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Smart but not adapted enough: Heuristic evaluation of smartphone launchers with an adapted interface and assistive technologies for older adults

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Abstract
Launchers have been suggested as a viable means of increasing the uptake of smartphones and assistive technologies (ATs) among older adults. Launchers can be designed to ease older adults' use of smartphones by addressing perceptual, cognitive, and motoric changes that might hinder their ability to operate smartphones. However, little research currently exists that analyses the characteristics and assesses the usability of launchers with an adapted user interface (UI) for older adults. Thus, we present a study in which we compared a set of commercialised smartphone launchers with an adapted UI and ATs for older adults by means of heuristic evaluation. The results showed that launchers generally integrate only basic features (i.e., calls, texting, contacts) and only one AT (i.e., an SOS service). Although considerable variation exists between them in terms of overall usability, we also report the limited adequacy of launcher UIs in meeting older adults' needs and abilities. In particular, usability problems linked to content and perception were discovered that limit the older adults' capability for error recovery as well as visual, auditory, and haptic access to the information provided by the UI. Interestingly, launchers with a larger number of features and ATs were found to have, on average, less usability problems. This indicates that reducing the number of features is not necessarily a feasible way to increase usability. Instead, more research-based development is needed, which should better consider recommendations for the age-friendly design of UIs on smartphones.

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1. Introduction

Even though smartphones[1] are rapidly becoming an ubiquitous portable technology in the western world and the diffusion of smartphone apps could influence the adoption of smartphones among older adults (Berenguer et al., 2017), the most recent population-based figures from the US and the UK have shown that the use of smartphones is still highly age-dependant. For instance, when 58% of adults owned a smartphone in the US, the percentage of younger old adults (aged 55-64) was 49%, while the 65 and older age group was only 19% in 2013 (Smith, 2013). A similar age-related gap was reported in the UK. In 2013, when 62% of adult Britons owned a smartphone, only 20% of those aged 65–74 and only 5% of those aged 75 and over were smartphone users (Ofcom, 2014).

Researchers have suggested that age-dependant gaps in smartphone adoption could be addressed and potentially reduced in two ways. On one hand, smartphones and smartphone apps should have an optimal design that is appropriate for older adults to accommodate their age-related perceptive, cognitive, and movement control resources (Holzinger, Searle, & Nischelwitzer, 2007). Accordingly, it is argued that gestural interfaces and other design characteristics of smartphones (e.g., a large display) could overcome existing barriers related to the use of feature phones (Piper, Garcia Cornejo, & Brewer, 2016; Zhou, Rau, & Salvendy, 2012). On the other hand, the uptake of smartphones could be fuelled by the proliferation of user-friendly services and apps that meet their social and personal needs as well as generating positive expectations in terms of their quality of life (Doughty, 2011; Piper et al., 2016; Plaza, Martín, Martin, & Medrano, 2011).

In this sense, many researchers have identified in smartphones the potential for developing apps that would integrate assistive technologies (ATs). For instance, Doughty (2011) suggested that apps could be used as ATs for overcoming age-related sensory deficits,

[1] In this paper, we use the term "smartphone" to refer to a smartphone with a touch screen.

for detecting accidents and incidents while ageing in place, for supporting older adults with chronic diseases, and for enhancing personal communication and social companionship. In particular, many authors have identified health-related ATs on smartphones as having the greatest potential for older adults; including services for improving diagnosis, investigation, monitoring, treatment, self-management and adherence (Doughty & Williams, 2016; Joe & Demiris, 2013; Lamonaca, Polimeni, Barbé, & Grimaldi, 2015).

However, the practical exploitation of such apps is at present rather limited amongst older adults (e.g., Ernsting et al., 2017), as they are mostly focused on a specific health issue (e.g., diabetes, falls and fall risk), they seldom have an age-friendly interface design, or assume that older adults are proficient in installing, learning and using them on a (normal) smartphone (Joe & Demiris, 2013). Alternatively, very recently specific services have been introduced to the market that reduce the complexity of a smartphone by installing on the device an app with an age-adapted interface. Arab, Malik, and Abdulrazak (2013) showed that these so-called *launchers* enable older adults to be more successful and efficient in operating the smartphone. Likewise, Balata, Mikovec, and Slavicek (2015) demonstrated that the overall completion rate of tasks for the age-adapted launcher was much higher than for the standard Android user interface (UI). In addition, older adults in their study perceived the age-friendly launcher's UI as more comfortable and efficient than the standard Android UI.

Besides enclosing an adapted UI that replaces the generic interface of the smartphone's operating system (OS), launchers can also integrate a different number of basic features that are most often used by older adults (e.g., calls, contact book, alarm, display of date and time) with various ATs (e.g., SOS button, medication alarm). By having the ability to be installed on an existing smartphone's OS, they have also the advantage of being available to users relatively quickly at low or very moderate cost, without any requirement for the development of new specialized hardware. Another favourable aspect is their social unobtrusiveness in the sense that launchers are less likely to identify older adults who use them as a group of users with special needs and requirements. The literature, in fact, indicates that the social stigma associated with the use of ATs as well as “senior phones” is one of the most important barriers for the acceptance of ATs among older adults (Pedlow, Kasnitz & Shuttleworth, 2010).

However, virtually no research exists which would provide a comparison of the usability of launchers with an adapted UI for older adults that integrate some kind of ATs. Therefore, the aim of this study was twofold. First, to identify and examine what ATs, designed for supporting the independence and quality of life of older adults, are integrated into the launchers with an adapted UI for older adults. Second, to empirically determine the usability of such launchers through a heuristic evaluation in order to assess their overall level of usability as well as to identify the presence of the most common design problems associated with them, through a validated set of heuristics.

The remainder of the paper is structured as follows. Section 2 discusses the relevant literature pertaining to the availability and acceptance factors of ATs for older adults on smartphones, potential age-related usability issues with smartphone UIs and the results of existing heuristic evaluations of smartphones and apps designed for older adults. Section 3 describes the procedures and methods used in the empirical part of this study. In Section 4, the empirical results of the heuristic evaluation are presented. Section 5 discusses the empirical findings, while Section 6 offers our conclusions.

2. Literature review

2.1. Availability and acceptance of assistive technologies on smartphones

Plaza et al. (2011) suggested that smartphone apps with ATs target different areas and needs of older adults. They can help older adults with issues such as safety, security, privacy, and mobility (e.g., person location service, tracking devices, telecare monitoring, and an alarm system). They can include solutions that facilitate older adults' individual development (e.g., distance learning and training) and/or can support services that contribute to older adults' social lives. Such solutions can enable their broad communication with others (e.g., social network and community platforms), hobbies (e.g., digital games adapted for older adults' requirements), or even religion and spirituality (e.g., services offering religious calendars, holy and prayer books, religious ringtones).

However, most researchers agree that in the future the most important contribution to older adults' quality of life will be derived from the apps designed to help manage their health (Doughty, 2011; Joe & Demiris, 2013; Steinhubl, Muse, & Topol, 2013). In particular, Plaza et al. (2011) underscored the importance of health-related ATs such as voice response on the mobile phone or text messages that are used for monitoring wandering in dementia, monitoring blood glucose in diabetes, monitoring prescribed diet, and reminders to take medication. These services are especially relevant for older adults with chronic diseases and for those who need assistance with (instrumental) activities of daily living, since with their help the older persons are able to prolong and support self-management of their chronic health condition (Joe & Demiris, 2013).

Consequently, we can also observe a tendency of the integration of ATs on smartphones with telecare as part of the mobile care (i.e., mCare) services (Doughty & Williams, 2016). An important advantage of mCare is that it enables monitoring of vulnerable persons not only inside but also outside the home. For instance, in combination with a wristband (Plaza et al., 2011), pill dispenser (Mayhorn, Lanzolla, Wogalter, & Watson, 2005), devices integrated in clothing (e.g., wearable sensors), and various home care platforms and ambient assisted living solutions that integrate built-in smartphone sensors for detecting potential abnormal condition on the move (e.g., a long state of hibernation or a sudden fall) (Deen, 2015), mCare can improve older adults' living situation. Doughty (2011) even argued that ATs on smartphones could make some of the standalone telecare solutions for independent living either redundant or uncompetitive, suggesting that by combining several telecare services into one smartphone app, the acceptance and increased use of ATs are likely to rapidly increase.

