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Young vs old – landscape vs portrait: a comparative study of touch gesture performance

Linda Wulf, Markus Garschall, Michael Klein and Manfred Tscheligi

Linda Wulf is Scientist and Markus Garschall is Expert Advisor, both at Innovation Systems, AIT – Austrian Institute of Technology, Vienna, Austria.
Michael Klein is Scientist at CURE Center for Usability Research & Engineering, Vienna, Austria.
Manfred Tscheligi is Head of Business Unit at Innovation Systems, AIT – Austrian Institute of Technology, Vienna, Austria.

Abstract

Purpose – *The purpose of this paper is to gain deeper insights into performance differences of younger and older users when performing touch gestures, as well as the influence of tablet device orientation (portrait vs landscape).*

Design/methodology/approach – *The authors performed a comparative study involving 20 younger (25-45 years) and 20 older participants (65-85 years). Each participant executed six gestures with each device orientation. Age was set as a between-subject factor. The dependent variables were task completion time and error rates (missed target rate and finger lift rate). To measure various performance characteristics, the authors implemented an application for the iPad that logged completion time and error rates of the participants when performing six gestural tasks – tap, drag, pinch, pinch-pan, rotate left and rotate right – for both device orientations.*

Findings – *The results show a significant effect of age on completion time and error rates. Means reveal faster completion times and lower error rates for younger users than for older users. In addition, a significant effect of device orientation on error rates could be stated. Means show higher error rates for portrait orientation than for landscape orientation. Qualitative results reveal a clear preference for landscape orientation in both age groups and a lower acceptance of rotation gestures among older participants.*

Originality/value – *In this study the authors were able to show the importance of device orientation as an influencing factor on touch interaction performance, indicating that age is not the exclusive influencing factor.*

Keywords *Human computer interaction, Age-related differences, Device orientation, Interaction design, Touch gestures, Touch interaction*

Paper type *Research paper*

1. Introduction

Recently, touch interactions have been widely applied in public kiosk systems as well as current mobile and tablet devices. Being a direct and therefore more intuitive form of interaction compared to traditional point and click systems (Stößel and Blessing, 2010), touch interaction shows high potential for adoption by novice users in general, and specifically by older adults with little to no ICT experience (Kin *et al.*, 2009; Stößel, 2009; Czaja *et al.*, 2009). Tablet applications in particular have the potential to reach older adults and minimize the digital divide because they meet with a high degree of acceptance (Werner *et al.*, 2012).

This conclusion is supported by the growing number of senior-specific services (e.g. drug intake reminders – MyMedSchedule[1], cognitive training games – Lumosity[2], health app – WebMD[3] or memory assistance – Park ’n forget[4]) that are mainly provided on touch devices.

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However, designing touch interactions for older adults requires special attention and must take age-related changes – e.g. regarding fine motor control, finger size and joint flexibility – into account (Rogers and Fisk, 2003). Current developments bring new possibilities for advanced gestures on tablet devices into the design space such as drag, pinch and rotate. The focus in this paper is set on the basic gestures that are currently applied in consumer electronic products (e.g. smartphones, tablets) for object manipulation by using one or two fingers.

Although many studies investigate older users specifically, there is a need for more studies that compare touch interactions of older adults and younger users. Additionally, we aimed to investigate to what extent device characteristics like the device orientation has on influence on touch interaction behaviour, since there has been little prior research into this relationship.

We conducted a study that aims to aid the future design of interfaces and interactions for virtual object manipulation by comparing older and younger users' performance of six touch gestures under two devices orientations (portrait/landscape), as measured by task completion times, finger lift rates and missed target rates.

