (Balata et al., 2015). Besides enclosing an adapted UI that replaces the generic UI of a smartphone's OS, launchers for older adults can also integrate a different number of basic features that are most often used by older adults (e.g., calls, contact book, clock, calendar and alarm) with various ATs (e.g., lifeline, medication alarm). It is in this sense that scholars have even suggested that smartphone apps could integrate diverse ATs in the long run, partially replacing both the wired and wireless telecare infrastructure, such as ambient sensors and telecare communication gateways (Doughty, 2011).

In contrast to the abundant literature on the adaptation of a smartphone UI to limited vision, hearing, cognitive functioning and motor capabilities, few usability studies of smartphone launchers with adapted UIs and ATs have been conducted so far (Arab et al., 2013; Balata et al., 2015; Silva, Holden, & Nii, 2014). Usability tests of launchers are particularly rare. To our knowledge, only one article has been published that includes a usability evaluation of a commercially available launcher (Balata et al., 2015), though it gives no special consideration to errors that older adults might make while operating the system. Therefore, the main goal of this study was to explore what are the most important usability problems older adults experience with the UIs of launchers. To this end, we conducted – with five older adults, aged 65 to 70 – a series of usability tests of a commercially available launcher *GoLivePhone* that in addition to basic smartphone features also supports several ATs.

2 RELEVANT LITERATURE

2.1 Smartphone UI design for older adults

Fisk, Rogers, Charness, Czaja, and Sharit (2009) suggest that when applying the human factors approach to create design solutions for older adults, their sensory, perceptual, cognitive and motor resources should be carefully considered. These aspects received considerable attention in the investigation of the relationship between age and older adults' capabilities when operating a mobile phone or smartphone. In fact, the results of such research have recently been distilled into a number of design guidelines for touchscreen-based smartphone UIs (Calak, 2013; Díaz-Bossini & Moreno, 2014; Loureiro & Rodrigues, 2014; Silva, Holden, & Jordan, 2015), providing informative insight into the most pertinent capabilities and limitations of older adults that are directly relevant for the design of a smartphone UI.

With reference to *sensory and perceptual* issues, it is generally suggested that older adults prefer a larger size of text and (virtual) buttons (Al-Razgan, Al-Khalifa, Al-Shahrani, & AlAjmi, 2012; Calak, 2013; Díaz-Bossini & Moreno, 2014; Loureiro & Rodrigues, 2014; Silva et al., 2015), which should be separated by sufficient spacing (Al-Razgan et al., 2012) to prevent pressing multiple buttons simultaneously (i.e., the »fat fingers« issue) (Siek, Rogers, & Connelly, 2005). In fact, Silva et al. (2015) recomme an enlarged size of all user interface elements with a target area of at least 14 mm^2, with 2 mm of spacing between each element. In addition, the use of left-aligned text, an easy-to-read font family (e.g., Sans Serif) and medium or bold font face type is suggested (Loureiro & Rodrigues, 2014). In this context, it is also advised that text should be clearly distinguishable from the background by avoiding monochromatic colour themes (Díaz-Bossini & Moreno, 2014). Hence, the UI should provide users with a high-contrast graphical UI by avoiding white as a background colour as well as a combination of blue and green tones (Díaz-Bossini & Moreno, 2014; Silva et al., 2015). Accordingly, the maximum number of UI colours should be limited to four (Díaz-Bossini & Moreno, 2014). Furthermore, design adaptations of a smartphone UI should also meet accessibility expectations of older adults in terms of hearing impairments. Specifically, it is beneficial when the UI allows older users to fine-tune the volume levels of all types of auditory cues (i.e., not only ring tones and alerts) as well as to prolong the duration of sound signals and to choose sounds from the lower-frequency spectrum (Calak, 2013; Silva et al., 2015).

A smartphone UI can be adapted to the *motor and movement* capabilities of older adults by avoiding complex touchscreen gestures (e.g., double taps, pinches, snips) (Díaz-Bossini & Moreno, 2014). Moreover, the UI should provide older users with multimodal feedback (Calak, 2013; Díaz-Bossini & Moreno, 2014; Silva et al., 2015). For example, interaction with items on the screen should be supported not only by visual and auditory but also by tactile feedback, upon executing an operation. In the case of touch feedback, it is especially helpful if the vibration feedback is localised to the touching/activation finger rather than vibrating the entire device (Mi, Cavuoto, Benson, Smith-Jackson, & Nussbaum, 2014), and also if the vibrating patterns used are in line with older adults' haptic sensory modalities (Kobayashi & Nakano, 2015). Information should be concentrated mainly in the centre of the screen (Díaz-Bossini & Moreno, 2014) and multi-screen navigation should be employed instead of scrolling (Loureiro & Rodrigues, 2014). Since older adults are slower in performing finger gestures to input patterns on small touchscreens (Stössel, Wandke, & Blessing, 2010), longer action time-outs and prolonged screen-dimming functions can both be beneficial for them (Silva et al., 2015).

