A Comparison of the Usability of a Standard and an Age-Friendly Smartphone Launcher: Experimental Evidence from Usability Testing with Older Adults

Short title: Comparison of Standard and Age-Friendly Smartphone Launchers

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Abstract

Age-friendly smartphone launchers are tools designed to enhance smartphone handling among older adults with cognitive and functional limitations. While evidence exists about the positive effects of age-friendly smartphone launchers on older adults' usability performance in general, little is known about how the design and interface complexity of these launchers affect their interface usability effectiveness and efficiency when compared to standard Android smartphone interfaces. Thus, in this study, a randomized crossover experiment involving 50 older smartphone users, aged 60 and above, was guided by the principles of summative usability testing to assess whether an age-friendly launcher performs better than a standard Android launcher performs and to investigate the relationship between the user interface complexity and usability performance of launchers. The results of usability tests in which each participant solved 10 tasks on both launchers indicate that the two tested launchers had comparable effectiveness (i.e., completeness with which participants achieved the test tasks' goals), whereas the age-friendly launcher marginally outperformed its standard Android counterpart in terms of efficiency (i.e., the amount of time used by participants to solve the test tasks). The results also demonstrate that lower user interface complexity is associated with higher effectiveness and efficiency, suggesting that age-friendly smartphone launchers might lead to higher adoption rates of smartphones among older adults if interface designers could reduce their cognitive complexity by limiting the number of steps and alternative paths for task completion.

Keywords: age-friendly design, older adults, smartphone launchers, user interface complexity, usability testing

1. Introduction

Smartphones have the potential to promote independent living, active and healthy ageing, the maintenance of social relationships, and a sense of safety and security among older adults (Arab *et al.*, 2013; Doughty and Williams, 2016; Nielsen and Budiu, 2012; Plaza *et al.*, 2011). Their integrated sensors also make smartphones a promising avenue for monitoring health parameters and delivering rehabilitation interventions (Reyes *et al.*, 2018). Smartphone apps have been designed to provide various forms of rehabilitation services, including rehabilitation and assessment tools targeted at a diverse set of health problems and disabilities (Dicianno *et al.*, 2015). For instance, apps exist that help increase physical activity in people with cardiovascular disease (Maddison *et al.*, 2015), that allow for self-managed balance interventions (Reyes *et al.*, 2018), and that foster stroke rehabilitation (Wong *et al.*, 2017). There is ample empirical evidence that interventions that employ rehabilitation apps lead to positive outcomes not only in terms of improved health conditions but also in terms of subjective dimensions related to quality of life (Gandhi *et al.*, 2016; Park *et al.*, 2016; Siegel and Dorner, 2017).

However, at present, understanding of the population-based impact of such apps has been inhibited by the fact that smartphone use is not mainstream among the aging population. In the US, only 42% of those aged 65 and older (31% of those aged 75 to 79 and 17% of those aged 80 and older) own a smartphone (Anderson and Perrin, 2017). The uptake of smartphones in Slovenia is even lower, as only 27% of mobile phone users aged 55 and older own a smartphone (Dolničar *et al.*, 2016a). Moreover, representative survey figures for the US indicate that only 19% of smartphone owners have downloaded an app to track or manage health, and of those that have, only 16% are aged 50 to 64, while 10% are aged 65 and older (Fox and Duggan, 2013).

It has been suggested that these lower rates stem from older adults encountering various difficulties in interacting with smartphone user interfaces due to their age-related issues concerning perception, cognition, and movement control (Anderson and Perrin, 2017; Dolničar *et al.*, 2016b; Holzinger *et al.*, 2007; Petrovčič *et al.*, 2018a, 2018b). To enable older adults to exploit the potential of smartphones, age-dependent modalities need to be addressed in the interface design process (Fisk *et al.*, 2009). Launchers that allow for an age-friendly designed user interface within a mainstream smartphone have been developed for this purpose (Balata *et al.*, 2015). They are part of smartphone's user interface, enabling users to customize the home screen and perform other tasks more easily (Petrovčič *et al.*, 2018a). In general, age-friendly launchers are programmed with the aim of reducing the complexity of the smartphone user interface, as a lack of complexity leads to a better user experience for older users (Fisk *et al.*, 2009). In particular, a cognitively complex mobile phone interface can substantially amplify the negative effects of older adults' cognitive and memory deficits on system operation on small-size screens (Ziefle, 2002). For instance, it can diminish the visibility of interaction elements and interface controllers, increase users' confusion and disorientation in menu navigation, decrease the learnability and memorability of the user interface structure, and/or severely limit error recovery (Petrovčič *et al.* 2018b; Ziefle, 2002; Ziefle and Bay, 2005).