Our study is based on the work of Kobayashi *et al.* (2011). As their results indicate that a larger screen outperforms a smaller screen such as a smartphone, we focused our study on touch interactions on a tablet. We chose a 9.7-inch iPad in order to replicate the setup of Kobayashi *et al.* Furthermore, in addition to the four touch gestures of Kobayashi *et al.* (2011) (tap, drag, pinch, pinch and panning), we included two rotation gestures (left and right) as commonly found in mobile applications, such as Maps and iPhoto. By the virtue of this setup, we expected better insights about older adults performing complex touch gestures. Quantitative measurements for performance were task completion time and error rates. Data for both measurements were logged by the prototype while users executed object manipulation tasks that compared the six different basic touch gestures. Additionally, a post-interview queried user preferences for device orientation and for the gestures themselves.

Overall, our results indicate that young participants show faster completion times and lower error rates than older participants. Device orientation has no effect on completion time but shows an effect on error rates and furthermore an interaction effect of age and device orientation.

The following sections give an overview of related work, describe the study setup and prototype, illustrate results, discuss the findings and finally provide conclusions and an outlook on future work.

2. Related work

Touch gestures are a promising focus of current research and industry. Compared to indirect input paradigms such as the mouse, touch inputs are up to twice as fast to perform, easier to interact with and seen as more preferred by most users (Kin *et al.*, 2009). Moreover, touch interactions are manageable not only by young but also by older adults (Nacenta *et al.*, 2009).

The following section outlines the field of touch interaction by addressing ergonomic aspects, senior-specific studies and studies comparing young and older users.

Ergonomics and older adults

When designing touch interactions for seniors the ergonomics of the human hand and age-related limits have to be taken into account. It is a fact that in general older people have wider fingers (Rogers and Fisk, 2003). Moreover, it could be shown that in consequence of the inevitable distortion of fingers while touching, direct touch targets should have specific sizes to ensure adequate accuracy rates. Further, to limit arm fatigue, the main drawback of multi-touch interactions, gestures have to follow natural models such as rocking of fingers or varying the size of fingers' contact areas (Wang and Ren, 2009). These findings highlight that age-related changes are crucial for the design of touch interactions.

Gestures and older adults

Recent studies that have focused on older adults' use of touch gestures indicate that they show a general positive attitude towards multi-touch interactions as they rate them as less intimidating, frustrating and overwhelming than to traditional desktop systems (Czaja *et al.*, 2009; Stößel and

Blessing, 2010). Nevertheless, gestures designed for younger users might not be suitable for older ones (Stößel and Blessing, 2010). Especially for seniors the familiarity of gestures plays a crucial role since the advantages of using familiar gestures strengthen with age (Wang and Ren, 2009). Hourcade *et al.* (2010) state that specific age-related limitations, deficit of visuo-constructional abilities, visual perception and construction as well as fine motor speed and dexterity, may result in decreased accuracy rates and increased movement times. This is also affirmed by Culén and Bratteteig (2013) who state that age-related changes constitute challenges in touch and grip, but that new technologies offer new possibilities to facilitate touch interaction and to offer a more comprehensive design for elderly people.

Since these studies indicate senior-specific results the importance of a stronger focus on studies that compare touch interactions of older adults and younger users arises.

Comparing young and old

So far, relatively few studies have directly addressed comparisons between younger and older adults with a special focus on touch gestures.

Findlater *et al.* (2013) state that touch interaction can decrease older adults' performance time and the error rates of younger and older users when compared with desktop and mouse interactions. Results from Stößel and Blessing (2010) indicate no significant loss in accuracy but differences in the way older adults perform gestures. Older users are slower, are more likely to use symbolic gestures (e.g. alphanumeric) than gestures for direct manipulation (e.g. simple tap) and are less likely to work with multiple fingers (Stößel, 2009). A similar result from Siek *et al.* (2005) indicates that older and younger participants can physically interact at the same competence level when using personal digital assistant applications. However, as reported by Stößel (2009), older persons are less ready to perform multi-finger gestures but are more tolerant when it comes to gestures that are slightly more complex (Siek *et al.*, 2005). More precisely, older adults experience gestures covering a small area and performed by only one finger or hand as most comfortable (Rogers and Fisk, 2003). Overall, current studies indicate no accuracy differences between younger and older adults but slower task completion times for seniors. In contrast, findings from preferences for different gesture types and the number of used fingers showed different results for young and old users. This is supported by findings from Kobayashi *et al.* (2011) that show that senior participants preferred more advanced drag and pinch gestures over classic tapping interactions for direct object manipulation tasks. Kobayashi *et al.* (2011) evaluated four basic touch gestures (tap, drag, pinch with and without panning) on a large screen (iPad) and small screen device (iPod touch). Results indicate that older users performed most gestures reasonably well, except for tapping on small targets. Further, the larger screen outperformed the smaller screen for all gestures. The limit of this study is that it lacks in comparison with younger users. Kobayashi *et al.* (2011) state that further studies should focus on the comparison of younger and older users in terms of addressing performance measures, interaction behaviours and preferences for different gestures.