The avoidance of scrolling and short action time-outs is also related to *cognitive resources*. Older adults experience declines in working and prospective memory as well as in selective and dynamic attention (Fisk et al., 2009). For instance, they require more time to decide what to choose from a number of available navigation options (Loureiro & Rodrigues, 2014). Thus, developers should reduce the complexity of the UI by means of promoting recognition (rather than recall) and consistency in the use of UI elements (Silva et al., 2015). For example, UI navigation should be supported by simple, clear and consistent terminology (Díaz-Bossini & Moreno, 2014; Loureiro & Rodrigues, 2014); by self-explanatory icons that have meaningful labels that activate older adults' semantic memories (Silva et al., 2015); and by shallow interface menus.

In addition, the main navigation needs to be located in the same place on all screens, critical functions (e.g., the Back button) should never disappear and important functions should be placed at the top of the screen to avoid mistake touches (Al-Razgan et al., 2012; Silva et al., 2015). In general, a UI should leverage mental models familiar to older adults (Silva et al., 2015). With reference to attention, actions that require multiple tasks need to be avoided. For instance, a UI needs to be based on single-task dialog boxes; on the removal of interaction elements calling attention as soon as they are not needed; and on the avoidance of multiple home-screens (Calak, 2013). In multi-task actions, the UI should always clearly indicate the name and status of the task during all steps (Díaz-Bossini & Moreno, 2014) to support older adults' spatial cognition. In this sense, Calak (2013) also suggested that fast-moving objects should be avoided. Finally, it is recommended that error (recovery) messages are simple and easy to follow. Older users should also be provided an easy exit/cancel function in the form of a left-pointing Back button (Silva et al., 2015).

2.2 Research on smartphone launchers for older adults

Even though launchers ought to be designed with the aim of overcoming age-related functional limitations of older adults, this does not necessarily mean that the design recommendations presented in Section 2.1 have so far been adequately considered and implemented. Unfortunately, the research on launchers in this context is rare. In fact, a literature review of scholarly papers yielded only three studies that evaluated the usability of smartphone launchers for older adults.

Balata et al. (2015) evaluated the *Koala Phone Senior Launcher*, an adapted Android launcher, and compared the results with the evaluation of the standard Android UI. The study found that the overall completion rate of tasks for the age-adapted launcher was 40%, and only 7% for the standard Android UI. Moreover, the results not only indicated that the adapted launcher had a completion rate for all tasks that was six times higher, but also that it produced fewer errors (i.e., 2.4-times fewer errors) than the standard UI. The completion rate was higher particularly in terms of more complex tasks (e.g., adding a new contact, writing a text message, setting the alarm, sending a photo via e-mail).

Similarly, Arab et al. (2013) evaluated the prototype of an age-friendly UI launcher, *PhonAge*. They showed that the majority of the twenty older participants successfully executed the given tasks. This means that older adults did not experience many problems. In addition, Al-Razgan et al. (2014) carried out a heuristic evaluation of three Android launchers and three Android applications for older users. They found that the look and feel category had the highest number of critical issues. Functionality came second in terms of the number of usability problems, while the fewest problems were found in the interaction category (e.g., providing clear feedback and preferable gestures).

All three studies provide also specific insight into older adults' sensory and perceptual, motor and cognitive resources. For instance, in terms of *sensory and perceptual* issues, Al-Razgan et al. (2014) concluded that, when it comes to heuristics, the look and feel category has the highest number of critical occurrences, which raises the importance of addressing older adults' declining visual abilities and difficulties in recognising small icons. Evaluators indicated that changing the text font or colour using installed launchers is not possible, and therefore requires changes to be made through device settings. Conversely, *KoalaPhone's* high-fidelity prototype does allow for the setting of a larger font size for better readability. All buttons also provide haptic (i.e., vibrating) and sound feedback (Balata et al., 2015). In addition, evaluation results of *PhonAge* usability tests show that participants appreciated the clear colour (green, yellow, blue) of the wallpaper (Arab et al., 2013).

