How Older People Who Have Never Used Touchscreen Technology Interact with a Tablet

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Abstract. Touchscreen technologies have become increasingly common in personal devices, so it seems necessary to improve their accessibility and usability for the older people. In the past years, a lot of studies have been conducted to improve touch interfaces, however, most them do not consider older people with very low attitude with ICTs. Moreover, the majority of studies date back 2014, so they lack to consider the most innovative technologies available today. The present study involves a sample of older people without previous experience with ICTs with the aim of analyzing how basic features of a touchscreen interface affect their performances with typical touch-gestures. A total of 22 participants have been involved. Results partially confirm the existent literature and partially reveal new interesting findings that can be useful to improve the touch screen accessibility for older people.

Keywords: Touchscreen interface · Older people · Usability · Accessibility · Touch gestures · Human computer interaction

1 Introduction

Nowadays, several attempts have been made to analyze the impact of the new technologies for the older users, in terms of accessibility, usability and acceptability: studies of technology use, attitudes and skills have shown that they are less incline to use technology compared with younger ones [1]. However, depicting the older adults as technophobes represents an erroneous preconception as many evidences suggests that older users desire interaction with new technologies to remain active in the society and independent [2]. In fact, older adults can strongly benefit of new information and communication technologies (ICTs) [3], although there are practical issues that explain why older users do not use technologies: lack of motivation or reason to use ICT devices, lack of experience with current technology, cognitive differences and age-related decline, lack of knowledge on how to use ICTs, no access to the technological artifacts, no understanding of what to do with a device, and usability problems [4, 5].

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The most effective way to overcome the scarce use of technologies in the older population is to design technologies taking into account their abilities and preferences since the beginning [6–9], in order to support them in using the available services that are becoming more technology based, in particular embedded with touchscreen technologies.

In recent years, touch technology has flourished, so that it has become essential in everyday life: practically all personal devices (e.g., smartphones, tablets, PCs) implement it [10]. The reasons for the success of touchscreen interfaces is mostly due to the fact they allow direct input, and consequently support human-computer interaction in a more intuitive and accessible way. In fact, this imply a screen size larger than no-touch interfaces and virtual button items bigger than those of a keyboard based interface (i.e., large enough to be pressed with a finger).

In the case of touchscreen technologies, some studies have shown that also younger adults may encounter some frustrations during the use, suggesting that improving the design of touchscreen interface for older adults will improve the rate of usability also for the other user groups [1]. On this matter, several studies have been carried out to try to define a set of informal guidelines for interface design for seniors [11]. The dimension of the screen and the characteristics of the screen items (e.g., size, color, grouping, etc.) have been studied to guarantee that touchscreen interactions result accessible and usable for older people [12]. These studies demonstrated that larger items, figure and links should be used to improve interaction. Regarding button size, at least 20 mm square is recommended to ensure an optimal finger selection [13, 14], while the minimum recommended width is 13 mm [15]. Regarding button spacing, a space at least equal to 3.17 mm seems to lower performance error rate for older people [16] although other studies found that gap size does not affect user performance [14].

Some studies [17, 18] found that the interface should support older people to interact without difficulty and should avoid the focus loss, especially for user with visual and cognitive impairment. As a result, they suggest designing the visual objects (e.g., text, icons) with appropriate featured using high contrast colors, and a layout based on clearness and simplicity. In particular, the dark color of background should not be used because it stands out fingerprints and intensifies glare, although the major tablet operating systems provide it as an accessibility setting [19]. To keep attention on the interface, the information should be provided in a simple way, avoiding the unnecessary objects like decorative animations, useless pictures, wallpaper patterns, moving text or flashing text [18] and replace data entry with other simpler choice (e.g., tapping on predefined values, providing sliders or button for incrementing and decrementing values, etc. [19]). Finally, several studies have analyzed the user's gestures (i.e., tap, slide, drag, pinch, swipe, etc.) while they interact with a tablet. These sought to evaluate which of these gestures best support user performance for older people [11]. Their results show that, older users with high manual dexterity prefer dragging and pinching rather than tapping [20].

The literature study showed that there is a strong interest to understand the interaction on touch interface related to age. Nevertheless, most of the existing studies on the usability of the touchscreen devices get primarily involved older people with previous experience using computers and/or other touchscreen technologies (i.e. smartphones, tablet, e-book reader etc.) [11]. Indeed, only few studies in literature have involved subjects without experience with ICTs. Moreover, although in the recent years, touchscreen technology is considerably improved [21, 22], studies on interaction of older people with these recent technologies are still lacking.