Our study intends to pick up where the work of Kobayashi *et al.* (2011) and others left off by comparing detailed performance measures from younger and older adults when carrying out six different gestures under two device orientations. Additionally, our inclusion of rotation and pinch-panning gestures, device orientation variations, and detailed error analysis differentiates our work from that of Findlater *et al.* (2013).

Since the previously mentioned results indicate that the larger screen outperformed the smaller screen for all gestures, we focused our study only on touch interactions on a tablet.

3. Experimental design

For the comparative evaluation a 6×2×2 design was chosen. Each participant executed six gestures with each device orientation (within-subject factors). Age was set as a between-subject factor. The dependent variables are task performance time, missed target rate and finger lift rate. A "missed target" refers to any detection of fingers outside of the target image object. A "finger lift" refers to any time a user lifted one or both fingers after having started a gesture but before completing the task. For instance, if a user needed three separate rotation gestures in order to fully complete a rotation task, the number of finger lifts would be counted as 2.

3.1 Participants

In total 40 participants were invited and divided into two age groups: older and younger participants. In total 20 younger (ten female, ten male) between 25 and 45 years old (mn = 33.9; SD = 6.18) and 20 (11 female, nine male) older adults between 65 and 85 years old (mn = 71.85; SD = 5.13) participated in the study. We deliberately omitted participants between 46 and 64 years in order to enhance differentiation of age-related effects. All participants were right-handed and had no self-reported restrictions of hands or fingers. In the younger user group half of the participants had previous experience with touch devices, while in the older user group 12 participants had no experience and eight some experience.

3.2 Apparatus and setup

A native iPad application, created using Xcode and taking advantage of the iOS 5 SDK's pre-defined gesture recognizers, was developed for the purpose of the comparative evaluation. The app was run on a 9.7-inch first-generation iPad, with a resolution of 1,024×768 pixels at a density of 132 pixels per inch.

Six gestural tasks were implemented – tap, drag, pinch, pinch with panning, rotate left and rotate right (see Figure 1, device in portrait mode).

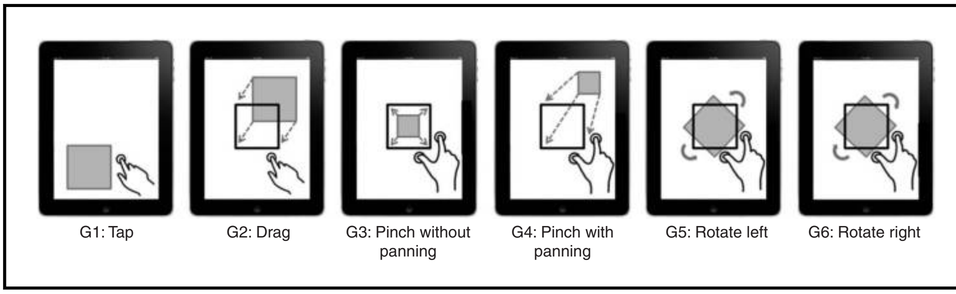
The tasks were based on those used by Kobayashi *et al.* (2011), with the addition of the rotation gestures. Two additional gestures (rotate left, rotate right) were added since these gestures require a more complex performance. The following paragraph provides a short description of the six different gestures in focus:

A tap involves quickly placing a finger on a target and then removing it. A drag involves placing a finger on a target, moving it to a new position and then releasing it.