With reference to *motor resources*, Balata et al. (2015) showed that buttons at the top right corner were not easily accessible by touch. As a result, most buttons were placed in the bottom part of the screen. Furthermore, since older people are slower and less accurate in performing finger gestures, accidently pressing the wrong button is more common for them. Providing easy error recovery to older adults is thus important. In this context, Al-Razgan et al. (2014) also considered whether a confirmation message for critical actions such as deletion is displayed. It was found that this feature was not available in the launchers that have been tested, concluding that older adults have to be warned before completing any action by presenting a message along with a sound.

With reference to *cognitive resources*, the importance of understandable icons with meaningful labels was mentioned in all three studies. For instance, Balata et al. (2015) showed that older users did not understand the original icon depicting the Menu button, so it was changed to a Menu label. The importance of meaningful text descriptions of icons was stressed also by Arab et al. (2013). Even though most of *PhonAge*'s icons (e.g., phone, emergency) were easily interpreted by participants even without labels, labelling the icons helped participants to understand the navigation and social service icons.

Guidelines for designing a smartphone UI for older adults typically suggest the avoidance of scrolling. Interestingly, however, usability tests for the two studied launchers indicate that, once novice users are instructed on how to use scrolling, it does not pose many problems and may even become the preferred option compared to multiple-screen positioning. Balata et al. (2015) tried to substitute scrolling with Next and Previous buttons. However, their new navigation model was not intuitive. Consequently, they implemented a simple scroll mechanism with a large scroll bar displayed on each screen. Similar difficulties with navigation were identified with *PhonAge* (Arab et al., 2013).

One of the commonly suggested guidelines related to the cognitive resources of older adults is to leverage mental models familiar to older adults. The usability test of *KoalaPhone*, for example, demonstrated that splitting contacts into two distinct screens (i.e., Favourite Contacts and All Contacts) was not very intuitive because the functionality of adding a new contact was now in two places and not just one (Balata et al., 2015). Participants were confused as to how to set a contact as a favourite. When they wanted to remove a contact from their favourites, they sometimes accidentally removed it from the phone entirely. The same study showed also that filling in forms proved to be the most problematic task. The most common problem was that participants did not know how to fill in the phone number after filling in the contact's name.

2.3 Research questions

While Section 2.1 indicates a consensus on a consistent number of design guidelines for a smartphone UI adapted to the characteristics of older adults, Section 2.2 reports limited evidence regarding how these guidelines are applied to smartphone launchers. Within this context, our exploratory study aims to investigate the usability of *GoLivePhone*, a smartphone launcher with an adapted UI for older adults and integrated support for a number of ATs, by addressing the following research questions:

- RQ1: What is the usability performance of the smartphone launcher with an adapted UI for older adults in terms of task success, time-on-task, errors and efficiency?
- RQ2: Are there any differences in usability performance when using basic features and ATs supported by the smartphone launcher?
- RQ3: What are the most important usability problems older adults encounter while operating the smartphone launcher with an adapted UI?

3 METHODS

3.1 Procedure and design

To answer the RQs, older adults completed a 40- to 50-minute usability testing session composed of elements of summative and formative usability evaluation (Lewis, 2012). The testing session was conducted at participants' homes and consisted of three parts. In the first (pre-test) part, participants were provided basic information about the study. They signed a consent form and filled in a short pre-test questionnaire on their socio-demographic and smartphone usage characteristics. In the second (test) part, participants were given five minutes to familiarise themselves with the test launcher. Then, they were asked to complete eight test tasks, during which they were invited to think aloud about what they liked and disliked about the launcher. Next, participants were given written instructions for the testing scenario. Each task in the scenario had a nominal time limit ranging from two to ten minutes, depending on its length and complexity. Participants could also give up on a task. After they completed a task, gave up on it or allowed the designated time limit to expire, a short debrief interview was performed. Participants' actions and comments were recorded using *Mobizen* screen-streaming software. Real-time streaming of the smartphone screen on the computer was used to observe participants during task execution and to determine whether the task was completed. In addition, the research assistant made field notes regarding any errors and observations about ease of use. In the last (post-test) part, a short questionnaire was administered to participants asking them about the visual appeal, perceived usefulness and perceived ease of use of the application using a 5-point Likert-type scale. Quantitative measures were adapted from instruments validated by previous studies (Davis, 1989; Lindgaard, 2007; Venkatesh & Davis, 1996).

