Interaction techniques for older adults using touchscreen devices: a literature review

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ABSTRACT

Several studies investigated different interaction techniques and input devices for older adults using touchscreen. This literature review analyses the population involved, the kind of tasks that were executed, the apparatus, the input techniques, the provided feedback, the collected data and author's findings and their recommendations. As conclusion, this review shows that age-related changes, previous experience with technologies, characteristics of handheld devices and use situations need to be studied.

Mots Clés

Interaction techniques; touchscreen; older adults; input devices

ACM Classification Keywords

H.5.2. User interfaces: Input devices and strategies (e.g., mouse, touchscreen)

INTRODUCTION

New technologies are being developed and improved to increase access to the information and communication of everyone, including elderly and people with special needs. Consequently, new interaction techniques have been created, enlarging the possibilities for human-computer interaction through new user interfaces and input techniques.

Several studies have evaluated usability issues of classical computer input devices as mouse and keyboard for older users [36,47]. Mouse manipulation is not easy to learn because it demands high hand-eye coordination, by consequent more cognitive effort [43]. Concerning older adults, some gestures as double clicking and dragging need precise movements of the hands. The emergence of touchscreen devices can be explained by the direct contact on the display screen; there is no need for intermediary devices. This is also a good factor for handheld and mobile technologies which involves new situations of use: users can access email messages in public places, interactive maps can help localization and provide itineraries and devices are used during displacement as well as at home, installed on a desk.

Mobile devices could also be used for e-health applications, supporting older people with chronic diseases such as diabetes and providing outpatient care [25,27]. Learning how to use technologies and using them, to keep social networks for example, are a challenging mental activity. Games can be designed to stimulate memory and attentional abilities of older adults.[14]

Older users could completely benefit of touchscreen interaction advantages. They are a heterogeneous population; age-related changes in cognitive and motor skills affect each person differently. Research has been done about input techniques and interfaces in order to improve usability and accessibility for older users. The aim of this paper is to review 24 studies about touchscreen interaction of older people in order to identify current state of the art and to point out the limitations of these studies.

RELATED WORK

Literature reviews about touchscreen and older users take into account the advantages and disadvantages of this human-computer interaction (HCI) technique as well as the variability of characteristics of this population [**2**, 38], but they don't analyze the multiple parameters of the conditions of the experiments neither the different situations of use of touchscreen devices.

Some studies of older adults bring out the evolution of their technology experience and social habits [9, 46]. It has also been discussed the difficulties of representing disabilities on HCI research [33] as well as average older individual [46].

Several studies have evaluated indirect input techniques for older adults using technologies as mouse, keyboard, touch panel and wireless pen.

Mice have been evaluated using different tasks (click, double click, drag and drop, menu selection). It has been described that older adults do more sub-movements, taking longer and making more errors than younger adults to select targets [36,43]. Age-related changes in motor skills, the incidence of chronic diseases or disabling conditions due to stroke or arthritis also affects the ability to perform precise hands movements [6,27,36]. Decline in cognitive skills also affects mouse manipulation [43]. Data of mouse interaction has been collected through software applications and subjective questionnaires.

Physical standard keyboards can present good legibility and key sizes, but key labels are sometimes confusing for users who are not familiar to typewriters [6]. Force and displacement during text-entry tasks have implications on fatigue and discomfort in the forearm and in the hands [27, 30], affecting hand's function.

The usability of touch-panel has been studied and it have been recommended for older adults instead mouse for pointing tasks [23]. The performance of older adults during pointing movements with wireless pen on a digital tablet has also been evaluated [7]. Targets size and location as well as distance affect older users' performance, so the importance of reducing the difficulty of motor control during computers tasks [6,7,36].

External input devices as mice and keyboards can influence people's attitudes towards computers [40]. Touchscreen don't need intermediary devices, so there is less apprehension of use. Besides, touchscreen technologies have been continuously improved: better touch resolution, multitouch interaction, better luminance and high resolution screens, resistive and capacitive technologies that accept new interaction techniques and gestures recognition on the surface. Pen or fingers interaction, one or two hands, single and multitouch gestures have been studied to evaluate touchscreen interaction of older adults.