A pinch involves placing two fingers within a target's boundaries and increasing or decreasing the space between the fingers in order to resize the target. Pinch with panning is similar to a pinch, except that parallel movement of both fingers can additionally be used to move an object. Rotate left involves placing two fingers within a target's boundaries and turning the two fingers in a counterclockwise direction, as one would turn a dial; rotate right functions similarly but with a clockwise turn.

For all gesture types other than rotation, images were positioned pseudo-randomly (to ensure even distribution) in one of 16 screen areas. Image size was 70×70 px (134.7 mm) for the tap gesture, 200×200 px (384.8 mm) for the drag gesture, 200×200px for both rotate gestures, and a pseudo-randomly chosen size of either 120 px (230.9 mm), 180 px (346.3 mm), 240 px (461.7 mm), 300 px (577.1 mm) or 360 px (692.6 mm) for both pinch gestures. All tasks other than tap involved manipulating a square photo by performing gestures within

Figure 1 Basic gestures for object manipulations



the photo’s boundaries, in order to bring its edges within a 20-pixel-thick, 200×200 square border in the centre of the screen: i.e., the task was completed when the edges of the image fit into the space between two squares, one of size 190×190 and one of size 210×210 (see Plate 1).

Task repetitions used varying images, image sizes, positions and rotations; all variations were randomized in a balanced fashion. For the tap, drag and pinch-pan gestures the initial image position was one of 16 possibilities as defined by a grid of centre-points evenly distributed across the screen. For pinch and pinch-pan gestures the initial image size was one of five sizes (120 px, 180 px, 240 px, 300 px or 360 px on a side). For the rotation gestures the initial image rotations were randomized to be one of five angles (30, 60, 90, 120 or 150 degrees for rotate left, −30, −60, −90, −120 or −150 degrees for rotate right).

The app allowed specifications of which gestures had to be performed, the number of repetitions, as well as whether to use portrait or landscape orientation. After initially specifying the orientation, the rotation remained “locked” for the duration of all repetitions. Only the specified gesture was recognized by the app for the duration of all repetitions: e.g., if the pinch-pan gesture was specified and the participant attempted to perform a rotate gesture, the image would not rotate in response.

Tasks could be performed in training mode, in which no logging was performed, or in timed trial mode, in which data such as initial image position/size/rotation, task completion time, number of finger lifts and number of missed targets was logged.

All error types were automatically logged from our prototype. The expected error types that may occur during the evaluation study were defined as following:

- target miss: finger tap outside the target; and
- finger lift: lifting the finger from the tablet during the execution of a specific gesture.

All error types were automatically logged from our prototype. Errors were measured per task, e.g. if a person at least made one error per task it was counted as error.

Plate 1 Screenshot of actual app (pinch with panning gesture, portrait orientation)

3.3 Hypotheses

In order to investigate the extent to which device orientation and age influence the performance of touch gestures the following hypotheses were formulated:

H1. Younger and older users differ from each other in their task completion times, missed target rates and finger lift rates under both device orientations.

H2. Device orientation has no influence on completion times, missed target rates or finger lift rates for younger or older users.

To compare performance differences of the one-handed single – and multi-touch gestures for the manipulation of objects, the study was divided into four steps:

1. Introduction: All participants were instructed for the following training and evaluation phase. Users were asked to hold the tablet PC in a manner that it was comfortable for them to hold it but not placing it flatly on the table. Thus, single-hand touch gesture performance was guaranteed. This instruction was chosen to create a near-realistic situation for the performance of the gestures in mobile situations.
2. Training phase: within the training phase each single gesture for the manipulation of objects was explained to the participants and demonstrated by the study supervisor. This was followed by five training tasks for each gesture. During the training phase participants had the chance to get used to the gestures without having the pressure of being timed (without logging).
3. Evaluation phase: for the evaluation study participants were asked to perform 16 timed tasks for each of the 6 gestures (with logging). Participants were instructed to perform the gestures as fast as possible. All gestures and the device orientation (portrait/landscape) were presented in random order.
4. Post evaluation: in a final step participants were asked to provide feedback on usability and user experience for each single gesture. Qualitative user feedback was collected on positive and negative aspects of each single gesture.