3.2 Participants

The study's five participants were recruited opportunistically through the local pensioners club in Slovenia. The small sample size was determined in accordance with guidelines for formative usability testing by Lewis (2012) and by the time and budget constraints implied by the specific selection criteria of participants. In fact, eligibility criteria for participants were that they were older than 65 years of age and should own a smartphone with a touchscreen and/or understand how to use one. Among the five participants, there were three males and two females aged between 65 and 70 (Table 1). Two participants had been using smartphones for three years and two for two years, whilst one participant had become a smartphone user just five months earlier. In addition, all participants self-reported normal or corrected-to-normal vision and no health conditions that diminished arm, hand or finger movements.

Table 1. **Sample characteristics**

Variable	P1	P2	P3	P4	P5
Age (years)	68	65	70	68	67
Gender	Female	Male	Male	Female	Male
Smart phone use (years)	3	2	3	2	0.4

3.3 Apparatus

GoLivePhone is an Android launcher developed to address the needs of older adults and their caregivers. It was developed in the *Java* programming language with a graphical user interface provided by the Android Application Programming Interface (API). *GoLivePhone*'s user interface aims for an age-friendly design that addresses the sensory, cognitive and motor resources of older adults. For example, its UI incorporates features such as large buttons and text size (Figure 1), white text on a black background, ample button spacing, multi-screen navigation (i.e., tabbed navigation), labelled icons, adapted error (recovery) notifications, a Back button etc. In addition to basic features such as calls, texting, contacts, the Internet, the camera and the gallery, *GoLivePhone* provides older adults with several ATs (e.g., Emergency Call button, »I'm Fine« button) (Gociety, 2014).

The *GoLivePhone* launcher was tested on a Samsung Galaxy S4 smartphone with a 5-inch 1080×1920 pixel touchscreen display and Android OS version 4.4.2 (KitKat) as this combination of hardware and software enables optional system support for all available ATs in the *GoLivePhone*.

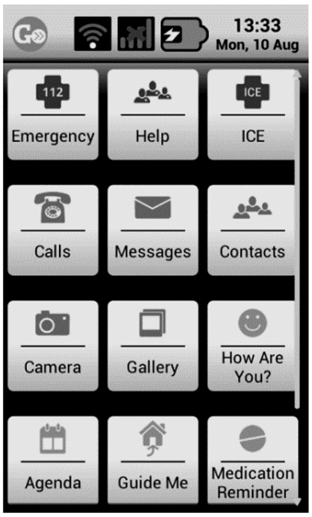

Figure 1. **Home screen of the GoLivePhone launcher**

3.4 Test scenario

The test scenario consisted of eight tasks. The goal of Task 1 was to call a given phone number, which had to be added to contacts in Task 2 (Table 2). Task 3 required sending an SMS to the saved contact. The Emergency Call button had to be activated in Task 4, while Task 5 involved informing caregivers of how participants were feeling at the moment. Task 6 required participants to add a medication reminder. The aim of Task 7 was to interpret the current fall risk, which involved participants launching the Fall Risk feature to report their current fall risk rating to the research assistant. Finally, in Task 8, participants were required to add an appointment to the agenda.

Table 2. **Testing scenario tasks**

Task	Feature/AT	Description
1	Call	Call the telephone number '123456789'.
2	Contacts	Create a new contact named Marija Novak with the telephone number '123456789' without adding a picture or e-mail address.
3	Text message	Send a text message with the content »Hello« to the contact Marija Novak.
4	Emergency Call button	Place an emergency call by pressing the Emergency Call button.
5	»I'm Fine« button	Find the »I'm Fine« button and inform your relatives/caregiver that you feel »very well« today.
6	Medication reminder	Add the medicine Exforge and parameters of its intake to the medication reminder. (A dose of one tablet every day at 8 AM.)
7	Fall detector	Find the Fall Risk detection feature on the start screen and report what the current fall risk is.
8	Agenda	Add an appointment for »coffee with colleagues« with a detailed description. (You are going to meet every Tuesday between 8 and 10 AM at the Rosca Coffee Shop.) Set a reminder for 60 minutes before the event.

3.5 Usability metrics

During usability tests, four quantitative usability measures were recorded in line with definitions proposed by Albert and Tullis (2013) and Lewis (2012). These were as follows: (1) *Task success (TS)*, or the percentage of participants who successfully completed a task; (2) *Time-on-task (TT)*, or the average time participants took to complete a task; (3) *Error (E)*, or the average number of errors made by participants in terms of the average number of additional touches beyond the shortest path to task completion;[1] (4) *Efficiency (EF)*, or the ratio between the optimal number of screen touches needed to complete a task (i.e., the shortest path to task completion) and the actual number of screen touches made to complete a task. Accordingly, task efficiency was calculated exclusively for those participants who completed a given task.