Even though there is promising research underway related to the usability performance of age-friendly launchers (Balata *et al.*, 2015; Dolničar *et al.*, 2016b; Hwangbo *et al.*, 2013; Petrovčič *et al.*, 2018b), no study has yet compared the usability performance of an age-friendly smartphone launcher with that of a standard Android smartphone launcher or explored how the difference in user interface complexity between

them affects their usability performance. Therefore, the purpose of this study is to fill that gap by addressing the following two research questions (RQs):

RQ1: Are there any differences in task success and task efficiency between a standard Android and an age-friendly designed launcher?

RQ2: What is the relationship between the complexity of the user interface on a standard Android and an age-friendly designed launcher, and what is the difference in their usability performance in terms of task success and task efficiency?

2. Methods

2.1 Procedure and design

To answer the two RQs, older adults completed two summative usability testing sessions (Lewis, 2012) in a crossover experimental design in which participants were randomly distributed into two groups of equal size. The first group first carried out the usability testing session on the Android launcher and then tested the GoLivePhone, an age-friendly designed launcher.¹ Conversely, in the second group, the GoLivePhone launcher was used first, followed by the Android launcher.

Test sessions conducted in summer/autumn 2017 included three parts. In the first (pre-test) part, participants were provided basic information about the study. Each participant signed a consent form and answered a short pre-test questionnaire about their socio-demographics and smartphone proficiency. In the second (test) part, each

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¹ For a more detailed description of the GoLivePhone launcher, see Dolničar *et al.* (2016b). The selection of the GoLivePhone launcher was informed by a study showing its top-ranking performance among age-friendly launchers in terms of congruence with age-friendly design guidelines for mobile phones (Petrovčič *et al.*, 2018a).

participant was given five minutes to familiarize him/herself with the launcher. Then, s/he was asked to complete ten tasks within a time limit ranging from three to four minutes.² In the third part, once the session for the first launcher was completed, each participant filled in a short post-test questionnaire about his/her subjective evaluation of the launcher's usability. Afterwards, the second and third parts of the test session were repeated by the same participants but this time for the second launcher.

The actions of the participants were recorded using a document camera and Morae Usability Testing software (TechSmith, 2018). Real-time streaming of the smartphone screen on the computer was used to observe participants during task execution, to identify errors, to determine task completion, and to make other field notes.

2.2 Apparatus

All participants carried out the tasks on Android and GoLivePhone launchers using the same type of device, a Samsung Galaxy A3 (2016) with a 4.7-inch 720×1280-pixel touchscreen display and Android OS version 6.0.1 (Marshmallow). When conducting tests on Android, the device was set to the factory settings.

2.3 Sample

Non-probability purposive sampling was used to recruit 50 older smartphone users aged 60 years or older. Participants were recruited from five institutions, working in the field of life-long learning and inter-generational cooperation in Slovenia. The sample was 66% female, 44% of the participants were aged 61 to 65, and 10% were aged 76 or older. Fifty-four percent of participants had some university education. Almost all (94%) used their smartphone every day or almost every day, 64% had started using a smartphone three years ago or earlier, and 88% were users of an Android smartphone.

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² Time limits were set because participants had previous experience with smartphone handling.

2.4 Test scenario

Tasks in the testing scenario were divided into four groups, depending on their contents, the type of feature, and their complexity (Table 1). The order of the task groups was assigned to participants randomly and remained the same for both launchers.