However, even though older adults represent the most relevant target group in the field of mCare (Lorenz & Oppermann, 2009), ATs in smartphones are still used by only a very small number of older adults. This is mainly related to the general low-adoption of smartphones and smartphone apps among older adults, which has been explored in the past with the Unified Theory of Acceptance and Use of Technology (UTAUT) and Technology Acceptance Models (TAM). For instance, Gurtner, Reinhardt and Soyez (2014) showed that perceived usefulness, perceived ease of use, and enjoyment significantly affect the behavioural intention to use smartphone apps with higher enjoyment also predicting higher perceived usefulness in the 50+ age group. Furthermore, Choudrie, Pheeraphuttharangkoon, Zamani and Giaglis (2014) examined the acceptance of smartphone devices among older adults, and their results showed that compatibility, effort expectancy, enjoyment, facilitating conditions and social influences significantly affected the behavioural intention and use of smartphones. Both of the above studies indicated that the behavioural intention to use significantly affected the actual use (Choudrie et al., 2014; Gurtner et al., 2014). The study of Gurtner et al. (2014) also ascertained a significant correlation between perceived ease of use and the actual use of smartphones. Conversely, Zhou, Rau and Salvendy (2013) focused on the factors predicting the acceptance of new functions on smartphones amongst older adults. They revealed six significant factors, which were awareness and attractiveness, soft keys and multi-tap, social influence, touch screen, connectivity and concern of learning. The problem of smartphone age-friendly design and learning to use smartphones was also investigated by Leung et al. (2012) and Chiu et al. (2016). Their studies confirmed other investigations that associated smartphones with low perceived usability and low ease of learning for older adults due to the rather limited level of adaptation of the design of devices and UIs to their needs (Barnard, Bradley, Hodgson, & Lloyd, 2013; Doughty & Williams, 2016; Piper et al., 2016).

2.2. Age-friendly design of smartphones: key issues and interaction elements

Previous research has reported various elements of smartphone UI that are associated with age-friendly design and that affect older adults' performance while operating smartphone UI. In an early study, for example, Holzinger et al. (2007) argued that touchscreen-based phones are difficult for older adults to use due to the small size of the targets. Conversely, Boulos et al. (2011) underscored how the use of mobile phones without buttons and with large touchscreens could be very appropriate for older adults, since a touchscreen allows the construction of virtual buttons that are as large as needed – because of a larger screen size and better screen resolution (Gao & Koronios, 2010; Lorenz & Oppermann, 2009). Such suggestions were confirmed by Sulaiman and Sohaimi (2010). Their study involving 20 participants aged 50 and older revealed that 90% of the participants preferred a touchscreen to a normal keypad. However, Leitão and Silva (2012) argued that official OS guidelines for the target sizes should be revised and increased to a value between 14 and 17.5 mm in order to meet older adults' specific visual and motoric requirements. Jin, Plocher, and Kiff's (2007) experimental data confirmed that large buttons have a shorter reaction time than smaller ones. However, the larger space between the buttons did not improve the task performance of older adults. Moreover, older adults with visual impairments and poor eyesight may have problems with the text legibility and the adequacy of the contrast between the text and background colours on high-resolution small-size touchscreens (Barnard et al., 2013; Isaković, Sedlar, Volk & Bešter, 2016). As these aspects are further exacerbated with the flat design of touchscreen UIs, Cho, Kwon, Na, Suk and Lee (2015) explored older adults' preferences between skeuomorphism and flat design in terms of icon style degree of realism and level of abstraction. The results revealed that the degree of realism was more important for having aesthetic satisfaction, whereas the level of abstraction was more relevant for better understanding the function of an icon. In general, Cho et al.'s (2015) findings support the assumption that for older adults it is better to portray icons on smartphone touchscreens in a realistic and skeuomorphic manner than in a flat and abstract way.

Related to the usability problems caused by impaired vision and screen size are issues associated with the reduced dexterity and muscle control of older adults (Barnard et al., 2013; Kobayashi et al., 2011). For instance, Piper, Campbell, and Hollan (2010) as well as Barnard et al. (2013) claimed that older adults can experience significant difficulties with gestures while using touchscreen devices, especially with those involving fine motor movements (Furuki & Kikuchi, 2013), multi-tap gestures (Zhou et al., 2013) and controls with specific inputs that required a correct calibration of press duration time, speed and accuracy (Barnard et al., 2013). Consequently, touchscreens can also provoke difficulties for older adults with the use of virtual keyboards (Barnard et al., 2013; Jin et al., 2007; Motti, Vigouroux, & Gorce, 2013; Zhou et al., 2013, 2012), which can be partly explained by older adults' motoric and haptic limitations. Furuki and Kikuchi (2013) and Harada et al. (2013), for instance, noted that older adults do not have a good sense of tapping on the screen. Furthermore, associated with older adults' declining sight and motor abilities, slower movements are a problem related to not seeing where they touch and not feeling the position of virtual keys and buttons (Harada et al., 2013; Zhou et al., 2012). In this sense, Lee, Poliakoff, and Spence (2009) found that multimodal feedback with auditory signals via a touchscreen device results in enhanced performance and subjective benefits for older adults.

Moreover, older adults also demonstrate the need for an adapted design for menus and other navigation elements. In fact, the complexity of the menus on smartphones can (even) increase due to smartphones' functional complexity. In particular, the cognitive complexity of device usage has been identified as a serious barrier for older adults (e.g., Bay & Ziefle, 2003; Ziefle, 2010; Ziefle & Bay, 2005), which can be observed when they experience difficulties in switching among multiple start screens, organising applications, and closing applications during multitasking (Zhou et al., 2012). Part of such usability problems might be surmounted with the personalisation capabilities of smartphones (e.g., Kobayashi et al., 2011; Piper et al., 2010) since they allow users to install and use only a small number of functions and applications based on their personal needs and interests. Personalization can also reduce complexity and allow better transparency of the menu structure if menus are displayed on a larger screen size that allows optimal spatial visualisation with bigger menu buttons (Zhou et al., 2013), prolonged screen-dimming (Barnard et al., 2013; Furuki & Kikuchi, 2013), and use of the intuitive labelling of controls in menus (Barnard et al., 2013).

2.3. Heuristic evaluations of smartphone apps for older adults

Even though this work collectively offers a number of important findings and design guidelines on the specific aspects of age-friendly design of smartphone devices and UI, there is sparse scholarly investigation that would comprehensively evaluate the usability of smartphone apps across different heuristics. The issue is even more intriguing as various smartphone apps that integrate a number of age-friendly design solutions and offer older adults an adapted smartphone UI can be found on the market (Balata et al., 2015).

Of the limited existing research applying guidelines, heuristics and checklists for age-friendly design of smartphone devices, apps, and launchers, the findings of Silva, Holden, and Nii (2014) as well as Silva, Holden, and Jordan (2015) revealed the visual design as the most violated heuristic. In both studies where they evaluated how two smartphone fitness apps accommodate the needs of older adult users across six heuristics,[2] two of the visual

[2] Please refer to Section 3.4. for more details.

design sub-heuristics[3] which were the most often violated were use of simple and meaningful icons and use of appropriate text types, styles, and sizes. Visual design was followed by heuristic navigation and perception, whereas the four remaining heuristics revealed fewer problems. Conversely, Diaz-Bossini and Moreno (2014) developed a checklist for accessibility of mobile UI for older adults. The checklist, combining web, Android UI, and age-centred guidelines, was applied to the evaluation of three launchers with an adapted UI for older adults. The authors reported the most violations in terms of the use of colour contrast, the avoidance of scroll bars, and the accompaniment of audio prompts with visual prompt or notification (Díaz-Bossini & Moreno, 2014). Likewise, in the study of Al-Razgan, Al-Khalifa, and Al-Shahrani (2014), which tested three launchers and three apps, the largest number of usability problems occurred at sub-heuristics regarding possibility of customising colours and enlargement of buttons and icons when the rest of the text size is increased. Further, a critical number of violations was also assessed for the sub-heuristics related to confirmation messages for critical actions, to the option to enlarge the font size, and to the easy availability of default phone settings. In addition, Mi et al. (2014) developed an original heuristic checklist from design guidelines, based on a preliminary set of user requirements related to accessible touchscreen-based smartphone design. The heuristics were applied to two smartphone prototypes (i.e., one with the installed screen reading software and the second with installed voice activation software). The results of the evaluation, conducted by six participants with either severe visual impairments or upper extremity disabilities, unveiled difficulties in finding touchscreen soft keys and determining activated features relying on screen reader or audio and tactile feedback.