In this context, the present study involves a sample of older people without previous experience with ICTs (except for traditional mobile phone) with the aim of analyzing how basic features of a touchscreen interface affect their interactions. For this purpose, the paper inspects the older people performances, during their first experience with the latest generation touchscreen. In detail, this exploratory study aims to: (a) verify whether the guidelines relating to the GUI design for older people based on studies conducted on older technologies are still valid today with latest technologies; (b) assess the level of accessibility of current technologies for older people without prior experience in the use of touchscreen and scarce experience in the use of ICTs.

2 Touchscreen Application

To support the evaluation of the interaction, a touch screen application has been developed, to assess the performance of the participants with tapping, dragging and pinching gestures. The application is composed by three game sessions:

- Tap: tapping a button on the screen;
- Drag and drop: dragging an object on the screen;
- Pinch-to-zoom: expanding or shrinking an object on the screen using two fingers.

The architecture of application (Fig. 1) is composed by three main functional modules. The Application Manager allows to read pattern configuration and startup application parameters and manage all the interaction flow during the three different sessions. Every session manages the items' appearance and behavior according with the configuration data loaded by the manager: these sub-models provide to configure the user interface.

In addition, a background routine is in running during the user interaction in order to collect performance data that are stored in a dedicated report as shown in Fig. 1.

Each session provides a set of mini-tasks in which the target object changes its attributes (e.g. position, shape, color, size, etc.), which are described in detail in the sections below. Each session uses predetermined patterns to change the appearance attributes of the target object, which were randomly assigned. Furthermore, each session can collect key performance parameters useful for the data analysis, which are described in detail in the following paragraphs. Each parameter allows to detect an aspect of user performance: the *Task completion time* (in milliseconds) is the time within the user completes the mini-task, while the *Success value* give the success/failure condition. In order to determine the failure condition, a *Limit time session* is defined for each game. A session is considered failed if the participant does not correctly complete the gesture within the prescribed time.

The interface application was realized to comply the standards and the design guidelines related to web accessibility [23–25].

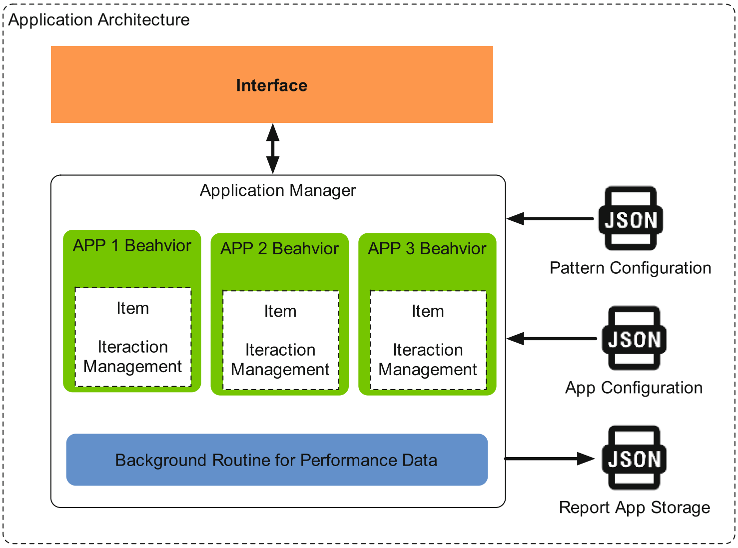


Fig. 1. Architecture of pilot application.

2.1 Tapping

The first application tries to investigate the tapping interaction (Fig. 3a). The user's task consists in tapping a graphical target item (i.e. colored circle): it can be modified about size, contrast, shape and screen position.

The variability range of the first session can be summarized in Fig. 2 and has the same structure in the other experimental sessions. The four attributes used in App1 are:

- **Position**: the screen surface is divided into 6 regions and the target object to be manipulated appears in the center of the assigned region;
- **Shape**: three different shapes are selected (square, square with rounded edges and circle);
- **Color**: three different variants are chosen for the color variability: more precisely, contrast combinations between object and background are defined to test the influence of the choice of color in the interface design. The three variants shown in Fig. 2 are low-contrast, high-contrast and reverse high contrast;
- **Size**: according to the accessibility guidelines three variants of size attribute are defined (small with 38 × 38px, medium with 76 × 76px and large with 113 × 113px).

According with the appearance variables, random combinations of the target item aspect is generated: the total number of the combinations is 162. The item appears on the screen and when the user taps it disappears and the next one is shown. If the user does not achieve the task within the limit time session (4.000 ms), the next step is triggered to guarantee the session conclusion.