[Table 1 to be placed here]

2.5 Measures

2.5.1 Launcher Usability Metrics

The usability performance of a launcher was evaluated based on its effectiveness and efficiency. Effectiveness is the accuracy and completeness with which a certain goal is achieved by the user, whilst efficiency refers to the amount of resources a user expends to achieve a certain goal (ISO, 2018) and, generally, denotes the deviation from what is expected to be an optimal user behavior (Sonderegger and Sauer, 2010). In this study, effectiveness was measured using the metric of task success which was calculated as the percentage of participants who successfully completed the task (Albert and Tullis, 2013). Efficiency was determined by the metric of task efficiency that was calculated as the average of proportions between a participant's task success and the time spent on the task across all valid subjects³ solving a task (Sergeev, 2010)—with higher values indicating greater task efficiency.

2.5.2 User Interface Complexity Matrix

Drawing on Campbell's (1988) notion of task complexity, we defined the User Interface Complexity Matrix (UICM) in this study. The UICM consists of two dimensions: (1) the minimum number of actions (taps) that needs to be taken to achieve the goal along the

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³ Valid subjects were participants who at least attempted to complete the task.

optimal path in the user interface (Endsley, 2011)⁴ and (2) the presence of multiple potential ways to arrive at a desired end state (i.e., to achieve the goal) in the user interface. Based on these two dimensions, a 2×2 matrix with four sub-divisions can be drawn, as illustrated in Figure 1. The dimension “length of optimal path” was divided according to the median value of the number of actions along the optimal way for all 10 tasks in both launchers. Tasks consisting of five or fewer actions were defined as “Simple,” whereas tasks consisting of six or more actions were characterized as “Complex.” Likewise, the dimension “number of optimal paths” was divided into two categories: tasks with one optimal path were defined as “Simple,” while those with more than one optimal path were defined as “Complex.”

[Figure 1 to be placed here]

2.6 Analysis

To answer RQ1, McNemar’s two-tailed exact binomial test for paired nominal data in 2×2 contingency tables was used to explore potential differences between the Android and GoLivePhone launcher for each task in terms of task success. To investigate potential differences in task efficiency, the Wilcoxon signed-ranks test with exact distribution was run due to non-normally distributed data. To answer RQ2, each task (of which there were twenty in all, when considering both tested launchers) was classified according to the UCIM.

3. Results

With reference to RQ1, the results indicate significant differences between the two launchers in three out of ten tasks in terms of task success (Table 2). Notably, for creating

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⁴ The steps on the optimal path could be also referred to as *production rules* according to the Cognitive Complexity Theory (Ziefle and Bay, 2005).

contacts and changing the phone number of a contact, Android outperformed GoLivePhone, while the latter marginally outdistanced Android for setting a contact profile picture. Significant differences in task efficiency were observed in seven out of ten tasks. GoLivePhone was found to be more efficient when deleting a contact, sending a short message service (SMS) message to a number, sending a picture to a contact via email, and setting the profile picture of a contact. Conversely, Android was found to be more efficient for creating a contact, changing the phone number of a contact, and deleting an event reminder.

[Table 2 to be placed here]

To answer RQ2, we compared the expected and observed outcome for task success and task efficiency of both launchers (Table 3). The expected outcome of the two launchers was determined according to their position for a selected task in the UICM, whereas the observed outcome was assessed based on the performance of the two launchers in the usability test. We expected an outcome with no differences between the two launchers in terms of task success and efficiency for the tasks positioned within the same quadrant of the UICM for both tested launchers. For tasks positioned in two different quadrants of the UICM for each of the two launchers, we expected a better performance in terms of both metrics for the one with a less complex/simpler user interface for task execution.

[Table 3 to be placed here]

With reference to task success, nine out of ten observed outcomes were in line with expected outcomes. For instance, as expected, there were no differences between launchers' performance for the "call phone number" task, as this task is positioned in the same UICM quadrant ("Simple") for both launchers. The only divergence between the observed and expected outcomes was found for task "send picture to contact via email,"

where no significant differences were observed in task success between the launchers even though, based on the UICM, GoLivePhone was expected to outperform Android.

With reference to task efficiency, seven out of ten observed outcomes were in line with expected outcomes. For instance, there were no differences between the launchers' performance for creating an event reminder, as this task is positioned in the same UICM quadrant ("Complex") for both Android and GoLivePhone. For deleting a contact and sending an SMS message to a number, task efficiency was better on GoLivePhone, whereas Android was better for deleting an event reminder; however, no differences were expected for these three tasks according to the UICM.