[1] Specifically, errors were defined and identified in line with Morrell, Park, Mayhorn, & Kelley's (2000) notion of performance errors, which includes omission errors, commission errors and wrong-action errors. An omission error indicates that a step in a procedure was left out. A commission error refers to the inclusion of an inappropriate additional and/or redundant step in a procedure. A wrong-action error represents a clear attempt at a step in a procedure that was, nevertheless, mistakenly executed. Owing to a small number of participants, the three types of errors were combined into one category in the analysis of quantitative metrics.

4 RESULTS

4.1 Quantitative measures

In this section, we address RQ1 by analysing the collected data in terms of quantitative usability metrics. As shown in Table 3, all five participants successfully completed (though not always without problems or errors) five out of the eight tasks (i.e., the call, SMS, Emergency Call button, »I'm Fine« button and agenda tasks). The contact, medication reminder and fall detector tasks were each successfully executed by four participants. Notably, the fourth participant (P4) failed to create a new contact (Task 2), while P5 failed to complete Tasks 6 and 7 within the defined time limits.

On average, participants spent the largest period of time creating an appointment in the phone agenda (M = 388 s), followed by the medication reminder entry (M = 345s) and adding a new contact to the phone book (M = 178s). They spent on average 165s to send a text message. Their current fall risk was interpreted in 40s, whilst participants took an average of 37s to place a call to a given number. The least amount of time was required to assess participants' fall risk by consulting the Fall Risk feature (M = 34s) and to send a status update to caregivers using the »I'm Fine« button (M = 18s).

The highest average number of errors (M = 29.6) occurred when participants attempted to add an appointment to the phone agenda. Likewise, on average, many mistakes were made when adding a medication reminder (M = 19.4) and sending a text message (M = 15.4). On average, a new contact was added with 10.8 errors, fall risk was discerned with 3.4 errors and an emergency call was placed with 1.6 errors. Interestingly, tasks requiring a call to be placed to a given number and to inform a caregiver of the participant's current mood were error free.

Since errors cannot be directly compared across different tasks due to their diverse complexity, the efficiency metric was calculated. This metric divides the number of optimal touches by the number of actual touches made by participant during task execution. Due to the error-free execution of Task 1 and Task 5, their efficiency was optimal (EF = 1). Substantial efficiency was also ascertained for the tasks of placing an emergency call by pressing the Emergency Call button (EF = 0.84) and finding out the current status of the participant's fall risk (EF = 0.83). In contrast, serious efficiency issues were discovered when participants were requested to save a new appointment in the phone agenda (EF = 0.44) and to write and send a text message (EF = 0.36).

Moreover, the informative calculation of Spearman's rho correlation coefficient and its corresponding significance test indicated that participants did not spend more time per touch to complete a task when the completion required a higher number of touches (rs = -0.12, p = .778), suggesting that the correlation between time-on-task and task complexity could not be confirmed. Likewise, results did not confirm the correlation between the optimal number of touches and average task efficiency (rs = -0.56, p = .149). Furthermore, the results of a non-parametric two related samples sign test for RQ2 did not demonstrate statistical differences (p = .375) between basic features and ATs in terms of task efficiency.

When surveyed about the visual appeal, perceived usefulness and perceived ease of use of *GoLivePhone*, participants reported on average considerably high visual appeal (M = 4.2, SD = 0.44) and usefulness (M = 4.6, SD = 0.54) of the tested launcher. Accordingly, they also reported a relatively high mean score for ease of use (M = 2.6, SD = 1.52), with smaller values indicating better ease of use.

Table 3. **Results of usability testing**

Task	Type	OT	T	TS	TT (s)	E	EF[a]
1	F	5	5	1	37	0	1
2	F	8	17	0.8	178.2	10.8	0.65
3	F	5	19.8	1	165	15.4	0.36
4	AT	2	3.6	1	34.4	1.6	0.84
5	AT	3	3	1	17.6	0	1
6	AT	20	38.4	0.8	345	19.4	0.57
7	AT	1	4.4	0.8	40	3.4	0.83
8	F	21	50.6	1	388	29.6	0.44

Note: F – feature; AT – assistive technology; OT – optimal number of touches for task completion; T – average number of touches; TS – task success; TT – average time spent on the task; E – average number of errors; EF – average efficiency. [a] Efficiency was calculated solely for participants who completed the given task.