[3] Following the approach of Yáñez Gómez et al. (2014), we refer to heuristics as global usability issues/dimensions that must be evaluated or taken into account when designing smartphone apps, whereas sub-heuristics are specific guideline items derived from the global usability issues/dimensions that help evaluators to assess the usability of smartphone apps.

Even though the above presented studies are valuable because they carried out an assessment and evaluation of smartphone apps, launchers or prototypes for older adults across several heuristics, they could be improved across several points. First, the evaluations were conducted by a different number of evaluators with a different background what makes them hardly comparable. Second, there is lack of reliability analysis and expert validation of (sub-)heuristics in the reviewed studies. The latter was accomplished only by Silva, Holden, and Jordan (2015), whereas in other studies with validation presented herein (i.e., Al-Razgan et al., 2014; Mi et al., 2014), this was done only by non-professionals. Third, the reviewed studies dealt with different smartphone apps for older adults and only two of them (i.e., Al-Razgan et al., 2014; Díaz-Bossini & Moreno, 2014) focused on launchers. In addition, none of these studies systematically explored and inspected the ATs supported by the launchers. Lastly, the heuristic evaluations of launchers compared only a small range of apps within one study, making a comprehensive interpretation of the results difficult.

2.4. Research questions

Since only a few studies have conducted a heuristic evaluation of the design requirements of launchers with an adapted UI for older adults, and even fewer have focused on systematically comparing launchers with ATs for older adults, this exploratory study aims to compare the usability of a larger set of commercialised smartphone launchers with ATs and with UI customised for the needs of older adults. In particular, we aim to answer the following exploratory research questions:

- RQ_1: How many and what types of assistive technologies are integrated into launchers with an adapted UI for older adults?
- RQ_2: What age-related aspects of usability are respected and violated in launchers with an adapted UI and assistive technologies for older adults?

- RQ_3: Are there any differences in the usability problems between launchers with an adapted UI for older adults according to the number of basic functions and assistive technologies?

3. Empirical study

3.1. Procedure

The data collection for this study proceeded in three stages. First, following past studies (e.g., Watkins, Kules, Yuan, & Xie, 2014), a set of launchers with an adapted UI and ATs for older adults was selected for examination. We defined the launcher as part of the smartphone OS UI that allows users to customise the home screen (e.g., the smartphone desktop), launch mobile apps, and perform other tasks on smartphones (Balata et al., 2015), whereas AT was defined as any app installed on a smartphone that supports older adults' independent daily living inside or outside the home and gives them an opportunity to participate in society longer and more fully (Hakobyan, Lumsden, O'Sullivan, & Bartlett, 2013). Second, in order to assess what age-related aspects of usability are respected and violated in the launchers, the heuristic evaluation process was defined, including the selection and training of the evaluators as well as their familiarisation with the project's overview, (sub-)heuristics and unit of analysis. In the third stage, a set of heuristics and sub-heuristics was defined and applied to the selected launchers in the form of an expert review. In addition, an analysis of inter-rater reliability was carried out to determine which of the evaluated sub-heuristics provided reliable scores that could be used in the statistical analysis. In the following, the details of the three stages of data collection are presented.

3.2 Units of analysis

Since the unit of analysis in this study was defined as a launcher with an adapted UI for older adults that provided at least one AT, the selection of units was carried out as a three-step procedure. In the first step, launchers were accessed through the iTunes Store, Google Play

Store, and Windows Phone Store. An initial search using the terms “senior”, “seniors”, “elderly”, “launcher”, “older adults”, “older”, “aged”, “grandparent”, “granny”, “assistive technology”, “assistive service”, and “assistive solution” was conducted in February 2015 and returned a list of 262 apps. In the second step, the official descriptions of the apps available in the corresponding stores were harvested and analysed by the authors of this study. If the app’s description did not mention that it provided an adapted UI for older adults, at least four basic features, and at least one AT, the app was excluded from further analysis. In such a way, the final list of 21 launchers was obtained from the search of the app stores.

In the third step, the selection inspection was carried out. One of the authors of this study (AR) and a study assistant independently inspected them in order to, on one hand, verify the relevance of the content, functionality, and target audience, and, on the other hand, code the available features and ATs supported by the launchers. The 21 selected launchers were first downloaded and installed on a smartphone with an appropriate OS.[4] Next, the launchers were checked to be operational in supporting the declared functionalities and ATs. At this stage, potential technical errors and failures in functionalities and the UI of the launchers were also systematically documented. In addition, the two evaluators enlisted the available features and ATs supported by 21 launchers. After inspecting the launchers independently, the two evaluators discussed the collected information. In the event of any discrepancies, they reviewed the launchers together in an attempt to reach a consensus.

The selection inspection revealed that two of the launchers (i.e., My Nurse Alert, Senior Home) did not work due to technical errors with an internal cause (i.e., unrecoverable crash, problems with the start-up) and that one was only available for tablets (i.e., Oscar Senior). Therefore, all three were excluded from the analyses. In terms of content,

[4] The hardware consisted of a Samsung Galaxy S4 mini with a 4.3” screen AMOLED display (540 x 960 pixels) for Android OS, a HTC 8S with a 4.0” screen S-LCD display (480 x 960 pixels) for Windows Phone OS, and an iPhone 5 with a 4.0” screen IPS-LCD display (640 x 1136 pixels) for iOS.

functionality, and target audience, another launcher (i.e., Senior Times over 50s) was judged to be unsuitable for the analysis because its content was limited in terms of context (i.e., not appropriate for everyday use).

The inspection of the remaining 17 launchers showed that – contrary to the official descriptions in the app store – five of them did not fulfil the criteria of supporting at least four basic features and at least one AT. In fact, four did not support any AT (i.e., GrandPhone Senior Launcher, KK Easy Launcher [Big Launcher], MojPlus, Wiser - Simple Launcher), while one launcher (i.e., El Abuelo) offered only two basic features (see Table 3). Accordingly, the heuristic evaluation was carried out on the remaining 12 launchers whose starting screens are presented in Figure 1.