4. Discussion

The purpose of this exploratory study was two-fold. First, it sought to compare the usability performance between a standard Android smartphone launcher and an age-friendly GoLivePhone launcher (RQ1). Second, it sought to investigate how the user interface complexity—an important aspect of age-friendly design—of the two launchers is related to their usability performance (RQ2). With reference to the first aim (RQ1), the performance of the Android and GoLivePhone launchers was significantly different in terms of task success for only three tasks. The differences between the launchers were, however, more pronounced in terms of task efficiency, indicating the slightly quicker overall successful execution of tasks using GoLivePhone.

Such mixed evidence led us to examine the relationship between the user interface complexity and the usability performance of the launchers. In general, the comparison of the observed and expected outcomes of usability tests based on the UICM suggests that higher user interface complexity leads to lower usability performance in terms of both task success and task efficiency. Nonetheless, we also identified a task in which lower

user interface complexity was not associated with higher task success. Notably, in spite of GoLivePhone having a less complex interface structure according to the UICM, no significant differences were found between the two launchers. Such a result might be explained by a higher number of optimal paths for the completion of that task on Android. Tellingly, a higher number of alternative optimal paths generally increases the likelihood of task completion. At the same time, in such cases, task efficiency decreases, and this was also confirmed in our data, with a significant difference in efficiency in favor of GoLivePhone.

In addition, in terms of task efficiency, the observed outcomes were not in line with the expected outcomes for deleting contact and sending SMS messages. A potential explanation might be found in the design guidelines for age-friendly user interfaces on smartphones. They suggest that an interface should help an older user to focus on one task on the screen at a time instead of requiring the user to actively monitor two or more tasks (Silva *et al.*, 2015). GoLivePhone better follows such recommendation because it has a larger number of different screens through which the user passes while solving the task on the optimal path. In addition, a post-test inspection of both launchers revealed that users conducted a smaller number of actions on the same screen (according to the number of steps on the optimal path) on GoLivePhone than on Android. Further, the higher efficiency of GoLivePhone for the tasks “delete contact” and “send SMS to number” might be explained by a higher ratio between the average number of different screens on the optimal path divided by number of actions required to successfully complete the task following the optimal path. For example, the optimal path for deleting a contact includes five taps and five different screens through which the user passes. Accordingly, the ratio between number of different screens and actions required is 1. Conversely, the ratio for

the same task on Android is 0.75. The last deviation between the observed and expected outcomes was found for the task of deleting an event reminder, where Android outperformed GoLivePhone despite no difference being expected according to the UICM. A potential explanation could be related to participants' limited experience with and only occasional use of the calendar on a smartphone (Chen *et al.*, 2013; Dolničar *et al.*, 2016a; Lee, 2007). As participants in this study were predominantly Android users (88%), it seems reasonable to assume that for many of them, it could be easier to cope with an unknown feature on a known interface than on an unknown one. Tellingly, the ability of older adults to learn how to use technology is, in general, lower than that of other age groups (Kelley and Charness, 1995; Marquié *et al.*, 2002).

The results of this study must be considered in light of study's limitations. First, while a fairly large sample for summative usability testing was used (Lewis, 2012), the results may not generalize to a population level due to the non-random selection of participants. Second, the relatively large number of experienced and longstanding Android smartphone users in the sample might have led to an overestimation of the usability performance of the standard Android launcher. It could be that if the test had been performed on another group of older adults with less experience in using smartphones, the results could have been substantially different (presumably in favor of an age-friendly launcher). Hence, further research needs to consider the use of a more heterogeneous sample in that respect. Third, future investigations might also benefit from comparing a standard Android launcher with more than one age-friendly designed launcher. Finally, the restricted selection of the two usability metrics might also render the comparisons inappropriate for establishing norms. However, since task success and task efficiency have been widely considered valid objective measures of two central

usability dimensions—effectiveness and efficiency, respectively (Ziefle and Bay, 2005)—our selection seems to be appropriate and relevant for the study’s purposes.

Overall, our results reveal that at least among older smartphone users the two tested launchers had comparable effectiveness, whereas the age-friendly launcher marginally outperformed the standard Android smartphone interface in terms of task efficiency. Moreover, they confirm that reducing the user interface complexity in terms of the number of optimal paths and the optimal path length is a viable design strategy to improve the user experience of older adults with smartphones. This finding is promising not only for designing age-friendly launchers with basic and most frequently used smartphone features but also for delivering rehabilitation interventions to older adults via smartphone apps.