4. Results

4.1 Qualitative results

Results of the qualitative user feedback about positive and negative aspects of touch gesture performance reveal on the one hand general issues in touch interaction performance and on the other hand issues that are related specifically to certain gestures. Especially for elderly users, big fingers and on average longer fingernails represent a common obstacle in performing gestures that require more accuracy such as pinch with panning or the rotation of targets. Moreover older participants complained about the lack of accuracy due to less agility in their wrist. Additionally they tend to exert more pressure on the touch-screen when the first attempt to manipulate the target failed. As a consequence some elderly participants mentioned that the exhaustion experienced when performing a gesture was particularly high in the two rotation conditions. Furthermore, some elderly participants stated that due to bigger fingers it was hard to place their fingers precisely onto the targets' rim in order to minimise it. Mostly they put their fingers outside the target rim and tried to reduce the target size by "compressing" it.

Another issue is that the rotation gestures seemed to be less accepted by older participants than the other gestures. They claimed this gesture to be "unpractical", "useless" and "inefficient", whereas the tap and drag gesture were perceived to be "very easy", "practicable" and "fast to perform". Pinch with panning was indicated to be "fun" and that they can exercise some dexterity. Preferences between left or right rotation were not evident. Overall elderly participants seemed to be quite open and positive towards touch gestures. They appreciated the novelty of device control offered. In particular, the fact that some of the gestures required more fine motor skills and a certain learning process was perceived as pleasantly challenging.

Regarding the device itself, some older participants mentioned that holding it for a while just in one hand, as was required by the study instructions, would become quite heavy to carry.

Furthermore a clear preference of landscape format could be found for both age groups ($landscape_{old} = 62.5$ per cent, $portrait_{old} = 11.1$ per cent; $landscape_{young} = 40$ per cent, $portrait_{young} = 25$ per cent).

4.2 Quantitative results

In the following section the results of the quantitative measurements (task completion time, orientation, and error rate) are reported.

To test our hypotheses three mixed ANOVA were conducted with age as between-subjects factor, device orientation as within-subjects factor and task completion time, missed target rates and finger lift rates as dependent variables. Considering our hypotheses, this test has the highest statistical power. Table I provides an overview about main effects of age on performance measure.