24 studies from different authors have been selected and analyzed. The next section describes the review's methodology. Section 3 describes the population involved, the apparatus, the tasks, the collected data, the findings and the recommendations of these studies. Section 4 presents the impact of this literature review and a discussion. Finally, conclusion is presented in section 5.

METHODOLOGY

24 studies about touchscreen interaction of older adults from different authors have been chosen. They were published between 2000 and 2013:

- 9 studies came from the field of HCI (5 CHI [1,8,11,27,44], In. Journal of HCI [12], BCS-HCI [10], INTERACT [17], GW [37]),
- 4 from accessibility (3 UAHCI [16,39,41], Univ. Access. Inf. Soc. [40]),
- 4 from handicap (MSIADU [13], ICCHP [19], 2 ACM ASSETS [21,24]),
- 4 from ergonomics (Journal of Ergonomics [1], Ergonomics[48], Human Factors [33,36]),
- 1 from usability(USAB [25]),
- 1 from computer's science (EICS [20]) and
- 1 from gerontology (The journal of applied gerontology [47]).

Older people interaction with new technologies is becoming a major topic on different fields and the subject of real research of multidisciplinary studies.

All the chosen studies analyse touchscreen interaction on flat touch sensitive display screens.

RESULTS

Population

Older adults from North America, European countries and Asia are represented. There is a big variation in the number of subjects and their ages: from 3 to 85 participants; older adults age 50 to 91 years old.

Users' skills or impairment have been identified before experiment tasks trough questionnaires or measures: vision (8 studies), hearing (3 studies), cognition (4), and hand motor function (8). Different methods were used to measure user's disabilities, as Purdue Pegboard test for manual dexterity [16,21,47], Paper Folding Test [33] Archimedes spiral drawing [24,44] or 9 holes steadiness test for tremor [21]. Pointing performances were also used to differentiate inter-groups during the experiments [12]. Cognitive skills were evaluated with computer assisted tests [39] or standardized measures [47].

Some aspects of subjects' background were taken into consideration as predictors of performance on interaction tasks and subject's attitudes towards new technologies. Subjects were interviewed about years of education, reading skills, professional activities and health conditions.

Previous experience with touchscreen devices, computer or mobile phone use was an important factor for recruiting subjects. 13 studies questioned the participants about the frequency of computer use, mobile phones or touchscreen devices. Having previous experience with computers was inclusion criteria for three studies [17,27,33] and exclusion for 2 others [20,40]. Having previous experience of touchscreen was inclusion criteria for one study [8] and exclusion for 3 others [21,44,47]. One study about digit-input recruited subjects with regular use of automated teller machines [1] and one study about smartphones recruited subjects who didn't use a mobile phone [12]. One study recruited participants with different previous experience with technologies [48]. 10 studies compared the interaction task results between younger and older participants. 5 studies made the comparison between groups with different levels of motor [12,16,44,47] or cognitive skills [39].

Apparatus

Screen sizes vary from 3.5 to 42 inches. Only one study compared interaction on different screen sizes: 9.7 and 3.5 inches [17].

During the experiments tasks of the four studies using small mobile devices users hold the device in their hands [10,11,17,24,48]. Large screens (9.7 inches or more) were fixed on a desk with an inclination angle of 30° or 35°, users were generally seated. Three studies placed large screen (15,17 and 19 inches) vertically or with 75° of inclination angle on a desk [10,16,40].

The orientation of the screens was landscape for 12 studies and smaller devices were used in portrait mode in 4 studies. Only one study with a small screen device used landscape orientation [24] and only two studies used large screen sizes (10 and 12 inches) in portrait mode [21,37].

Most of studies before 2010 used resistive touchscreens (8 of 9). Resistive touchscreens were used only for single touch tasks, with finger or pen. Studies after 2006 started using capacitive touchscreens that allow new possibilities for multi-touch interaction

Feedback
All studies provided visual feedback.

Two studies provided audio feedback (a beep sound) when the users misses the target [21] or entry a wrong number [1].

One study evaluated the effects of providing visual feedback during tactile interaction [39]. When the user touches a soft button on a small screen device, it presents a magnifying effect, a movement effect or the color changes. The combination between different effects was also evaluated.