4.2 Analysis of errors

In order to answer RQ3, the usability of the *GoLivePhone* UI was further examined by analysing the errors identified during task execution. The analysis of test recordings showed that when participants were required to add a new contact, they started on the right path to solving the task by tapping the Contacts button. However, they got disoriented during the next step because they were not able to find the Add Contact button (Figure 1). As a result, some participants either incorrectly chose the New Favourite button, which is intended for adding an existing contact to the favourite contacts list (Figure 2.1), or returned back to the home screen instead of tapping the All Contacts button. Some participants added the contact through the call history by tapping the Calls button (Figure 1).

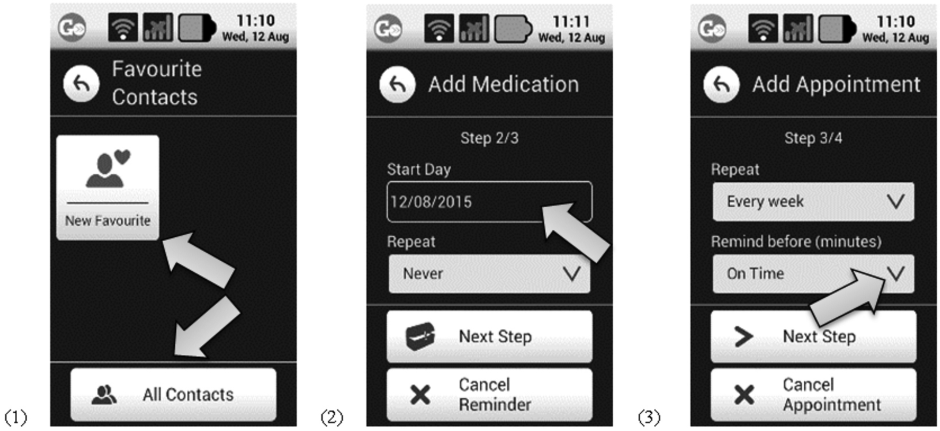

Figure 2. **2.1: Contact, 2.2: Medication reminder – Step 2/3, 2.3: Agenda – Step 3/4**

Call history was also used for sending a text message (Task 3). Instead of pressing the SMS button on the home screen (Figure 1), three participants directly chose the Call history feature, selected a previously called number (i.e., the same number that was used during Tasks 1–3) and sent a text message. Moreover, a different kind of error was committed during the medication reminder and agenda tasks. As shown in Figure 2.2 and Figure 2.3, both tasks required entering several parameters on the same screen and at the same time. For instance, when entering a new medication reminder, participants were required to set start and recurrence days. However, they skipped the »start day« field and pressed the Next step button immediately after determining the recurrence of medication intake time from the drop-down menu. One of the participants complained that they overlooked the »start day« field because it looked different from the other selection fields in the launcher. Specifically, unlike other selection fields which are generally displayed as a white button with a menu icon to the left, the »Start day« field is black with white text (Figure 2.2). Likewise, when setting the appointment's date and time, many participants did not notice both the »repeat« and »remind before (minutes)« fields. Therefore, once one of the two parameters was set, participants incorrectly continued to the next step.

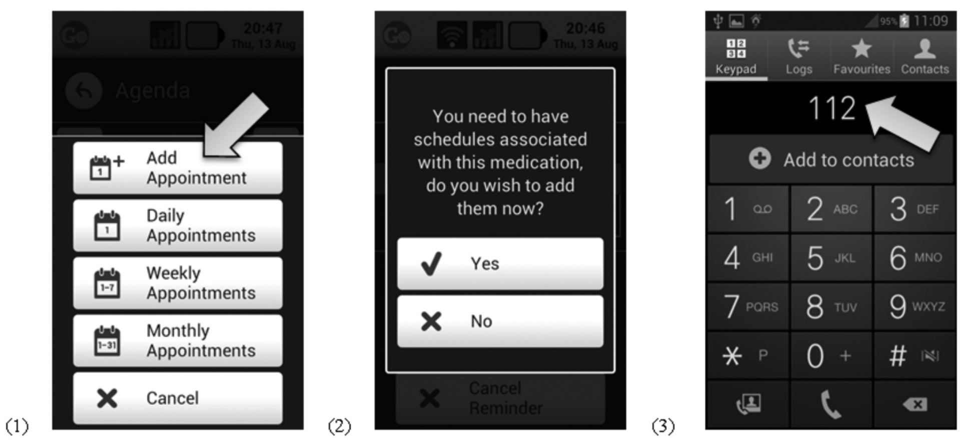

Figure 3. **3.1: Agenda – Step 1/4, 3.2: Medication reminder – Omission error message, 3.3: Emergency call**