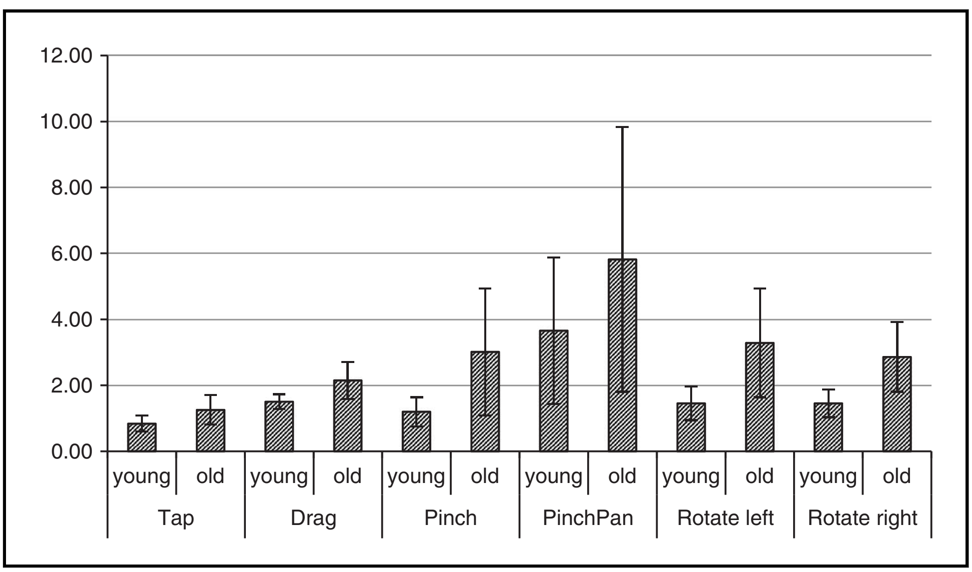
For the first hypothesis (influence of age on the performance of touch gestures), the results showed a main effect of age on completion time, $F(1, 38) = 21.977$, $p < .05$, $\eta^2 = 0.366$; on rates of missed target, $F(1, 37) = 25.708$, $p < 0.05$, $\eta^2 = 0.41$; and on rates of finger lifts, $F(1, 36) = 29.149$, $p < 0.05$, $\eta^2 = 0.447$. Means reveal faster completion times for younger participants (mn = 1.684, SD = 0.208) than for older participants (mn = 3.063, SD = 0.208). For rates of missed targets, the means show lower rates for young participants (mn = 3.506, SE = 1.842) than for older participants (mn = 16.887, SE = 1.89). For finger lift, means of younger users (mn = 27.951, SE = 1.894) are lower than for older users (mn = 42.048, SE = 1.797). Means reveal faster completion times and lower error rates of both types for younger users than for older users. Figure 2 shows the completion time of the different gestures by age groups.

Table I Results of the ANOVA - main effect of age on completion time and error rates

Performance measures	*Age (reported in means (SD))* *Young*	*Old*	*Sig.*
Completion time	1.684 (0.2089)	3.063 (0.208)	$p \leqslant 0.5^*$
Missed target	3.506 (1.842)	16.887 (1.89)	$p \leqslant 0.5^*$
Finger lift	27.951 (1.894)	42.048 (1.797)	$p \leqslant 0.5^*$

Note: $^*p = 0.00$

Figure 2 Completion time of gestures by age groups



For the second hypothesis (influence of device orientation on the performance of touch gestures), the results showed that the effect of device orientation on completion time is not significant ($p = 0.61$). For rates of missed targets (see Plate 1), the effect of device orientation is significant, $F(1.37) = 12.123$, $p < 0.05$, $\eta^2 = 0.247$. Means show higher values for portrait orientation (mn = 11.521, SE = 1.52) than for landscape orientation (mn = 8.872, SE = 1.208).

Further calculations showed a significant interaction between device orientation and age, $F(1.37) = 16.444$, $p < 0.05$, $\eta^2 = 0.308$. Means reveal higher values for older participants for both device orientations ($mn_{portrait} = 19.754$, $mn_{landscape} = 14.021$) than for younger participants ($mn_{portrait} = 3.288$, $mn_{landscape} = 3.724$).

For the finger lift condition (see Figure 3), the results alsoshowed a significant effect of device orientation, $F(1, 36) = 351.163$, $p < .05$, $\eta^2 = 0.907$, but with higher mean values for landscape orientation (mn = 48.994, SE = 1.849) than for portrait orientation (mn = 21.005, SE = 1.052). The interaction between device orientation and age is also significant, $F(1, 36) = 18{,}718$, $p < 0.05$, $\eta^2 = 0{,}342$. Means reveal higher finger lift rates for landscape orientation than for portrait orientation for both age groups.

Figure 3 shows the rates of missed targets and finger lifts showed that younger participants' finger lift rate was five times higher than the missed target rate when using portrait orientation, while finger lift rate was ten times higher than missed target rate when using landscape orientation. Older participants exhibited a similar number of missed targets and finger lifts under portrait orientation, while under landscape orientation the finger lift rate was four times higher than the missed target rate.