One other study provided tactile, audio and audio-tactile feedbacks and compared the performances of older users [12].

Input techniques
Only one study compared touchscreen interaction of older users with fingers (touch) or pen (tap) [11]. Only one study compared single touch and multi-touch interaction of older adults [19].

2 studies used pen-based interaction on touchscreen [21,48]. 15 studies evaluated single touch interaction with fingers contact, in some of these studies, users were told to use the index finger of the right hand [41]. When the use of the hands was free, authors indicate that users hold the mobile with the non-dominant hand and used the index finger of the dominant hand to select the targets [24].

Only 4 studies investigate multitouch gestures interactions of older adults among the selected studies [1,8, 17, 19].

One study compares several input devices: touchscreen, mouse, touch pad and enlarged mouse [47]. Some studies made a comparison between touchscreen interaction and one other input technique: standard keyboard [33,40], small keyboard [48], numeric keypad [1], mouse [8, 33] and eye gaze input system [33].

Only one study allows multitouch collaborative interaction, with two users at the same time [1].

Tasks
All the studies allowed some practice trials, training or familiarization tasks before the experiment, especially for users who had no previous experience with touchscreens [24]. One study included a one week practice period [17] between two evaluation sessions.

For this literature review, interaction tasks have been classified into three categories:

- target selection tasks,
- text or digit input and
- gestures of interaction (single or multitouch).

Complex exercises allowed the evaluation of different kinds of interactions, such as sending an email [10,40], manipulating digital photographs [1] or managing health care support systems [27].

Target selection tasks
Target selection tasks included two different input techniques: pen was used on 2 studies [11,21] and single touch with the fingers was used on 9 studies [8,10,12,13,16,17,33,40,41].

Some experiments evaluated simple target acquisition tasks with tapping [11,12,16,33,41] and others evaluated tapping tasks among others exercises [8,10,17,21,40].

Three studies analyzed the amplitude of the interaction movement during the target selection tasks: targets were placed with 45° interval around the initial position for the tasks with a small screen (4.3') [12] and with a 17' touchscreen[33] and targets were placed on a range of 0° to 180° from the initial position on a big touch surface (42') [41]. Users should accurately tap the target with one finger.

Different input devices demand different motor and cognitive skills. One study compares four different input devices, including a resistive touchscreen, during menu selection and drag-and-drop tasks [47].

Menu selection tasks were also evaluated using graphical icons [13] or drop down textual menus [21].

Text or digit entry
Text or digit entry tasks by tapping on a soft keyboard or numeric pad were evaluated with two different input techniques: pen [48] or single touch with the fingers [1,10,17,24,39,40].

Digit entry tasks included 4 to 20 digit input [1,20,39]. One study evaluates this exercise in password mode [1]. One study evaluates swipe to select numbers on a small touch screen device [20]. Users were questioned about their preferences between different kinds of digit input: digit soft buttons (as a calculator), cursor soft buttons (plus or less, high or low) or slider [25].

Text entry with a pen-based virtual keyboard was compared to a small keyboard on a mobile device [48].

Gestures of interaction

Single touch and multitouch gestures of interaction were studied.

Single touch gestures with the finger was used to swipe or pan [20,27,44], drag or move [8,17,27] and drawing gestures patterns [27,37].

Drag-and-drop performances of older users were compared between four different input devices: mouse, enlarged mouse, touch pane and resistive touchscreen [47].

Multitouch with one or two hands was evaluated through different gestures of interaction on touchscreen as rotating, resizing, pinching and steering [1,8, 17,19,27].

Data collection

All studies collected time and error data through software, registering touch information on the touchscreen, except 2 studies [10,25] that evaluated the most familiar interfaces and interaction techniques.

Quantitative data included:

- Error rates,
- Time,
- Responses of subjective questionnaires.

Four studies used subjective questionnaires to collect information about user's preferences, fatigue, previous computer or mobile technologies experience, background and attitudes towards technologies [8,20,27,40]. Qualitative data was obtained by observation and interview [13,24].