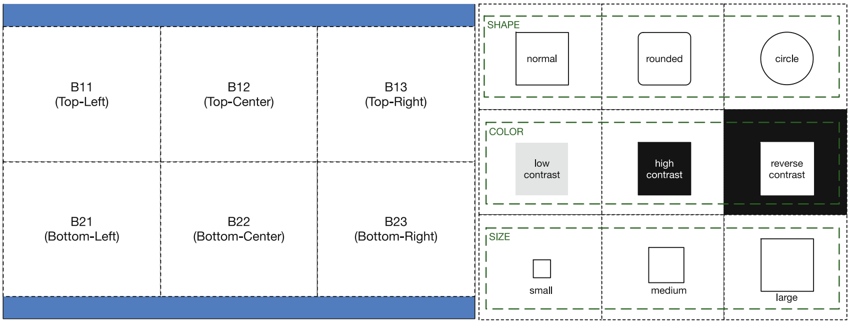


Fig. 2. Variability ranges of object attributes

2.2 Drag and Drop

The second app is focused on the drag and drop interaction (Fig. 3b). Two circles (colored target item and white endpoint) with same size are displayed on the screen. The user must hook the target item (colored) and move it into the white one. When it is left, and does not match with the endpoint circle, its position is reset. In this case, the attributes of the target object are two:

1. **Type of gesture**: a classification of possible dragging trajectories has been defined (see Table 1), which is based on the possible combinations of positions the two displayed objects may assume in the six areas of the screen defined above.
2. **Size**: the three sizes mentioned above are proposed again for both displayed items.

The second session provides 90 combinations. A limit time session equal to 5000 ms determines timeout for the step duration.

Table 1. The considered dragging gestures

Typologies of gestures	Dragging trajectories
Vertical up	B21 → B11, B22 → B12, B23 → B13
Vertical down	B11 → B21, B12 → B22, B13 → B23
Long horizontal right	B11 → B13, B21 → B23
Long horizontal left	B11 → B13, B23 → B21
Short horizontal right	B11 → B12, B12 → B13, B21 → B22, B22 → B23
Short horizontal left	B12 → B11, B13 → B12, B22 → B21, B23 → B22
Long diagonal upper right	B21 → B13
Long diagonal upper left	B23 → B11
Long diagonal bottom right	B11 → B23
Long diagonal bottom left	B13 → B21
Short diagonal upper right	B21 → B12, B22 → B13
Short diagonal upper left	B22 → B11, B23 → B12
Short diagonal bottom right	B11 → B22, B12 → B23
Short diagonal bottom left	B12 → B21, B13 → B22

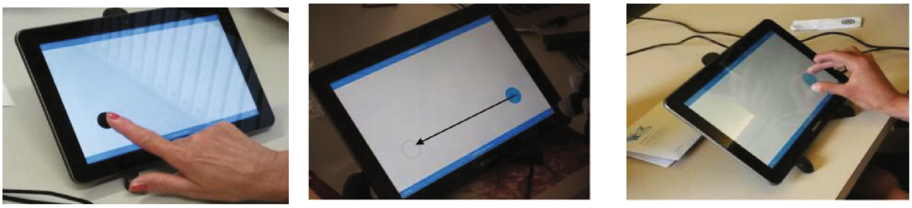
2.3 Pinch-to-Zoom

The third application concerns the pinch-to-zoom interaction (Fig. 3c). In this case, the possible actions performed by the user are two: he/she can modify the size of the target object by moving closer or away his/her fingers on the screen. The objective of this session is matching a target object (colored) with a concentric endpoint circle (white).

Table 2. The considered zoom percentage

			Object size	Circle size
% Zoom	Zoom out	44%	340px	150px
		62%	240px	150px
		70%	340px	240px
	Zoom in	141%	240px	340px
		160%	150px	240px
		226%	150px	340px

The considered attributes in this session are position (the same six defined above) and the zoom percentage. The zoom percentage is compute as the ratio between the size of the target object and the endpoint circle (see Table 2). The total combination for Pinch-to-zoom interaction are 36. A limit time session equal to 7000 ms determines timeout for the step duration.