Furthermore, we identified errors on the first screen of the Agenda feature, where the calendar and the Appointment Options button are placed. When setting the details of the coffee meeting during the first step, participants had access to a list with four options/buttons (Figure 3.1). As they were asked to choose among these four different (but all viable) options, they were puzzled and mostly failed to tap the required Add Appointment button. Since the other three buttons opened a list of existing appointments, participants started to move back and forth within the Agenda steps, showing signs of disorientation and discontent. The multi-step procedure of setting the medication reminder caused another common error. Notably, participants did not notice the Add Schedule button when configuring the schedule of medicine intake. Accordingly, they got confused because they did not understand the error message that indicated that a schedule had to be added before saving the reminder (Figure 3.2).

An error related to the visual design of the *GoLivePhone* UI also emerged, connected with the Emergency Call button. When one of the participants pressed the Emergency Call button, they overlooked the number »112« that was pre-entered and displayed in the »call number« field (Figure 3.3). Consequently, the participant added another »112« into the »call number« field (i.e., »112112«), and was only able to recover from the error.

5 DISCUSSION

5.1 Research findings

Although the results of the usability tests in this study are based on a small sample of older adults, they provide an informative insights into a number of usability problems. Indeed, these results enable us to re-examine at least some of the design guidelines for smartphone UIs presented in Section 2.1. In this context, the usability problems that emerged during usability tests while carrying out specific tasks can be classified into three broad categories: (1) problems related to older adults' limited cognitive resources; (2) problems caused by and associated with older adults' restricted motor abilities; and (3) issues associated with older adults' sensory and perceptual capabilities.

The limited cognitive capabilities of older adults could be clearly observed in the participants' attempts to create a new contact in the phone book (Task 2), to send a text message to a selected contact from the phone book (Task 3) and to enter a medication reminder and agenda appointment (Task 6 and Task 8, respectively). Specifically, the results indicate that cognitive limitations were related to the rather complex mental and navigation models implemented in the *GoLivePhone* UI. For instance, the insertion of a new contact could not be executed from the launcher's home screen, but only through a complex multi-step procedure, which resulted in many commission and wrong-action errors observable in the fact that even though participants started executing the task via the optimal path (i.e., by pressing the Contacts button), they had severe difficulties finding the Add Contact button.

In addition, Task 2 demonstrated a relatively weak fit between the UI structure and older adults' mental models; rather than adding a new contact with the Add Contact button, many participants wanted to execute the task via the call history list. Likewise, a scarce fit with older adults' mental models was assessed for the text message feature. Instead of using the Messages button on the launcher's home screen, many participants decided to send a text message by selecting a contact/phone number from their call history.

Conversely, it seems that in Task 6 and Task 8, cognitive problems stemmed from the launcher's UI demanding that users focus on multiple tasks at once. As noted by Fisk et al. (2009), older adults experience a considerable decrease in their attention allocation abilities which in the case of *GoLivePhone* was apparent when participants became distracted by many entry fields on the same screen when adding a medication reminder and an agenda appointment. Although the UI conveyed to the participants their spatial position in the navigation structure (»Step 2/3«, Figure 2.2), participants got lost because both tasks demanded at least two actions to be executed simultaneously during each step. Consequently, they also needed more working memory resources to process and remember all the required steps and fields that had to be filled in to successfully complete the task.

Although the examined launcher UI seems to adequately support the design guidelines related to multi-screen navigation and step-by-step models (e.g., as with the contacts, medication reminder and agenda features), these are not applied consistently across all supported features and ATs. The above observations could also partially explain the absence of differences in usability performance between features and ATs. What appears to be important is not the type of service (feature vs. AT) but rather the way that the UI is designed and integrated into the launcher.

While using *GoLivePhone*, participants were also challenged by UI elements that required a relatively precise execution of gestures and movement patterns. In fact, Stössel et al. (2010) note that gestural interfaces could be beneficial for older adults if they are tolerant of some older adults' motor limitations. Generally these limitations affect the precision, speed of execution and complexity of their gestural inputs. In this study, errors related to motor limitations were mostly induced by scrolling and the use of sliders. Notably, because of scrolling on the home screen (Figure 1), one of the participants encountered problems when searching for the Emergency Call button (Task 4). In addition, the size and use of a vertical slider in the drop-down menus caused participants some difficulties when setting an appointment occurrence (Figure 2.2) and searching for the contact to whom they were sending a text message (Task 3).