Findings

Longer completion times were related to slower

Table 1 – examples of average times (ms) and average error rates to the acquisition of one target with tapping interaction according to the different target widths (mm), target spacing (mm), population involved and input techniques on small screens (between 3.5' and 4.3').

Ref.	Target size	Target spacing	Time	Error rate	Population	Feedback	Input	Screen size	Task
[12]	5	1, 3	40.81, 30.96	22.38, 18.68	Older users, no previous experience with smartphone	Visual	Finger	4.3'	Target selection
[39]	6	-	11.01	0.82	Older users, accurate and fast manual dexterity	Magnifying effect	Finger	3.7'	Digit input
[39]	6	-	18.80	3.57	Older users, inaccurate and slow manual dexterity	Magnifying effect	Finger	3.7'	Digit input
[12]	8	1, 3	17.54, 14.21	3.35, 1.56	Older users, no previous experience with smartphones	Visual	Finger	4.3'	Target selection
[12]	12	1, 3	12.20, 12.26	0.24, 0.39	Older users, no previous experience with smartphones	Visual	Finger	4.3'	Target selection
[11]	16	-	-	1.9	Older users, body abled	Visual	Pen	3.5'	Target sel.
[11]	16	-	-	1.1	Older users, body abled	Visual	Finger	3.5'	Target sel.

Table 2 – examples of average times (ms) and average error rates to the acquisition of one target with tapping interaction according to the different target widths (mm), target spacing (mm), population involved and input techniques on big screens (17').

Ref.	Target size	Target spacing	Time	Error rate	Population	Feedback	Input	Screen size	Task
[16]	6.35	-	3600	-	Older users, high manual dexterity	Visual	Finger	17'	Target selection
[16]	6.35	-	3200	-	Older users, low manual dexterity	Visual	Finger	17'	Target selection
[16]	16.5	3	1400	-	Older users, high manual dexterity	Visual	Finger	17'	Target selection
[16]	16.5	3	2200	-	Older users, low manual dexterity	Visual	Finger	17'	Target selection

movements but also to number of errors or number of sub movements.

Table 1 and 2 exemplifies user's performance according to the targets sizes in different experiments according to the screen size (small screens between 3.5' and 4.3', big screens are 17'). Average time and error rates are related to the task (target selection or digit input), to the population involved (according to previous evaluation of manual dexterity) and the apparatus (screen size, input technique, provided feedback).

Error rates and kinds of errors provide important information to improve interaction techniques and provide usability recommendation. One author classifies target selection most frequent errors with pen interaction into three categories [21]:

- Slipping, mostly older users,
- Drifting, all users,
- Missing just below, all users.

One study analyses stroke patterns during target acquisition tasks and two different input techniques: tap with a pen and touch with one finger on a 3.5 inches touch screen mobile device [11]. Graphical representation of interaction gestures allows the identification of different patterns of interaction, it has also been used during text-entry tasks [24] and gesture patterns drawings [37].

For text-entry tasks, soft keyboards have been compared to standard keyboards. One study shows user's preference to soft keyboard on a 15 inches touch screen because it can be adapted to the user's need (Japanese characters) [40]. During a pen-based interaction on small resistive screens (8 inches), older users committed more errors and take longer times, so they preferred small mobile keyboards [48]. Software based assistance have been showing good results increasing the performance of older adults typing on handheld devices.

Digit entry was investigated on numeric key pad and touchscreen. Older adults performed faster on touchscreen but made more errors [1].

One author classified three common kinds of errors during text entry tasks of older adults with tremor, using a small handheld device (3.7 inches) and interacting with one finger [24]: omission, substitution and insertion. A previous study with older users tapping a text with a pen on an 8 inches screen handheld device found the same kinds of errors and analyzed the causes [48]. Table 3 synthetizes these findings and summarizes some of the authors' recommendations.

Three studies evaluated the graphical interface for mobile applications destined to older users: font size, colors, icons and images of an interactive agenda [13], familiar interactions for an email system [10] and familiar interfaces for digit input [25].

Table 3 – Kinds of errors during text entry tasks, error evaluation and author's recommendations.