(a) (b) (c)

Fig. 3. (a) Tap interaction; (b) Drag & Drop interaction; (c) Pinch-to-zoom interaction

3 Material and Method

3.1 Participants

For the purpose of the study, volunteer subjects were recruited in facilities of the local municipality. To be enrolled, the following inclusion criteria were fixed:

- Age 60 and older;
- Native speakers of the trial language;
- Mini Mental State Examination (MMSE) score ≥ 24;
- Geriatric Depression Scale (GDS) score ≤ 10;

- Subjects should not have any significant mobility impairment (upper or lower extremity);
- Fulfill hearing and vision criteria set by self-reported questionnaires (hearing and vision criteria anticipate that both could be augmented, i.e., via eyeglasses or hearing aids);
- Ability to make time commitment;
- No previous experience in the use of computers, Internet or other ICTs (except for old-fashioned mobile phone).

The total sample was composed of 22 participants, 5 males and 17 females, with a mean age of 76 years old (SD $\pm$ 6.69). The totality of the sample was retired and the most income source is constituted by pension. Almost all the subjects (13 out of 22) were married and live with the partner, while 8 subjects live alone and 1 with the sons. Eight participants (8 out of 22) use mobile phone, while 14 never owned it. On the cognitive side, the mean value of the MMSE is 29.31 (SD $\pm$ 0.77), while the mean score obtained at the GDS is 3.72 (SD $\pm$ 2.54).

3.2 Experimental Equipment

The touch application was presented on a Samsung Galaxy Tab A (10.1″). The whole interaction with the pilot application was recorded by means of dedicated cameras. Specifically, two cameras (Nikon d5300 + AF-P DX 18-55 VR) were placed in the environment and recorded participant's actions to allow offline computer-supported structured video-analysis. Finally, the BORIS software (Behavioral Observation Research Interactive Software) [26] is used to support a video-analysis.

3.3 Procedure

The experiment took place in appropriate equipped room. On a large table, the participants had access to the tablet placed on a fixed special support.

Each participant was asked to sit in front of the tablet. In order to set the correct distance between the user and the tablet, the user has been asked to hold the tablet and position the chair in the way to make a 120° angle between his arm and forearm. Furthermore, the experimenter has assured that the user was taking the correct position and posture. Participants are required to maintain head and neck aligned with the screen focused area, to keep their hips and knees lined up and parallel to the floor, to maintain their back in contact with the chair, avoiding to tilt on the back and to take care that the arms were parallel to the work surface. In the experiment, subjects were also asked to operate with just one hand. The hand choice was not restricted to the left hand or the right hand but was primarily based on the subject's handedness. Anyway, all the users that participated in the tests were right-handed. This test configuration was set to ensure the user comfort during the test and the same interaction conditions for all the users.

The participants were welcomed in the laboratory room and researches have presented the trial objectives and collected the informed consents.

Before starting, the experimenter explained to the participants the three MiniApps operation through the aid of a video demonstration and they were informed about the

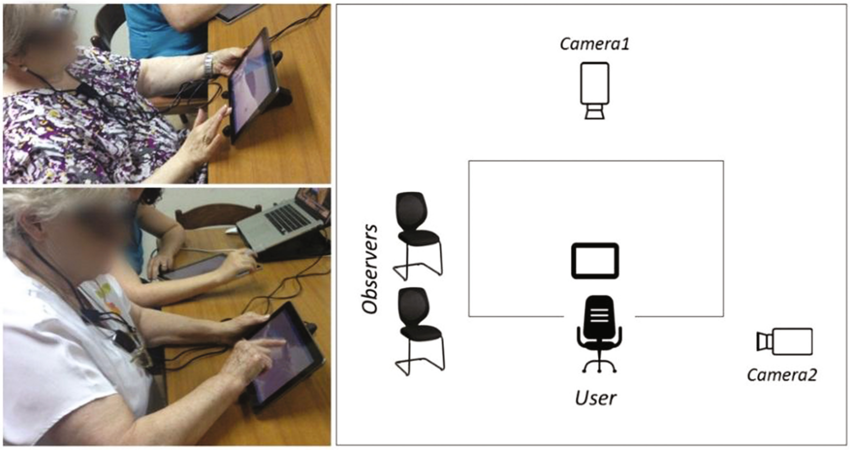


Fig. 4. The experimental setting.

total duration of the test. Then the participants received a full explanation of how the touch application was structured and how to operate it (Fig. 4).

The experimenter started the video-recording and the experimental phase began with the experimenter asked the users starting the first Mini App. Later, the users were asked to interact with others developed MiniApps, according to the functional sequence described in the previous paragraph. In additions, during the entire interaction, users were encouraged to express their thoughts, feelings, possible boredom signs and opinions aloud while the experimenter was taken annotation of the performance, errors and user attitudes. The experimental session was completed when the user has completed the three MiniApps. The total experimentation time about 22.5 min has been established and all involved users have concluded the experiment without any breaks between sessions.