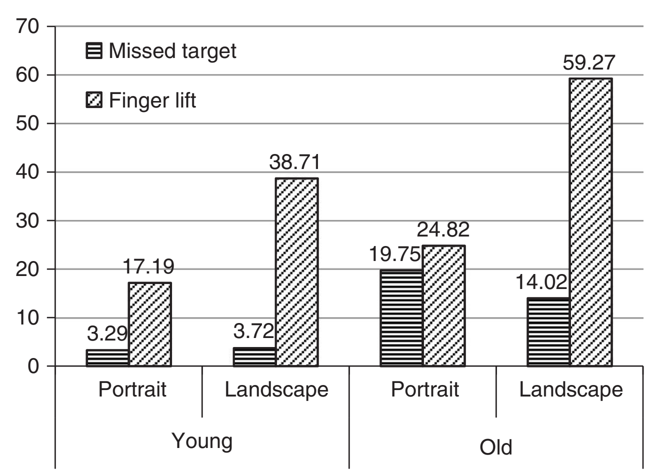
A further analysis showed that on average (including both error types) most errors were made performing the pinch gesture (40 per cent), followed by the rotate left gesture (39 per cent) and the rotate right gesture (31 per cent). The lowest error rates were made in the tap (3 per cent) and drag gestures (4 per cent).

Results from the qualitative analysis partly align with the quantitative results. In particular, a clear preference for landscape format in both age groups could be asserted and the feedback about the easiness to perform certain gestures (e.g. tap vs rotation gestures) is also reflected in the quantitative results (Figure 2).

5. Discussion

The first research question, whether older participants differ from younger participants in completing touch gestures under both device orientations can be affirmed partially. Age seems to

Figure 3 Rates of missed targets and finger lifts



have a crucial influence on the completion time in order to perform touch gestures, but gestures themselves evoke different completion times as well (Figure 2). Some gestures (such as pinch with panning,) require a more complex performance sequence, which is reflected in longer completion times, especially for older users. This leads to the assumption that gestures, particularly for older users, should require only a low degree of complexity. Tapping, for example shows the fastest completion times (Figure 2), assuming that it is a very easy to perform touch gesture. However, Kobayashi *et al.* (2011) postulate that elderly users tend to prefer dragging and pinching operations over tapping. Based on this, they consider tapping to be quite difficult to perform due to small target sizes and generally bigger fingers of elderly people (Kobayashi *et al.*, 2011). Nevertheless, the results of our study indicate that tapping is easy to perform, because of the low completion times and error rates. These findings are in contrast to the results of Kobayashi *et al.* (2011). The disparity probably results from the influencing effect of other confounding variables, in this case presumably the target size. Kobayashi *et al.* (2011) used target sizes of 30 (57.7 mm), 50 (96.2 mm) or 70 (134.7 mm) pixels for the tapping condition. In contrast we used targets that had the size of 70 (134.7 mm) pixels for tapping gestures. Therefore it was easier for the older participants to meet the target, even if they had bigger fingertips.

This leads to the assumption that in this condition age is not the significant influencing factor on touch gesture performance and error rates but rather target size. In other words, target size has an influence on the relationship between age and task performance due to age-related issues, such as bigger fingers. As a consequence changes in error rates could be attributed to changes in target size. Regarding the pinch condition of our study, high error rates (40 per cent) resulted from this touch gesture. The target size in this condition was at least 120 and at most 360 pixel. Therefore big enough ($>$ 8 mm) according to guidelines for touch applications (see Kobayashi *et al.*, 2011) so that target size did not affect performance in the pinch condition. A better clarification of this finding might come through the assumption of Kobayashi *et al.* (2011) that bigger fingers lead to a gap between intended and actual touch location. This would explain why older participants tried to "compress" the target because they were not aware of being out of the target with their fingers and thus making more errors (see Figure 3). Another explanation for this effect would be that for resizing the pinch gesture is not perceived as appropriate metaphor by elderly users.