Type of error	Error evaluation	Authors' recommendations
Omission	Spelling	Spaces and language-based correctors and prompts
Substitution	Wrong letters, spelling	Adapting key-centroids, bigger key sizes
Insertion	Wrong pressure	Filtering, adapting inter-key threshold

Users preferred explicit interfaces, i.e. tapping into digit soft buttons (as a calculator) than using cursor soft buttons (plus or less, high or low) or sliding to select numbers [25].

Concerning the studies that compared mouse and touchscreen, when investigating drag and drop performance on a resistive touch screen, older users felt frustrated because they had a problem to sustain pressure [47]. Familiarity with the mouse resulted in higher performances for experienced computer users. In a more recent study, using capacitive technologies, touchscreen has been recommended instead mouse because it reduces performance gap between younger and older adults when using different manipulation tasks as pointing or clicking, dragging, crossing and steering [8].

Generally, authors agreed that providing some kinds of feedback is an important factor to increase older users' performance during touchscreen interaction [1,24,40].

Recommendations

Two kinds of main objectives have been identified in the reviewed studies: provide information about the psychomotor interaction of older adults in relation to the most adapted visual interface or to the most accurate gestures of interaction.

- Visual interface: 11 of them analyze visual presentation on touchscreen. 7 of them describe the results of pointing tasks (tapping) of older users in order to identify best target sizes, positions and spacing [1,4,12,16,24,39,40,41]. The others three evaluated graphical interface for their own mobile applications [10,13,25].
- Gestures of interaction: The others 13 evaluate users' performance during the execution of different gestures of interaction on touchscreen, with pen or fingers [11,21,48], single or multitouch [8,17,19], in order to provide information to improve interaction techniques for multiple tasks, including target selection [33,47], drawing gestures patterns [37] and text-input [20,44]. They also evaluate the usability

Table 4 - Visual interfaces: targets sizes recommendation for older adults for tapping with one finger and situation of the experiments.

Ref.	Targets width evalua-ted	Space between target	Am-pli-tude	Angle	Population	Screen size	Task	Feed back	Recommenda-tions
[12]	5mm, 8mm, 12mm	1 and 3 mm	-	45° between targets, (0° to 360°)	Older users without previous smartphone experience	4.3’	Target selection	Visual, audio, tactile or audio-tactile	13 mm width, 3 mm spacing and audio or audio-tactile feedback
[16]	6 mm to 26 mm	3.17 to 6.35 mm	-	-	Older users, fine manual dexterity	17’	Target selection	Visual	16.5mm width, 3.17 to 6.35 mm spacing
[16]	6 to 26 mm	6.35 to 12.7 mm	-	-	Older users, poor manual dexterity	17’	Target Selection	Visual	19.5mm width, 6.35 to 12.7 mm spacing
[39]	6 mm	-	-	-	Older, high accuracy, slow movements	3.7’	Digit input	Visual	Visual feedback: magnify, moving
[41]	23mm	-	20mm, 40mm	10° between targets, (0° to 180°)	Older and younger, right handed	42’	Target selection	Visual	20° to 40° for quick movements, 90° for accuracy

of the interfaces and applications designed for older users [1,27].

Visual interface

Older adults’ performances are affected by target sizes, spaces between targets, targets location on the screen, provided feedback and presentation aspects as font size.

Touchscreen technologies have different screen resolutions, screen sizes, weight and size of handheld devices, orientation and position that can also affect user’s performance.

Table 4 places target’s size recommendation in their corresponding situation, according to the experiments. It summarizes the different targets size that have been evaluated, the population involved, the screen size, the kind of input technique (pen or finger), the gesture of interaction and the provided feedback.

According to Jin et al. (2007), targets with 16.5 mm width and spacing between targets of 3.17 to 6.35 mm are appropriate for older users with good manual dexterity. For users with poor manual dexterity, they recommended a larger target size, 19.5 mm, with 6.35 mm to 12.7 mm spacing between targets [16].

Chung et al. (2010) created an interface for digit-input tasks on touchscreen where buttons were presented with 20 mm width and 3 mm spacing [1].