Figure 1. The start-screen of the 12 analysed launchers with an adapted user interface for older adults

(a) Big Launcher (b) BigBig Elderly Desktop (c) CareZone

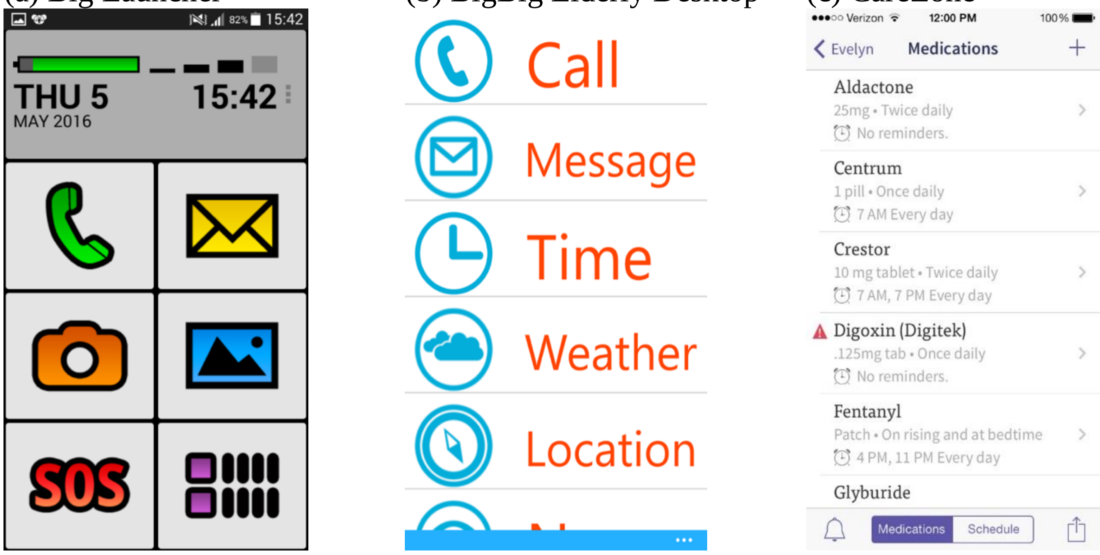
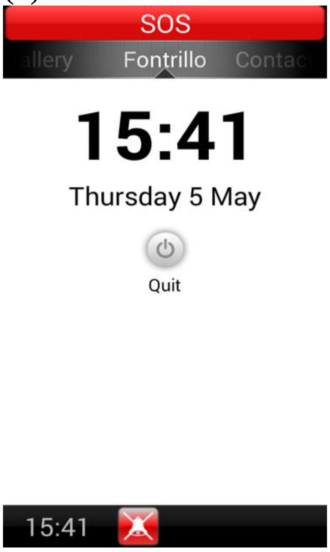
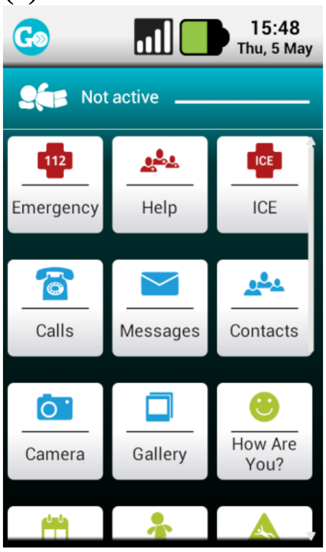


Figure 1. Contiuned

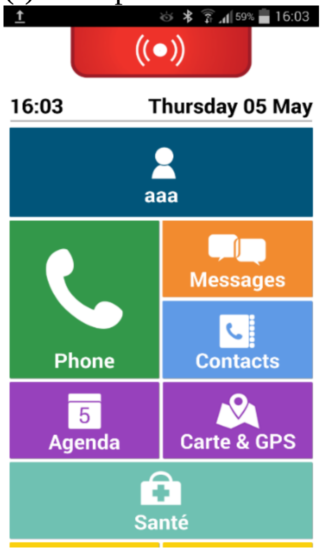
(d) Fontrillo



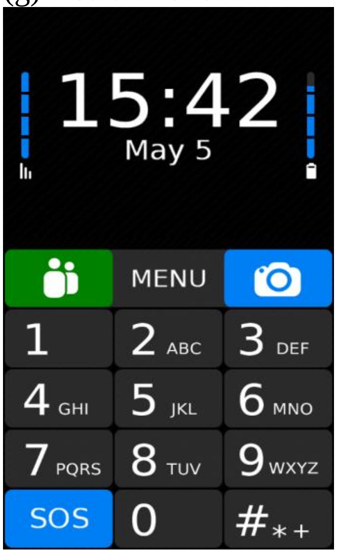
(e) GoLivePhone



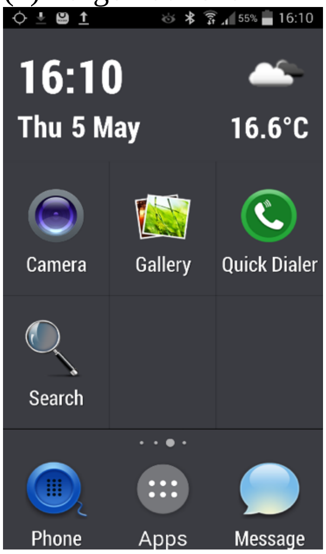
(f) iCompanion



(g) Koala Phone



(h) Large Launcher



(i) Necta Launcher

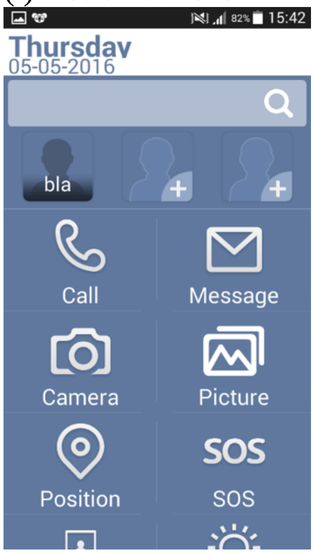


Figure 1. Contiuned

(j) Seniors Phone (k) Sentizens (l) Silverline Mobile

3.3. Heuristic evaluation

The heuristic evaluation was performed following the general guidelines suggested by Nielsen (1994) and Galitz (2013) as well as the procedures adapted for the analysis of smartphones for older adults (see Section 3.1). The two evaluators who participated in the selection inspection were joined by two additional evaluators who conducted the heuristic evaluation. The four evaluators were independent practicing researchers with a background in user experience research, social informatics and age-friendly interface design. Two of them had previously worked as assistant researchers in projects about universal design specifications for online health and mobile applications. The third expert had been a senior researcher working as an external consultant in this study, while the fourth was a study assistant who was completing her thesis on smartphone interface design for older adults.

Before beginning the evaluation, the evaluators received a coding book with a list of the 35 sub-heuristics (see Section **Error! Reference source not found.**) and a list of procedures (see Appendix). The latter specified how the evaluators should go through the UI of the launcher, on which specific features and ATs to focus (see the next paragraph), and introduced them to a recommended procedure for testing the UI so as to identify possible problems and violations of the sub-heuristics included in the coding book (Nielsen, 1994). Subsequently, all evaluators attended a series of training sessions led by one of the authors of this study (AP). The training sessions consisted of presentations and group discussions to familiarize the evaluators with the coding procedure and to reach consensus on the meaning of sub-heuristics in the coding book. The training included also a pilot test of the coding book where all evaluators were asked to code a set of test cases. Based on the results of the pilot test some minor changes to the application of the coding procedure and coding book were made in agreement with the evaluators.

Table 1. List of evaluated features and assistive technologies by smartphone launchers

Name	F1	F2	F3	F4	F5	F6	AT
Big Launcher	Con	Call	SMS	Clk	Cam	PVG	SOS
BigBig Elderly Desktop	Con	Call	SMS	Clk	News*	Weather (forecast)*	Geolocation
Care Zone Family	Con	Call	Notes*	Journal*	Calendar*	PVG	Medication reminder
Fontrillo	Con	Call	SMS	Clk	Cam	PVG	SOS
GoLivePhone	Con	Call	SMS	Clk	Cam	PVG	SOS
iCompanion Senior Launcher	Con	Call	SMS	Clk	Cam	PVG	SOS
Koala Phone Senior Launcher	Con	Call	SMS	Clk	Cam	PVG	SOS
Large Launcher Senior Phone	Con	Call	SMS	Clk	Cam	PVG	SOS
Necta Launcher(for senior)	Con	Call	SMS	Alarm Clk*	Cam	PVG	SOS
Seniors Phone	Con	Call	SMS	Clk	x	x	SOS
Sentizens	Con	Call	Reminders*	Flashlight*	GPS navigation*	Service section*	SOS
Silverline Mobile	Con	Call	Alarm Clk*	Clk	Cam	Lifestyle*	SOS

Note: Con – Contact book, Call – Voice call, SMS – Short text message service, Clk – Clock, Cam – Camera, PVG – Photo/Video Gallery. Substitutive features are marked with an asterisk (*). “X” indicates that the functionality was not evaluated. F – feature. AT – assistive technology.