4 Results

Tests show interesting results which partially confirm the existent literature and partially reveal new findings that can be useful to improve the touch screen accessibility for older people.

In general, for tapping we obtained a success rate equal to 78.09%, while success rate decreases to 44.83% for dragging and falls down to 24.49% for pinching. According to the literature [11, 20] this confirms that tapping is the easier gesture for older people.

To assess if gender may affect user performance in term of task completion time, a t-test has been carried out. As show in Table 3, the results illustrate that did not evidenced significant differences between gender.

Table 3. Task completion user performance related to participant's gender

		Mean time (ms)	SD	t	p
Tapping	*Male*	1886,14	627,08	t(2782) = 0,78	0,435
	Female	1864,08	593,39		
Dragging	*Male*	3569,09	1004,94	t(865) = 1,88	0,061
	Female	3427,79	926,28		
Pinching	*Male*	4702,18	1309,02	t(192) = 1,02	0,31
	Female	4468,52	1557,8		

In order to analyze how the considered features of the interface affect user interaction, different ANOVA analysis were individually performed. To assess equality of variance, Levine's test was used.

4.1 Tapping

Four One-way ANOVA analysis were performed on the experimental results for the tapping task. The first one used size (38px, 76px and 113px) as an independent variable to investigate the effect of size on performance value (i.e., Task Completion Time). The second one used the position of target on the screen area (B11, B12, B13, B21, B22, B23) to analyze the effect of the target position on older people performance. The third one used target contrast (low, high and reverse contrast) as independent variable to investigate the effect of target visibility on performance. The last one used the icon shape (square, square with rounded edge and circle) as independent variable to understand the effect of the shape of the targets on the users' performances.

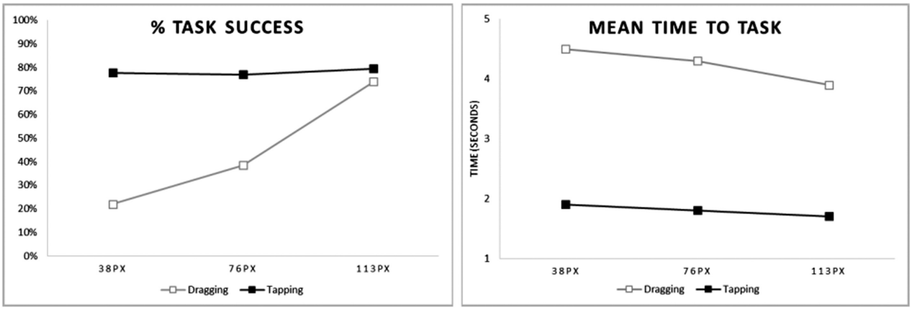


Fig. 5. Tapping and dragging success rate and mean time to task for each target size

Results show that size had a strongly significant effect on the older people performance (F(2,2781) = 33.29, p < 0.000). Older people perform more quickly the greater are the targets (Fig. 5): the average of Task Completion Time (T) is equal to 1.77 s with 113px target and increase to 1.84 s and 1.99 s with targets respectively of 76px and 38px width. This confirm results of several previous studies [19, 20]. However, an increase in the size of the targets does not seem to improve success rate: participant performed well also with small targets.

The position of the targets on the screen significant affect older people performance ($F(5,2778) = 3.49$, $p < 0.004$). Older people performed more quickly if targets are located in the middle of the screen ($T_{B12} = 1796.96$ and $T_{B22} = 1845.05$) or on the right side ($T_{B13} = 1841.25$ and $T_{B23} = 1875.75$), while target positioned on the left side slow the performances ($T_{B11} = 1943.02$ and $T_{B21} = 1908.78$). Those results, for right-handed subjects basically confirm the Fitts' law [27]. However, position does not influence the success rate.

Furthermore, there were not significant main effects of the contrast ($F(2,2781) = 1.57$, $p > 0.05$) and of the shape of targets ($F(2,2781) = 0.04$, $p > 0.05$).

4.2 Dragging

Two ANOVA analysis were individually performed on the experimental results for the dragging task. The first one used size (38px, 76px and 113px) as an independent variable to investigate the effect of size on performance value (i.e., Task Completion Time).

The second one was performed to understand how the features of the dragging gesture affects older people performance. To this end, the type of gesture has been used as independent variable to compute the ANOVA analysis.