Kobayashi et al. (2011) suggested at least 8 mm size buttons for small screens but target located close to each other should be larger [17]. Calibration should reduce the gap between intended and actual touch locations, considering different situations when users rotate or tilt the device. They also find that older users prefer pinch and drag than just tap. Nischelwitzer et al. (2007) related that users preferred tap explicit buttons than using a slider or cursor buttons to select values [25].

Tsai and Lee’s experiment (2009) about visual feedback related better performances when a visual magnification effect is added to the shape of an icon after the icon is touched [39]. Two other effects could also help some groups of users: color changes and icon small displacement. Tactile feedback is inappropriate for older users according to Hwangbo et al. (2012); it can be distracting and affects a stable hand grip on handheld devices. Audio feedback provided better results as well as audio tactile feedback in terms of satisfaction and usability [12].

Recommendations for increase users' performance during text-entry tasks on soft keyboards are based on personalization [24]. Calibration systems could identify hit point location and inter-key interval. Text-entry can be afforded by word prediction, swabbing and automatic correction [24, 44].

Besides, error rates are related to the number of simultaneous options presented on the screen, especially for users with tremor, according to Mertens et al. (2010) [20]. Iglesias et al. (2009) also recommended reducing the number of interactions [13].

Gestures of interaction

Some guidelines have been provided to the development of more ergonomic interfaces and to reduce the gap between younger and older adults performance.

Findlater et al. (2013) showed that touchscreen reduces the gap between younger and older adults using a capacitive touchscreen device with a 10 inches screen size [8].

Age-related changes in accuracy are not systematic. Wood et al. (2005) study detected low performances in dragging interactions, especially on resistive touchscreens [47]. Kobayashi et al. (2011) recommended dragging and pinching instead of tapping for older users interacting with small capacitive touchscreen devices [17]. Stößel et al. (2009) results showed that older adults can produce finger gestures patterns on touchscreen, even on small devices, where more complex gesture patterns will take longer to be completed [37].

Table 5 summarizes author's recommendations about gestures of interaction of older people and describes the situation of the experiments. The analyses of this table show that gestures of interaction seem to be easier when the visual interface is correctly adapted, so authors also

Table 5 - Gestures of interaction: author's recommendations for touch screen interaction of older adults and the situation of the experiments.

Ref.	Recommended gestures	Population	Evaluated tasks	Recommendations	Target sizes	Screen size	Input technique	Feedback
[19]	Tapping with one hand	Older users without previous experience with touchscreen	Target selection	One hand interaction is faster than two hands interaction	20 mm	12.1'	One or two hands	Visual
[11]	Tapping with pen	Older users with high manual dexterity	Target selection	Using larger targets, different stroke patterns	16, 24, 32mm	3.5'	Pen	Visual
[21]	Tapping with pen	Older users with high manual dexterity	Text entry	Support for slipping, drifting and missing just below	3.3, 6.7, 13.4 mm	12'	Pen	Visual
[44]	Tapping with one finger	Older users with tremor	Target selection	Tapping big targets, < 54 mm	<54mm	10'	Finger	Visual
[44]	Swipe ("swabbing")	Older users with tremor	Target selection	Swabbing small targets, > 41 mm	>41mm	10'	Finger	Visual
[20]	Swipe ("trabing")	Older users with tremor	Digit input	Equidistant cases near the boundaries	Ten cases	10'	Finger	Visual
[37]	Repeating gestures patterns	Older users with high manual dexterity	Drawing	Avoid complex gestures patterns	-	10'	Finger	Visual
[8]	Using multi touch gestures	Older users with high manual dexterity	Dragging, pointing, steering, crossing	Dragging was the slowest on the touchscreen	9.2 to 24.5 mm	12'	Finger	Visual
[17]	Using multi touch gestures	Older users with high manual dexterity	Dragging, pointing, steering	Prefer dragging and pinching rather than taps	8 mm	3.5' and 9.7'	Finger	Visual

provide recommendations to graphical elements [9,17,38]. Wacharamanotham et al. (2011) recommended tapping for older users with tremor when targets are at least 54 mm wide and swabbing can be an alternative for targets smaller than 41 mm [44]. Concerning large touchscreen (a 42 inches was used for this experiment), Vetter et al. (2011) recommended 20° to 40° of motion angle to facilitate target selection on 20 mm interfaces and 90° was the motion angle with the lowest error rates on 40 mm interfaces [41].