The last set of issues relates to the visual design of the *GoLivePhone*. They were identified when activating the Emergency Call button (Task 4), entering the medication reminder (Task 6) and adding an agenda appointment (Task 8), with implications for three human factors (i.e., sensory and perceptual, motor and cognitive capabilities). A review of the errors that occurred while completing these tasks indicates that there might be some room for improvements in terms of UI visibility and discoverability (Norman & Nielsen, 2010). While the former relates to the need that it should be obvious to the user where to tap or otherwise interact with the device in a given setting, the latter refers to the need to give the user easy/obvious access to all available functionality. As described in Section 4.2, crucial information or buttons were overlooked when making an emergency call (e.g., in Task 4, the pre-entered emergency call number was not pressed and »112« was incorrectly reinserted in the »call number« field; Figure 3.3). This was similarly shown when setting the day and time of an appointment (e.g., in Task 8, many participants did not take notice of both the »repeat« and »remind before (minutes)« fields; Figure 2.3). Similarly, while trying to add the medication reminder (Task 6), one of the participants mentioned that they overlooked the »start day« field because it appeared different from the other selection fields in the launcher (i.e., the black and white colours were inverted compared to other selection fields; Figure 2.2). Thus, it would be valuable to reconsider some of the general visual design guidelines for a UI adapted to older adults (Silva et al., 2014), particularly: the need to make links and buttons clearly visible and distinguishable from other UI elements; the need to make information easy to read/scan; the need to standardize the visual/graphical layout of interaction elements; and the need to use high-contrast colour combinations for fonts and/or graphics and backgrounds to ensure readability and perceptibility.

5.2 Limitations and future directions

Although the above findings provide original contributions to existing empirical research on usability of smartphone launchers for older adults, they must be considered in the context of the limitations of this study. First, usability tests were conducted only with five participants. While this sample size is not unusual for formative usability tests (Lewis, 2012), a larger number of participants would likely enable smaller sampling errors as well as better problem inspection.[2] Second, this study was based on a series of usability test sessions with users who had prior experience with smartphones. To improve the generalisation of the results it would also be beneficial to involve novice users as well as to repeat the usability tests with the same group of users after they had used the launcher for a while. In the future, we are planning to enlarge the sample size by involving more users with different socio-demographic characteristics and age-related difficulties (i.e., cognitive, perceptual, motor) as well as different skills and attitudes towards new technologies. Third, since we collected non-experimental data, we could not determine if (and how) the results are affected by the fact that participants were asked to use a new device (and not only the launcher). As there are many Android smartphones available on the market, it may turn out to be very useful to design an experiment with a usability test on different smartphones in such

[2] For instance, if we wanted to discover a larger proportion of usability problems that have a smaller or equal likelihood of occurrence, a larger sample size would be required (*cf.* Lewis, 2014).

a manner that participants would be able to use their own phones so we could measure how they perform with their smartphones with and without a launcher installed. Fourth, additional quantitative usability metrics such as 'lostness' or time *per* touch could also be examined (Albert & Tullis, 2013). Fifth, since our study aimed to detect usability problems and not to come up with detailed redesign solutions, it leaves many opportunities for future research in terms of user involvement in the iterative design process. Finally, we are planning to extend the list of launchers with adapted UIs and ATs to be tested. The results of these usability tests will be compared with the findings of usability inspection methods such as heuristic evaluation.

6 CONCLUSION

In summarising the results, three distinct concluding remarks can be made. First, close observation of participants during task execution indicates that wrong-action errors often occur because of a non-optimal fit between the mental models familiar to older adults and the structure of the UI. The results of our usability tests indicate that, when trying to better align older people's mental models with the structure of the launchers, the call history feature is an essential starting point for executing a number of tasks (e.g., for sending a text message and adding a new contact). Second, what appears to be important for the older adults' performance while operating a launcher is not the type of service (basic features vs. ATs), but rather the way that the UI of a service is designed and integrated into a launcher. Third, when designing an UI for older adults, it is advised to comply with some of the existing usability principles presented in Section 2, even though their simultaneous implementation can be challenging. For example, in a multi-step procedure that involves adding a new medication reminder or an agenda appointment, the developers of *GoLivePhone* needed to make a difficult compromise between (1) following the general recommendations of step-by-step navigation with single entry/selection fields on multiple screens and (2) the need to provide older users with shallow menus. However, this usability problem addresses many other trade-offs between design recommendations. In particular, our findings point to the importance of the consistent layout of interface elements. Therefore, in future research, we are also planning to focus on further improving smartphone launchers suited to older people's mindsets, age-related limitations and needs by further exploring the user experience and general guidelines in terms of complex feature sets.

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