To overcome this issue Kobayashi *et al.* (2011) suggest, that touch-screen applications designed for elderly users should provide at least targets 8 mm or larger in size, because elderly users tend to make errors when tapping a small target, such as a 30-pixel button. Moreover they suppose that applications do not need to avoid using drag and pinch operations, but should provide instructions and clear visual cues that show which gesture invokes which function (Kobayashi *et al.*, 2011). Another interesting approach to explain longer completion times for elderly users comes from the psychological research area (Salthouse, 1985; Sülzenbrück *et al.*, 2010). It has been suggested that elderly people in general would prefer accuracy over speed and maybe therefore focus more on precise finger work. Hence, this conclusion would predict lower error rates for elderly people while completion time is high. But nevertheless this conclusion is not coherent with our results.

Furthermore, this study showed that device orientation is an important influencing factor on touch gesture performance. It can be concluded that chronological age is not an exclusive influencing factor on performance on touch devices. We found that the rates of missed targets and finger lifts are influenced by device orientation as well as by the interaction of the factor age and the factor device orientation.

Our most significant finding regarding device orientation was that landscape orientation resulted in more than twice the number of finger lifts than portrait orientation, across both age groups. Thus, portrait orientation seems to be the better approach for discrete touch gesture performance. The cause of this effect is unclear. One possibility is that it is easier to stabilize the iPad in a second hand in portrait orientation; this points to possibilities for future studies. Despite these performance results, the mentioned preferences in both age groups clearly tended towards landscape orientation. Further research is needed to discover the reasons for this discrepancy.

Younger participants clearly have an advantage regarding hitting the targets on the screen. Our results showed almost five times higher missed target rates for older compared to younger users. This stands in contrast to the findings of Stößel *et al.* (2010). This difference potentially stems from the different task assignments that the participants from both studies were confronted with, e.g. the lack of multi-touch gestures that points to the need for more research regarding the influence of different device or task characteristics on touch gesture performance.

In order to focus our study on a limited set of research questions, it was necessary to limit it in a number of ways. We focused only on iPad usage; it remains to be seen whether similar results would apply to other devices and form factors. The requirement for participants to hold the tablet in one hand and perform gestures with the other helped ensure the comparability of our results, but at the cost of excluding some modes of real-world tablet usage. Our exclusion of participants between the ages of 46 and 64, while allowing us to draw starker contrasts, prevents us from drawing conclusions about gradual age-related changes.

Future work should further investigate the influence of personal factors such as habits and physiological constraints, as well as device characteristics such as weight and screen size on touch gesture performance.

Notes

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About the authors

Linda Wulf received a Diploma Degree in Psychology from the University of Vienna. In her thesis she investigated in a training study the effect of robot-child-interaction on executive brain function like planning, inhibition and cognitive flexibility. Currently she focuses as postgraduate researcher on psychological aspects in the human-computer interaction.

Markus Garschall has many years of experience researching the relationship between humans and technology. He is involved in several national and European research projects related to the topic of active and healthy ageing. In his research he focuses on the design and evaluation of multi-modal user interfaces and collaborative aspects of technology. Markus Garschall is the corresponding author and can be contacted at: markus.garschall@ait.ac.at

Michael Klein studied Media Informatics at the Vienna University of Technology. At CURE he was responsible for the design and development of functional graphical user interface prototypes. His activities centred around research topics include multi-modal interaction, ubiquitous and trustworthy computing.

Manfred Tscheligi has been working in the area of Interactive Systems, Human-Computer Interaction, Usability Engineering, User Interface Design and User Experience Research for more than 20 years. He is pioneer in establishing this field in Austria, author of several publications and distinguished speaker at conferences. He successfully managed numerous research and industrial projects and was responsible in establishing national and international initiatives. Since August 2013 Manfred Tscheligi is Head of the Business Unit Technology Experience at AIT. He is also founder of the research organization CURE and Full Professor for Human-Computer Interaction & Usability at the University of Salzburg (Center for Advanced Studies and Research in Information and Communication Technologies & Society). Further, he is leading the Christian Doppler Laboratory for Contextual Interfaces at the University of Salzburg.