Besides evaluating the general UI of the launcher’s desktop (i.e., starting screen), the evaluators were required to dedicate special attention to the usability of its basic features and supported ATs. Using the preliminary coding of the launchers (see Section **Error! Reference**

source not found.), a list of basic features and ATs was compiled in order to increase the reliability of the heuristic evaluation. While the basic features[5] included contacts, call, text message, clock, camera, and photo/video gallery, the evaluation of the ATs was limited to the "SOS system".[6] If the specific launcher did not support one or more of the six basic features and/or the "SOS system", the evaluators judged an alternative feature/ATs as indicated in Table 1. Finally, the evaluators were requested to document each problem identified in the UI with reference to the violated sub-heuristic(s).

3.4. Measurement

To measure the usability of the analysed launchers, we used the list of heuristics for smartphone apps targeted at older adults developed by Silva et al., (2014a) and later validated by Silva et al., (2015) and Silva et al., (2014b), which includes six heuristics and 35 sub-heuristics (Table 2). The heuristic *Cognition* contains six sub-heuristics that refer to cognitive changes that occur with age, such as a difficulty maintaining attention or managing a large number of items by working memory (e.g., avoid the use of interaction timeouts and provide ample time to read information). The four sub-heuristics related to *Content* measure the clarity of the information and language used in the apps (e.g., provide clear feedback and, when presenting error messages, make them simple and easy to follow). The heuristic *Dexterity* is measured by three sub-heuristics that cover the age-related changes in capabilities for movement control and movement speed while using a smartphone UI (e.g., avoid the use of scrolling on the home screen of the application). *Navigation* includes five sub-heuristics that are related to the understanding of the app's menu structure, the logic of its interactive elements, and how the user can flow through it (e.g., keep the user interface navigation structure narrow, simple and straightforward). *Perception* includes eight sub-

[5] These features and ATs were selected because they were supported by at least half of the 12 evaluated launchers.

[6] As an SOS system, we coded features such as any kind of SOS button, including an SOS help button, SOS contacts, SOS (priority) call lists, and SOS functions with geolocation (fencing).

heuristics related to the age-related limitations of the perceptual system, including hearing, visual, and haptic impairments (e.g., make information accessible through different modalities). The final heuristic, *Visual design*, is measured by nine sub-heuristics covering aspects of design details such as formatting and visual representations in the UI (e.g., use simple and meaningful icons). Following, Silva et al. (2015) the value of each sub-heuristic was coded as either 0 = "violated" or 1 = "respected".

Although the list of heuristics was already validated in terms of usefulness, clarity, completeness, and appropriateness (Silva et al., 2015; Silva, Jordan, et al., 2014), the reliability of all the sub-heuristics was assessed by having four independent evaluators score each launcher (see Section **Error! Reference source not found.**). Inter-rater[7] reliability was calculated using AC_1 statistics (Gwet, 2014). Using the benchmarking method proposed by Gwet (2014) for interpreting the magnitude of AC_1 statistics based on Fleiss' Kappa benchmark scale, it was determined that the extent of the agreement was "poor" or worse (i.e., $AC_1 < 0.4$) for 12 out of the 35 sub-heuristics (Table 2). Hence, they were excluded from further analyses.

The final value for each of the 23 reliably coded sub-heuristics was determined by the majority score given by the four evaluators. In all cases where an exact disagreement was reached between the evaluators (i.e., two evaluators coded a sub-heuristic as "violated" and two as "respected"), the results of the evaluations were discussed and the evaluators had to reach a consensus regarding the final value of the sub-heuristic (Yáñez Gómez et al., 2014). Afterwards, the heuristic score for each heuristic was determined by summing up the final values for all sub-heuristics in the corresponding heuristic and then dividing the sum by the total number of sub-heuristics in the corresponding heuristic, where higher heuristic scores (reported in percentages) indicated better levels of usability.

[7] The terms "rater" and "evaluator" are used interchangeably in this paper.

Table 2. The inter-rater reliability of heuristics for smartphone launchers targeted at older adults

Heuristics and sub-heuristics	AC_1	$SE(AC_1)$	p	V[a]
Cognition				
A1 - Focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times.	0.489	0.196	.030	10
A2 - Avoid the use of interaction timeouts and provide ample time to read information.	0.610	0.177	.005	10
A3 - Avoid the use of animation and fast-moving objects.	0.615	0.157	.002	2
*A4 - Leverage mental models familiar to older adults.	0.222	0.171	.220	
A5 - Reduce the demand on working memory by supporting recognition rather than recall.	0.812	0.120	.001	1
*A6 - Aim at creating an aesthetic user interface, by using pictures and/or graphics purposefully and adequately to minimize user interface clutter and avoid extraneous details.	0.135	0.173	.451	
Content				
B1 - Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an error than to recover from it.	0.592	0.175	.006	10
B2 - Provide clear feedback and when presenting error messages make them simple and easy to follow.	0.450	0.176	.027	8
B3 - Make sure they are descriptive and use meaningful words and verbs when requiring an action.	0.426	0.181	.038	10
B4 - Write in language that is simple, clear and adequate to the audience.	0.929	0.077	<.001	1
Dexterity				
C1 - Avoid pull down menus.	1			0
C2 - Avoid the use of scrolling on the home screen of the application.	0.722	0.147	<.001	6
C3 - Enlarge the size of user interface elements in general; targets should be at least 14mm square.	0.808	0.132	<.001	3
Navigation				
D1 - Keep the user interface navigation structure narrow, simple and straightforward.	0.479	0.167	.015	9
*D2 - Use consistent and explicit step-by-step navigation.	0.350	0.172	.067	
*D3 - Make sure that the “Back” button in the application behaves predictably.	0.351	0.178	.074	
*D4 - Support user control and freedom.	0.097	0.132	.476	
D5 - Disable inactive user interface objects.	0.890	0.085	<.001	0

Note: * Sub-heuristics, which were excluded from analyses because of insufficient inter-rater reliability (i.e., extent of agreement between evaluators). [a] The number of launchers with a violation of the corresponding sub-heuristic.

Table 2. Continued

Heuristics and sub-heuristics	AC_1	$SE(AC_1)$	p	V^a
Perception				
*E1 - Allow users to fine tune the volume.	0.294	0.148	.073	
E2 - Do not rely on colour alone to convey information. Be aware of colour blindness.	0.467	0.198	.038	4
E3 - Provide not only visual feedback, but also tactile and/or auditory.	0.747	0.150	<.001	3
E4 - Make information accessible through different modalities.	0.751	0.135	<.001	11
*E5 - Use lower frequencies to convey auditory information such as confirmation tones and alerts.	0.244	0.107	.043	
E6 - Do not use pure white or rapidly changing contrast backgrounds.	0.550	0.203	.020	5
E7 - Make it easy for people to change the text size directly from the screen.	1			12
E8 - Allow users to fine-tune screen brightness and contrast.	0.957	0.045	<.001	12
Visual design				
F1 - Use high-contrast colour combinations of font and/or graphics and background to ensure readability and perceptibility; avoid using blue, green and yellow in close proximity.	0.462	0.203	.044	5
F2 - Use colour conservatively, limiting the maximum number of colours in use to four.	0.611	0.168	.004	7
*F3 - Make sure text uses types, styles and sizes appropriate to older adults, for instance, but not exclusively: sans serif, non-condensed typefaces, non-italic, left justified and 12-14 point font.	0.334	0.144	.040	
*F4 - Make links and buttons clearly visible and distinguishable from other user interface elements.	0	0.125	1	
F5 - Make information easy to read, skim (or) and scan.	0.650	0.173	.003	4
*F6 - Group information visually (make good use of colour, text, topics, etc.).	0.320	0.211	.158	
*F7 - Allow sufficient white space to ensure a balanced user interface design.	0.268	0.179	.163	
*F8 - Use user interface elements consistently and adhere to standards and conventions if those exist.	0.228	0.157	.174	
F9 - Use simple and meaningful icons.	0.812	0.120	<.001	1

Note: * Sub-heuristics, which were excluded from analyses because of insufficient inter-rater reliability (i.e., extent of agreement between evaluators). [a] The number of launchers with a violation of the corresponding sub-heuristic

4. Results

Before addressing RQ_1, a breakdown of the 17 analysed launchers, their OSs and their basic features is given in Tables 3 and 4. The analysis shows that among the 17 launchers, 14 were developed for *Android,* two for *iOS* and one for *Windows Phone*. As shown in Table 3, the median number of basic features supported by the analysed launchers was seven, with values ranging from a minimum of two (*El Abuelo*) to a maximum of 12 features (*iCompanion Senior Launcher*). Accordingly, only two features (call and contacts) were supported by all 17 launchers (Table 4). Texting (SMS) was supported by 14 launchers (82.4%), clock and camera by 11 launchers (64.7%), and photo/video gallery by 10 launchers (58.8%). All other features were integrated into five or less launchers. Surprisingly, reminders and email were among them, being supported by five launchers and one launcher, respectively.