IMPACT DISCUSSION

Different interaction techniques for older adults using touchscreen devices have been evaluated: pen or fingers, single touch or multitouch, provided feedback. The analyses of the gestures and interaction movements have provided information to elaborate some usability and accessibility recommendations, especially on targets size and position.

Some important aspects of human-computer interaction and the new situations of use have not been studied yet with older adults population. Touchscreen technologies are commonly used on handheld devices. Screen size and orientation affect the way users interact with touchscreens [26], it should affects older user's performance according to their special needs. Some authors don't specify or don't provide enough information about the touchscreen technology employed in their studies neither about the screen orientation [12,40]. The body position has not been studied, as how standing up or seating, resting the arms and the device on a desk, affects the way users interact [3]. Differences between passive or active tasks (reading or watching a movie versus text-entry and web research, for example) have never been studied yet [27,29]. Besides, only 4 studies analyses multitouch interaction for older adults [1,8,17,27].

Despite the different techniques, author's findings and recommendations are still valuable, but they are related to some features and specific conditions of the experiments, such as the screen size or the characteristics of the population.

Registering fine details of the interactions during the task allows more precise evaluation afterward. Gestures and body movements can be registered with video cameras [45]. Studies about touchscreen interaction of motor impaired users have detected compensatory movements of trunk and upper limbs [5,35] through the use of3d sensors, capable of registering body movements in the space. Gauge and force plates can also be used to register interaction gestures [14,28].

Some related research evaluated hand grip strength when holding large devices (PDAs). Dominant hands generally exert stronger strength during holding but no significant difference was found of the force of dominant and non-dominant hand during interaction [29]. Also, the difference between the gripping strength of both hands reduces with time spent gripping due to fatigue.

On the reviewed studies, fatigue has been notified only by subjective questionnaires. Fatigue was generally related to repetitive tasks, small targets and screen on vertical position [40, 26]. Fatigue during mouse tasks has been evaluated through muscle activities (EMG) [18, 31]. There is also some relation between fatigue and force during key tapping [15,28,30].

Older users have different characteristics due to ageing and their use of technologies. Special needs and disabilities of older people are not specific represented in these studies but authors considered the incidence of sensory impairment, motor impairment and cognitive impairment in older adults. Arthritis and overuse disorders have been mentioned but not studied [2,21,24,27,33]. It would possibly have some impact on the interaction areas of a touchscreen interface. Older users with limited hand and forearm movements would provide different interaction patterns, especially with multitouch [22]. Besides, better adapted interaction devices and interfaces are important to prevent overuse injuries and musculoskeletal disorders [32].

The employed technologies and the characteristics of the population involved are strongly related to the performances. Touchscreens display allows adaptation of visual contents according to the user's needs and it can improve older adults' performance. Authors agree that touchscreen devices and applications developed for helping older adults should use gestures of interaction that are easy to learn, to perform and to remember [27]. In summary, older adults prefer more accurate input gestures, even if it takes longer times [37,44]. Following novices older users during their first steps to the use of new technologies is a priority, as well as adapting devices and interfaces to their special needs [41].

CONCLUSION

The review of the literature shows that several parameters may be considered in the design of interaction techniques or interactive systems for elderly people:

- Age-related changes in psychomotor, cognitive and perceptual skills;
- Previous experience with technologies and internet (computer's use, mobile phones, automated teller machines, handheld touchscreen tablets);
- Variability of devices and input techniques (screen sizes and orientation, screen resolution, pen of fingers input, single or multitouch interaction techniques);
- The kinds of tasks used to interact with a system or an application (target selections, text or digit input, complex patterns of gestures);

- The different situations of use for handheld devices, public places or at home.

Even if more specific surveys need to be performed, there is sufficient evidence to state that touchscreen interaction movements can be used to provide recommendations for:

- designing and developing more ergonomic interfaces and interactive systems;
- the conception of experiments to study accessibility and usability of touchscreen devices and interaction for older people.

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