Results show that size had a strongly significant effect on the older people performance ($F(2,864) = 18.99$, $p < 0.000$). According to the results (Fig. 5), only the targets of 113px width seem to be suitable to be dragged by older people. Regarding the effect of dragging gestures, results show that the type of gesture strongly affects older people performance ($F(13,853) = 6.83$, $p < 0.000$). In particular, older people perform more quickly with vertical gestures and diagonal gestures at the right top (Table 4).

Table 4. Dragging performance data

Typologies of gestures	% Success	Mean time (ms)	SD
Vertical up	44,33	2918,85	1334,84
Verical down	45,60	3101,45	785,84
Long horizontal right	50,00	3565,09	1039,28
Long horizontal left	41,98	3778,87	860,6
Short horizontal right	<u>41,09</u>	3359,09	912,05
Short horizontal left	<u>38,13</u>	3575,89	867,2
Long diagonal upper right	47,69	3306,05	932,53
Long diagonal upper left	43,75	3876,54	624,34
Long diagonal bottom right	47,62	3676,92	758,5
Long diagonal bottom left	**57,58**	3633,72	826,4
Short diagonal upper right	49,61	3198,97	893,45
Short diagonal upper left	43,85	3873,59	700,77
Short diagonal bottom right	48,06	3606,37	833,99
Short diagonal bottom left	47,29	3461,69	947,08

Moreover, by analysis performance data, it is possible to observe that diagonal gesture resulted in higher success rate than horizontal or vertical gestures (Figs. 6 and 7).

In particular, diagonal trajectories in the lower left resulted in best performance (57.8%), while short horizontal and long horizontal trajectories to the left resulted in lowest success rate.

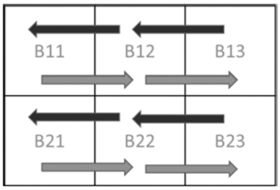


Fig. 6. Short horizontal gestures resulted in worse performances

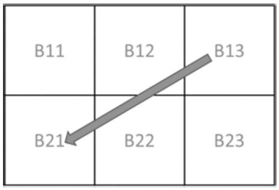


Fig. 7. Diagonal gestures in the lower left resulted in best performance

4.3 Pinching

Two ANOVA analysis were individually performed on the experimental results for the pinching task. The first one used the zoom percentage (see Table 2) as an independent variable to investigate the effect of direction and extension of pinching gesture on performance value (i.e., Task Completion Time). The second one used the position of target on the screen area (B11, B12, B13, B21, B22, B23) to analyze the effect of target position on older people performance.

Results show that the zoom percentage had a strongly significant effect on the older people performance ($F(5,188) = 7.46$, $p < 0.000$). According to performance data (Table 5), spreading gesture resulted more ease than pinching. However, it should be observed that zoom ratios that require very broad gestures to be performed (zoom = 226%) result in a dramatic reduction of the success rate. Regarding the effect of object position, results did not reveal significant effect ($F(5,188) = 0.86$, $p < 0.511$).

Table 5. Pinching performance results

	% Zoom	% Success	Mean time (ms)	SD
Zoom out	44	18,18	5440,38	1432,18
	62	18,94	4584,32	1929,83
	70	17,42	4169,57	1519,84
Zoom in	141	**43,18**	3710,47	1351,88
	160	**37,12**	4684,43	1344,25
	226	12,12	5511,56	957,57

5 Discussion

From the analysis of the results, it is possible to synthesize some guidelines for the designers of touchscreen interface, to be taken into account in addition to the already available documentation [20, 28].

As already evidenced by the literature [11, 20], it is emerged that the most ease gesture for the older users seems to be tapping, in terms both success rate and task completion time. In particular, a dimension of the object greater than 13 mm (76px) improves the user performance in terms of Time Completion Task, although the effect is minimal. Moreover, the object positions in the screen – B12, B13 – positively interfere with the success of the tapping task. However, the increase of the target dimension does not really seem to influence task success rate with tapping and the improvement resulted in terms of users' performance efficiency is very small (i.e. the task completion task with targets of 113px (i.e. 19 mm) decreases with the target of 38px (i.e. 6 mm) for only 220 ms). This result seems to refute a well-known guideline: that the icon size is very important for older people in performing tapping [13, 14] and at least 13 mm square is recommended to ensure finger selection 13 mm [15].

This result may be due to the improvement of touchscreen technology: in particular, the introduction of the high-resolution screen seems to support users' performance accuracy.