Table 3. The analysed launchers and their characteristics

Name	OS	Feature[a]	AT[b]	HE[c]	THS (%)[d]
Big Launcher	*Android*	5	1	Yes	66.7
BigBig Elderly Desktop	*WP*	6	1	Yes	38.9
Care Zone Family	*iOS*	8	1	Yes	36.1
El Abuelo	*Android*	2	3	No	
Fontrillo	*Android*	8	1	Yes	58.3
GoLivePhone	*Android*	11	7	Yes	77.8
GrandPhone Senior Launcher	*Android*	6	0	No	
iCompanion Senior Launcher	*Android*	12	3	Yes	45.8
KK Easy Launcher (Big Launcher)	*Android*	6	0	No	
Koala Phone Senior Launcher	*Android*	8	1	Yes	86.1
Large Launcher Senior Phone	*Android*	7	1	Yes	38.9
MojPlus	*Android*	8	0	No	
Necta Launcher (for seniors)	*Android*	9	2	Yes	61.1
Seniors Phone	*Android*	4	1	Yes	41.7
Sentizens	*iOS*	7	1	Yes	47.2
Silverline Mobile	*Android*	7	2	Yes	58.3
Wiser - Simple Launcher	*Android*	5	0	No	

Note: [a] The median number of basic features was 7 (7.5 for the apps included in the heuristic evaluation. [b] The median number of ATs was 1 (1 for the apps included in the heuristic evaluation). [c] Included in the heuristic evaluation (HE). [d] The mean of total heuristic score (THS) was 54.7%.

To answer RQ_1, we identified all the ATs supported by the analysed launchers. The median of the supported ATs was 1, with a range of 0 to 7 ATs (see Table 5 for brief descriptions and examples of images of the seven identified ATs). Specifically, there were four launchers without any ATs, eight supported only one AT, two launchers supported two and three Ats, while one laucher had 7 ATs (Table 3). The launcher with the highest number of supported ATs was *GoLivePhone®*. As shown in Table 4, 11 out of the 17 (64.7%) launchers supported a kind of "SOS system", five (29.4%) supported geolocation, while two (11.8%) supported fall detection, health monitoring, medication alerts, or ICE. Only one launcher (5.9%) was identified as providing older adults with activity monitoring.

Table 4. Basic features and assistive services supported by the analysed launchers

Feature			Assistive Technology		
Name	N	%	Name	N	%
Alarm clock	4	23.5	Activity monitoring	1	5.9
Clock	11	64.7	In Case of Emergency (ICE)	2	11.8
Calendar	5	29.4	Fall detector	2	11.8
Call	17	100	Geolocation	5	29.4
Camera	11	64.7	Health monitoring	2	11.8
Contacts	17	100	Medication reminder	2	11.8
Email	1	5.9	SOS system	11	64.7
Flashlight	5	29.4	No assistive technology	4	23.5
GPS location/navigation	5	29.4			
Health section	2	11.8			
Journal	1	5.9			
Learn	1	5.9			
Texting (SMS)	14	82.4			
News	1	5.9			
Notes	1	5.9			
Photo sharing	2	11.8			
Photo/video gallery	10	58.8			
Reminders	5	29.4			
Service section	1	5.9			
To-dos	2	11.8			
Weather (forecast)	3	17.6			

Table 5. Descriptions and examples of assistive technologies found on the analysed launchers

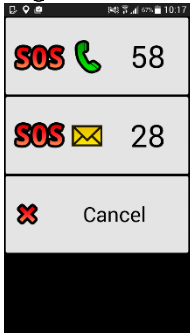
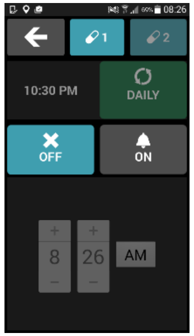
Assistive technology	Description of assistive technology	Example of assistive technology
SOS system	Enables users to (in case of emergency) call for help immediately (e.g., family members, caregivers or emergency service) by pressing just one button.	Figure 2a. *SOS system* in Big Launcher. 
Medication reminder	Enables data entry for all of a user's medications. It is possible to enter the name of the medicine and (optionally) a photo of its dosage. For each entered medicine, a reminder alerts the user at the specified time that they need to take that medicine.	Figure 2b. *Medication reminder* in Silverline launcher. 

Table 5. Continued

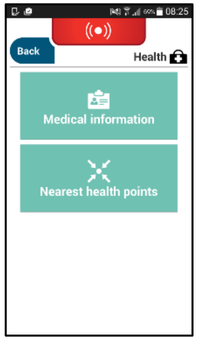
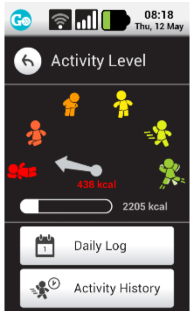
Health monitoring	Notifies family members, caregivers or the emergency service in the case of health problems (e.g., problems with blood pressure, blood sugar and heart rate).	Figure 2c. *Health monitoring* in iCompanion launcher. 
Activity monitoring	Monitors the user's physical activity, records burned calories, and (optionally) warns the user in case of low activity levels.	Figure 2d. *Activity monitoring* in GoLivePhone® launcher. 

Table 5. Continued

Geolocation	It enables the user to set points of interest and provides them with easy-to-use navigation to the specific address on the map. Awareness of the user's current location can be combined with defining geographical boundaries; if the user with the phone leaves the zone predefined with a set of boundaries, an alert is triggered and the application sends a message to the predefined phone numbers or email accounts of family members and/or caregivers.	Figure 2e. *Geolocation* in iCompanion launcher. 

With RQ_2, we aimed to investigate which age-related aspects of usability are respected and violated in the 12 evaluated launchers.[8] The results, reported in Table 6, show that the heuristic score related to dexterity (M = 75.0%, SD = 20.7%) yielded the lowest number of violations. Specifically, 75.0% of the sub-heuristics of dexterity were respected. Moreover, the heuristic score related to visual design and navigation yielded a somewhat higher number of violations, resulting in an average of 64.6% (SD = 27.1%) and 62.5% (SD = 22.6%) of respected sub-heuristics, respectively. The frequency of violation was above the total average for the 12 evaluated launchers (M = 54.7%) for the heuristics addressing cognition (M = 52.1%, SD = 22.5%), content (M = 39.6%, SD = 29.1%), and perception (M = 34.7%, SD = 21.9%). For perception, this means that, on average, the evaluators found that in the analysed launchers only every third sub-heuristic was respected.

In addition, to better understand the performance of the evaluated launchers, we report on the most frequent problems identified by the evaluators across the six heuristics (see column "V" in Table 2). With reference to dexterity, the evaluators were able to find six violations of the sub-heuristic related to avoiding the use of scrolling on the desktop screen of the launcher. Interestingly, however, no violations were found in relation to the use of pull-down menus. The heuristic of visual design was most frequently violated because of the inappropriate use of colour(s), either because too many different colours were used (seven violations) or because the colour combinations of the font and/or graphics and background did not provide enough contrast to ensure readability and perceptibility (five violations). Conversely, only one launcher was found to not use simple and meaningful icons.