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Tables

Table 1. Testing scenario tasks.

Task	Feature	Task description
T1	Call and contact	Call the phone number 01 580 53 80. When you hear ringing, end the call.
T2		Create new contact Helen Blunt with phone number 030 456 061.
T3		Delete contact Alice Emerson.
T4		Change phone number of contact Anna Spencer to 030 456 071.
T5	SMS	Send SMS message with content "Ok" to phone number 040 641 177.
T6		Send SMS message with content "I am coming" to contact Jane Booker.
T7	Gallery	In the gallery, find the photo of a house. Open the photo and send it to contact Martha Davison.
T8		Add the photo of a woman from the gallery to contact Lucy Parker.
T9	Calendar	Create an event "Visit" for Friday, 30 June at 3–4 pm in the city center. Set it as a one-time event without a reminder.
T10		Find and delete the event "Celebration," which should take place on June 28.

Table 2. Task success and task efficiency by launcher and task.

Task	n ^a	Task success			Task efficiency ^c		
		Android	GLP	p ^b	Android	GLP	p ^b
Call phone number	50	.920	.940	> .999	0.045	0.048	.587
Create contact	50	.760	.380	< .001	0.017	0.006	< .001
Delete contact	49	.878	.939	.453	0.037	0.068	< .001
Change phone number of contact	49	.857	.612	.002	0.026	0.013	< .001
Send SMS to number	50	.720	.860	.118	0.014	0.019	.026
Send SMS to contact	49	.857	.857	> .999	0.027	0.026	.461
Send picture to contact via email	48	.563	.646	.523	0.010	0.020	.005
Set profile picture of contact	45	.222	.333	.063	0.005	0.009	.004
Create event reminder	42	.095	.119	> .999	0.001	0.001	.469
Delete event reminder	40	.650	.525	.125	0.026	0.013	.004

Notes. ^a Number of pair-wise cases varies due to task refusals. ^b Differences significant at $p < .1$

level are marked in bold. ^c Higher value indicates higher task success and efficiency. GLP = GoLivePhone.

Table 3. Task success and task efficiency in terms of User Interface Complexity Matrix (UICM).

Task	User Interface Complexity Matrix (UICM)		Expected	Observed Outcome	Observed Outcome
	Android	GLP	Outcome ^b	TS	TE
T1	Sim (3), Sim (1) ^a	Sim (3), Sim (1)	nd	ns	ns
T2	Sim (4), Sim (1)	Com (8), Com (2)	Android	Android	Android
T3	Sim (4), Sim (1)	Sim (5), Sim (1)	nd	ns	GLP
T4	Sim (5), Sim (1)	Com (8), Sim (1)	Android	Android	Android
T5	Sim (4), Sim (1)	Sim (5), Sim (1)	nd	ns	GLP
T6	Sim (4), Sim (1)	Sim (4), Sim (1)	nd	ns	ns
T7	Com (6), Com (7)	Com (6), Sim (1)	GLP	ns	GLP
T8	Com (8), Com (4)	Com (7), Sim (1)	GLP	GLP	GLP
T9	Com (7), Com (2)	Com (14), Com (2)	nd	ns	ns
T10	Com (6), Com (4)	Com (7), Com (2)	nd	ns	Android

Notes. ^a Task T1 was assessed as simple according to both UICM dimensions. “Sim (3)” refers to simple in terms of the length of the optimal path, which requires three actions for task completion, whereas the second dimension, “Sim (1),” means that a task is defined as simple in terms of the number of optimal paths, with only one optimal path for a given task completion. ^b Instances in which expected outcomes are confirmed by observed outcomes are marked in bold. Nd = no differences in expected outcome; Ns = non-significant differences in observed outcomes at $p > .1$ level; TS = task success; TE = task efficiency. GLP = GoLivePhone.

Figure

Figure 1. User Interface Complexity Matrix.

		Number of optimal paths	
		= 1	> 1
Length of optimal path	≤ 5	Simple-Simple	Simple-Complex
	> 5	Complex-Simple	Complex-Complex