Contrariwise, only targets large at least 113px (19 mm) seem to be suitable to be dragged by older people. This is because the finger occludes the smaller targets during the performance of gesture. Furthermore, the trajectory of dragging gesture influences the performance. In particular, diagonal gestures in the lower left resulted in best performances, while, short horizontal gestures resulted in worse performances. Probably this is because such gesture, more than others, avoid the object to be dragged is occluded by the finger or the hand.

Finally, it is emerged that the most difficult gesture for the older users seems to be the pinching/spreading, in terms both success rate and task completion time. Also, this result is consistent with the literature [11, 20]. However, for zoom ratios that do not require very broad gestures to be performed ($\leq 160\%$), spreading gesture resulted more ease than pinching. This result partially confirms the findings of Kobayashi et al. [20]. In fact, in case of pinching/spreading gesture with panning, they found that spreading is generally easier that pinching.

6 Conclusion

Despite the interesting results collected, the sample size of the study is relatively small and this does not allow a proper generalization of the data. For this reason, it is important to take into account the present study as a pilot, with the aim of involving a higher number of users during the next research activities. Within the limits of the study, the most felt one is the neutrality of the application: the tasks were presented by means of stimuli, that do not contain any emotional salience for the users.

From the literature, it is well known that the emotional salience of the events can constitute an important contributor of memory-enhancing effect, for example, using stimuli ranging from pictures to words to narrated slide shows, as well as data from autobiographical memory [29]. For this reason, the personalization of the interfaces may support the successful performance with the tasks, if the screen elements, for example, can be anchored to significant meanings for the users. Despite this, our pilot was focused on achieving information on how to easier the use of any touch screen interfaces in general, by giving a sort of guidelines to be followed during the design, and that can be applied to any kind of contents.

Future studies on touch screen technologies and older users should take into account how the results will vary in consideration of the different attitude level and past experiences with the technological solution [7, 30], considering that improving the design in favor of the older users means also to reduce the frustration with the use for a wider plethora of users [1].

As it is well-known that the older people is represented by a highly heterogeneous group, it is important to find a personalized way - tailored on the individual preferences - to provide a training on technology literacy, in order to empower the users and mitigate the erroneous representations of the technology, often derived by scarce accessibility to the technological solutions.

The improvement of the technological literacy, defined as "the ability to use, manage, assess, and understand technology, involving knowledge, abilities, and the application of both knowledge and abilities to real-world situations, to be obtained through formal or informal educational environments" [31], should be a valuable complement intervention to support the use of the touch screen technologies, and thus collecting new insights for the design of the interfaces.

References

1. Czaja, S., Charness, N., Fisk, A., Hertzog, C., Nair, S., Rogers, W., Sharit, J.: Factors predicting the use of technology: findings from the center for research and education on aging and technology enhancement (CREATE). Psychol. Aging **21**(2), 333–352 (2006)
2. Kurniawan, S.: Older people and mobile phones: a multi-method investigation. Int. J. Hum Comput Stud. **66**(12), 889–901 (2008)
3. Gullà, F., Ceccacci, S., Menghi, R., Germani, M.: An adaptive smart system to foster disabled and elderly people in kitchen-related task. In: Proceedings of the 9th ACM International Conference on PErvasive Technologies Related to Assistive Environments, article no. 27. ACM (2016)
4. van Dijk, J.: The Network Society, Social Aspects of the New Media. Sage Publications, London, Thousand Oaks, New Delhi (n.d.)
5. Czaja, S., Sharit, J.: Age differences in attitudes toward computers. J. Gerontol. **53B**, 329–340 (1998)
6. Goddard, N., Nicolle, C.: What is good design in the eyes of older users? In: Proceedings of the 6th Cambridge Workshop on Universal Access (UA) and Assistive Technology (AT), [CWUAAT], Fitzwilliam College, University of Cambridge, pp. 1–9 (2012)
7. Agarwal, R.: Individual acceptance of information technologies. In: Zmud, R.W. (ed.) Framing the Domains of it Management Research: Glimpsing the Future Through the Past, pp. 85–104. Pinnaflex, Cincinnati (2000)