The problem of a complex and non-straightforward UI navigation structure was the most frequently violated sub-heuristic of navigation (nine violations). Problems of cognition

[8] Since we used a systematic procedure to identify all of the suitable launchers, it is highly plausible to assume that the 12 evaluated launchers represent the population of all available launchers that met the selection criteria. Thus, in the analyses, we did not run and report statistical significance tests.

were mostly related to the fact that the evaluated launchers required users to focus on more than one task at a time, without clearly indicating the name and status of the task at all times (ten violations). In addition, the evaluators found that only two launchers did not use interaction timeouts, thereby providing older adults with ample time to read information. Further, issues with content were most frequently related to insufficient, ambiguous, and broad instructions on how to use the launcher and the integrated ATs. In particular, only two of the launchers offered sufficient help, documentation or instruction for (new) users that explained the app's purpose or specific functions. Equally, the scarce use of simple language when requiring an action from the user (ten violations) as well as the frequent absence of clear feedback and the manner of presenting error messages (which would make them simple and easy to follow) (eight violations) were common violations in terms of content. Requiring users to complete unnecessary steps in order to change the text size and failing to provide them with an option to fine-tune screen brightness and contrast within the launcher's UI were the two most frequently violated sub-heuristics in terms of perception. Indeed, no evaluated unit met these two requirements. Moreover, 11 launchers also failed to make information accessible through different modalities (e.g., providing bi- or tri-modal feedback).

In order to allow a comparison of the overall usability performance between 12 evaluated launchers, the *total heuristic score* (THS) was calculated as an arithmetic mean of the six heuristics scores (Table 3). The THS revealed observable differences between the 12 launchers, with a range of values from 36.1% (*Care Zone Family*) to 86.1% (*Koala Phone Senior Launcher*). More importantly, the results further indicated that exactly half of the evaluated launchers respected less than half of the sub-heuristics (i.e., THS < 50%), suggesting that their low performance could not be caused by a violation of specific heuristic, but rather by a number of violations that span across different usability dimensions.

Table 6. The results of the heuristic evaluation by heuristics and characteristics of launchers

	Total		≤ 7 Features		> 7 Features		1 AT		> 1 ATs	
Heuristic	M	SD	M	SD	M	SD	M	SD	M	SD
Cognition	52.1	22.5	45.8	24.6	58.3	20.4	50.0	26.7	56.3	12.5
Content	39.6	29.1	37.5	20.9	41.7	37.6	40.6	22.9	37.5	43.3
Dexterity	75.0	20.7	77.8	27.2	72.2	13.6	75.0	23.6	75.0	16.7
Navigation	62.5	22.6	50.0	0.0	75.0	27.4	56.3	17.7	75.0	28.9
Perception	34.7	21.9	30.6	22.2	38.9	22.8	29.2	24.8	45.8	8.3
Visual design	64.6	27.1	50.0	27.4	79.2	18.8	59.4	32.6	75.0	0.0
Total (Mean)	54.7	24.0	48.6	20.4	60.9	23.4	51.7	24.7	60.8	18.3

Note: All heuristic scores are reported in percentages (%) of respected sub-heuristics. AT – assistive technology.

RQ_3 was investigated by comparing the mean values of the six heuristic scores between the launchers according to the number of supported features and ATs. As shown in Table 6, among the 12 evaluated launchers the ones with a larger number of features and ATs performed on average better across all six heuristics, with only three exceptions. First, launchers supporting seven or less features (M = 77.8%, SD = 27.2%) seem to perform on average slightly better in terms of dexterity than launchers with more than seven features (M = 72.2%, SD = 13.6%). Second, launchers that supported more than one AT (M = 37.5%, SD = 43.3%) had on average more usability issues related to content than launchers with only one AT (M = 40.6%, SD = 22.9%). Lastly, no differences were observed between the two groups of launchers in terms of dexterity since 75.0% of the respective sub-heuristics were on average respected by both groups (with one AT or with more than one AT) of launchers.

5. Discussion

Although this study is exploratory in nature and based on a limited number of launchers, we believe that it does offer some original insights into the usability of smartphone launchers with an adapted UI and ATs for older adults. In contrast to suggestions about the integration of smartphones with ATs that would increase, maintain, or improve the social and health capabilities of older adults (Doughty, 2011; Plaza et al., 2011), our results show that 17 analysed launchers that fulfilled all the selection criteria with an adapted UI for older adults provide only a limited number of different ATs. In fact, four of the analysed launchers did not have any AT, whilst eight of the analysed launchers supported only one AT. This was generally related to a kind of SOS service, whereas more advanced forms of monitoring (e.g., for health issues) and prevention services (e.g., fall detectors) were less common. On the one hand, this finding corroborates recent research which shows that the highest need that older adults gratify with the use of mobile phones is still personal security and emergency situations (Nguyen, Irizarry, Garrett & Downing, 2015). On the other hand, this result is somewhat surprising as the literature reviews of mHealth and mCare interventions involving older adults show that there are numerous advanced ATs available as single apps on the mobile app market, and many of them have been shown to have been useful in clinical trials (e.g., Dasgupta, Chaudhry, Koh & Chawla, 2016; Isaković et al., 2016; Joe & Demiris, 2013). Since many older adults are affected by multiple health conditions that demand various forms of care assistance and provision (Joe & Demiris, 2013), integrating solutions and services in a smartphone that supports the management of different domains of ageing in place simultaneously would be a promising path to be pursued in order to gain the full benefit of launchers. According to Dasgupta et al. (2016), the best outcomes of such launchers for the quality of life of older adults may be expected from the "synergistic effect" related to efficient AT support for older adults' needs emerging from the interlinkage of diverse health and care needs.

Relatedly, we also found that although the analysed launchers seem to adequately support the basic features used by older adults (i.e., calls, contacts, texting, camera), they are more limited in their support of other features (e.g., alarm clock, email, calendar, reminders) that have been revealed as appreciated by older persons (Balata et al., 2015). The results corroborate prior literature suggesting that at least in this particular kind of system, the needs and desires of older adults are often underestimated (Balata et al., 2015; Kurniawan, 2008;

Pedlow et al., 2010) when it comes to offering a range of advanced features on mobile phones. It seems that in order to reduce the potential problems with complex UIs, developers of adapted launchers targeted at the older adult market would rather eliminate some features than offer them through an age-friendly UI. This might not represent an optimal strategy for the future development of launchers since acceptance of new functions on a smartphone by older adults is determined by not only usability but also utility (i.e., whether the system provides users with what they need) (Zhou et al., 2013). Likewise, Pedlow et al. (2010) have shown that age-friendly mobile phones such as Jitterbug can be rejected by older adults if their functionality is restricted to only very basic features, or if the handsets give them limited control over the installed features, services and personalization. In addition, Deng et al. (2014) showed that amongst older adults the perceived value of mobile services was the second strongest predictor of their behavioural intention to use mHealth services and that such intention led to their positive attitude towards such services. Hence, as part of the user-centred design, further studies with older adults should be conducted for evaluating the benefits sought from a combination of basic and advanced features of launchers to make them more acceptable and function-appropriate for them.

However, again with reference to usability, the performance of 12 evaluated launchers was somewhat underwhelming. On average (across all six heuristics) the evaluated launchers respected only 54.7% of the 23 evaluated sub-heuristics. With regard to RQ_2, the study showed that the highest proportion of violations was related to the heuristics of content and perception. The former is mostly related to the limited ability of launchers to enable older adults' error recovery – a problem of launchers that was reported also by Al-Razgan, Al-Khalifa, and Al-Shahrani (2014) –, while the latter is affected by the limited adaptation of visual, auditory, and haptic access to the information provided by the UI – issues detected also in the study of Diaz-Bossini and Moreno (2014). Even though it is widely recognised that older adults' perception needs to be carefully considered when designing tools for them (Holzinger et al., 2007), the potential to humanise interactions with smartphones by employing a multitude of perceptual channels (i.e., multimodal feedback) (Lee et al., 2009) has apparently been only scarcely implemented by developers. For instance, only one evaluated launcher supported multimodal UI feedback, while none of them allowed users to fine-tune screen brightness and contrast or made it possible to change the text-size directly from the launcher's UI. As research has often indicated the sensory functional limitations of older adults as an important barrier to the adoption of ATs on mobile devices (Parker, Jessel, Richardson, & Reid, 2013), the designers of launchers could address this issue to make their UIs more age-appropriate.