8. Mackie, R., Wylie, C.: Factors influencing acceptance of computer-based innovations. In: Helander, M. (ed.) Handbook of Human-Computer Interaction, pp. 1081–1106. Elsevier Publishing Co., New York (1998)
9. Mengoni, M., Raponi, D., Ceccacci, S.: A method to identify VR-based set-up to foster elderly in design evaluation. Int. J. Intell. Eng. Inform. **4**(1), 46–70 (2016)
10. Lattanzio, F., Abbatecola, A., Bevilacqua, R., Chiatti, C., Corsonello, A., Rossi, L., Bernabei, R.: Advanced technology care innovation for older people in Italy: necessity and opportunity to promote health and wellbeing. J. Am. Med. Dir. Assoc. **15**(7), 457–466 (2014)
11. Motti, L.G., Vigouroux, N., Gorce, P.: Interaction techniques for older adults using touchscreen devices: a literature review. In: Proceedings of the 25th Conference on l'Interaction Homme-Machine, p. 125. ACM, November 2013
12. Murata, A., Iwase, H.: Usability of touch-panel interfaces for older adults. Hum. Factors **46**, 767–776 (2005)
13. Chung, M., Kim, D., Na, S., Lee, D.: Usability evaluation of numeric entry tasks on keypad type and age. Int. J. Ind. Ergon. **40**(1), 97–105 (2010). ISSN 0169-8141
14. Chen, K., Savage, A., Chourasia, A., Wiegmann, D., Sesto, M.: Touch screen performance by individuals with and without motor control disabilities. Appl. Ergon. **44**(2), 297–302 (2013)
15. Hwangbo, H., Yoon, S., Jin, B., Han, Y., Ji, Y.: A study of pointing performance of elderly users on smartphones. Int. J. Hum.-Comput. Interact. **29**(9), 604–618 (2013)
16. Jin, Z.X., Plocher, T., Kiff, L.: Touch screen user interfaces for older adults: button size and spacing. In: Stephanidis, C. (ed.) UAHCI 2007. LNCS, vol. 4554, pp. 933–941. Springer, Heidelberg (2007). doi:10.1007/978-3-540-73279-2_104
17. Fisk, A.D., Rogers, W.A., Charness, N., Czaja, S.J., Sharit, J.: Designing for Older Adults: Principles and Creative Human Factors Approaches. CRC Press, Boca Raton (2009)
18. Hawthorn, D.: Possible implications of aging for interface designers. Interact. Comput. **12** (5), 507–528 (2000)
19. Caprani, N., O'Connor, N.E., Gurrin, C.: Touch screens for the older user. In: Assistive Technologies, pp. 95–118. InTech (2012). ISBN 978-953-51-0348-6
20. Kobayashi, M., Hiyama, A., Miura, T., Asakawa, C., Hirose, M., Ifukube, T.: Elderly user evaluation of mobile touchscreen interactions. In: Campos, P., Graham, N., Jorge, J., Nunes, N., Palanque, P., Winckler, M. (eds.) INTERACT 2011. LNCS, vol. 6946, pp. 83–99. Springer, Heidelberg (2011). doi:10.1007/978-3-642-23774-4_9
21. Ibharim, L.F., Borhan, N., Yatim, M.H.: A field study of understanding child's knowledge, skills and interaction towards capacitive touch technology (iPad). In: Information Technology in Asia (CITA) - 8th International Conference on IEEE (2013)
22. Lee, D.: The state of the touch-screen panel market in 2011. Inf. Disp. **3**(11) (2011)
23. ANSI/HFES 100-2007. Human Factors Engineering of Computer Workstations
24. ISO 9241-11: Ergonomics of human-system interaction – Part 11: Usability: Definitions and concepts (1998)
25. World Wide Web Consortium: Web content accessibility guidelines (WCAG) 2.0 (2008)
26. Friard, O., Gamba, M.: BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. Methods in Ecol. Evol. **7**(11), 1325–1330 (2016)
27. Fitts, P.M.: The information capacity of the human motor system in controlling the amplitude of movement. J. Exp. Psychol. **47**(6), 381–391 (1954)
28. Díaz-Bossini, J.-M., Lourdes, M.: Accessibility to mobile interfaces for older people. Procedia Comput. Sci. **27**, 57–66 (2014)

29. Kensinger, E.: Remembering emotional experiences: the contribution of valence and arousal. Rev. Neurosci. **15**(4), 241–252 (2004)
30. Bevilacqua, R., Di Rosa, M., Felici, E., Stara, V., Barbabella, F., Rossi, L.: Towards an impact assessment framework for ICT-based systems supporting older people: Making evaluation comprehensive through appropriate concepts and metrics. In: Longhi, S., Siciliano, P., Germani, M., Monteriù, A. (eds.) Ambient Assisted Living, 215–222. Springer, Cham (2014). doi:10.1007/978-3-319-01119-6_22
31. ITEA: Standards for technological literacy: content for the study of technology (Reston VA) (2007). http://www.iteaconnect.org/TAA/PDFs/xstnd.pdf. Accessed Jan 2017