Conversely, the evaluated launchers seem to perform reasonably well in terms of dexterity, visual design, and navigation. With reference to dexterity, all of the launchers avoided pull-down menus and three out of four had targets on the screen of at least 14 mm square. Both aspects are important for improved usability as they help older adults to see the targets better and allow them to more accurately touch the target (Leitão & Silva, 2012). Dexterity was only undermined by the presence of scrolling on the home screen of the launchers (half of them were subject to this problem), which not only decreases the visibility of the interface elements (e.g., buttons, menus) but also reduces the capacity of older adults for optimal navigation (Renaud & van Biljon, 2010). In fact, the results showed that usability problems of navigation could be associated with the complex structure of UI navigation, which was related to the multi-level structure of menus that represents a challenge for older adults (Al-Razgan, Al-Khalifa, Al-Shahrani, & AlAjmi, 2012). Being age-friendly in terms of visual design means that the launcher's UI minimises the amount of colours, provides high-contrast colour combinations, uses meaningful and labelled icons, and makes information easy to read and skim (Díaz-Bossini & Moreno, 2014; Loureiro & Rodrigues, 2014; Mi et al., 2014). The results show that these aspects were not equally respected by the evaluated launchers. The use of appropriate colours and colour combinations were both found to be frequently violated, whereas the selection and design of icons was more frequently in line with the recommendations. Finally, recommendations related to cognition were also only partly respected (on average 52.1% of cognition sub-heuristics were respected). The violations were the most frequently associated with requiring older adults to focus simultaneously on more than one task on the screen and to the use of time outs and screen dimming, which have been shown to limit older adults' capability to complete tasks (Furuki & Kikuchi, 2013; Renaud & van Biljon, 2010). On the other hand, almost all of the launchers seem to compensate for the potential cognitive declines of older adults (Schieber, 2003) by avoiding animation and fast-moving objects as well as by supporting recognition rather than recall.

In addition, we note a great variation between the 12 evaluated launchers according to the total heuristic score. Its range was 50 percentage points, with a minimum score of 36.1% and a maximum score of 86.1%. This indicates that a clear margin of improvement over current design solutions exists for most of the heuristics, which would result in the higher usability of launchers with an adapted UI for older adults. In this context, the results related to RQ_3, addressing the relationship between the usability of the evaluated launchers and the number of their basic features and ATs, are very informative despite being based on a limited number of evaluated launchers. They indicate that launchers with a broader range of features and ATs generally have on average less usability problems across all heuristics than those with a limited amount of features and ATs. The only three exceptions are related to dexterity (launchers supporting less features seem to perform better on average; no difference between launchers in terms of the number of ATs) and content (launchers that supported more than one AT had more usability issues related to content than launchers with one AT).

Consequently, the often suggested trade-off between utility and usability in the design of mobile phones for older adults (Kurniawan, 2008; Zhou et al., 2013) could not be confirmed in this study. On one hand, designing a launcher with only basic features and/or ATs due to a desire for lower complexity does not necessary imply better usability. On the other hand, the higher complexity of launchers with more features and ATs does not always imply lower usability. In fact, the lack of complexity is only one of the aspects that leads to a better user experience for older adults. Smartphone launchers should also support other usability principles of optimising UI design (Fisk, Rogers, Charness, Czaja, & Sharit, 2009) to enhance the performance and satisfaction of older adults. In line with Balata, Mikovec, and Slavicek (2015), we might suggest that the future development of launchers and ATs on smartphones should not rely on the reduction of supported features, but rather on the consistent application of the design guidelines for smartphones for older adults that have recently been proposed (Díaz-Bossini & Moreno, 2014; Loureiro & Rodrigues, 2014; Mi et al., 2014). However, such development should also be accompanied by the introduction of new sales models for mobile phones and by the promotion (e.g., though the media, relatives, peer groups etc.) of older adults’ knowledge about how smartphones can assist them across various activities of daily living (Pedlow et al., 2010). In this latter context, various training activities in the community for older adult learning mobile apps could have an important role in familiarizing them with the various domains of ATs on smartphones that potentially match well with their needs for ageing (Parker et al., 2013). Hence, while being consistent in the application of the design guidelines for older adults, designers of launchers also need to address a larger scope of inquiry in order to properly learn and ascertain how older adults could be engaged with launchers in later life.

6. Limitations and future research opportunities

In spite of the consistency of our main findings, this study does have certain limitations that could be overcome in future studies. Although heuristic evaluation is useful in identifying many usability problems, it might also have some disadvantages. For example, Galitz (2013) suggested that with a heuristic evaluation it is difficult to identify deeper design issues associated with the structural problems, missing exits, and missing interface elements or features of the system. It is also difficult to range the assessed problems. In fact, Nielsen (1994) found that in heuristic evaluations experts are biased toward discovering minor problems. Assessing the violations with severity ratings is therefore a viable research direction for the future. However, this would require an additional validation of heuristics, as Silva et al. (2014) and Silva et al. (2015) only validated the herein used sub-heuristics with dichotomous response options. Indeed, the reliability of (sub)heuristics should be further strengthened as only 23 out of the 35 sub-heuristics demonstrated sufficient inter-rater reliability in our study. Additionally, the criterion validity could be assessed, which would involve a comparison of herein used (sub-)heuristics with other design guidelines and heuristics (*cf.* Petrovčič, Taipale, Rogelj & Dolničar, 2017) as well as a series of usability tests with older adults as end-users of these systems.

Moreover, optimization could be further achieved by evaluating exactly the same features and ATs across all launchers. Although we could speculate that this would improve the internal validity of this study, it would further reduce the number of evaluated cases and the capacity for generalisability.

In fact, another limitation that this study faces is related to the generalisability of its results. The study is focused on smartphone launchers with an adapted UI for older adults that support at least four features and one AT that we were able to retrieve from online mobile app stores at a particular point in time. A different choice of time and selection criteria might result in a different set of cases. While this study does provide a complete overview of all currently existing launchers with an adapted UI that offer older adults at least four features and at least one AT, the fact that we are facing a rapid development of this emerging field should be taken into account. Repeating the study in the future by using the approach suggested within this paper would most likely reveal new valuable insights into the availability and usability of age-friendly launchers and ATs integrated in smartphones.

Moreover, combining the results of heuristic evaluation with a series of usability tests would be extremely beneficial and insightful, not only in terms of the validation of heuristics but also for the generation of user-based ideas for eliminating usability problems. Due to the constraints of the research design, this study did not allow us to suggest user-generated solutions to the usability problems uncovered, to explore why some of the heuristics are better respected than others, and to elaborate on the reasons for relatively weak support of ATs by the launchers. Thus, future studies could also delve deeper into acceptance factors of ATs on smartphones in order to understand more adequately how the designs of launchers with ATs would better serve the needs of older adults while aging in place. The design of launchers with ATs might change, not only because of the evolving technological capabilities and/or changing individual human factors of older adults, but also because of changes in the needs and requirements of older adults related to changes in the personal, social and physical contexts of their cohorts (Petrovčič et al., 2017).

7. Conclusion

The present study shows that, currently, only a handful of launchers with an adapted UI that offer older adults a wide range of features and ATs with good usability exist on the market. The most pressing problems of usability are related to content and perception, which limit the older adults' capability for error recovery as well as their visual, auditory, and haptic access to the information provided by the launcehrs' UI. Although launchers with an age-friendly UI have represented a viable opportunity to increase the uptake of smartphones and ATs among older adults, further research-based development is needed to arrive at UI solutions that would better suit the needs and abilities of older adults in terms of usability and utility.

Apendix A

Supplementary data related to this article can be found at https://doi.org/10.1016/j.chb.2017.10.021.

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