Gestural Interfaces for Elderly Users: Help or Hindrance?

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Abstract. In this paper we investigate whether finger gesture input is a suitable input method, especially for older users (60+) with respect to age-related changes in sensory, cognitive and motor abilities. We present a study in which we compare a group of older users to a younger user group on a set of 42 different finger gestures on measures of speed and accuracy. The size and the complexity of the gestures varied systematically in order to find out how these factors interact with age on gesture performance. The results showed that older users are a little slower, but not necessarily less accurate than younger users, even on smaller screen sizes, and across different levels of gesture complexity. This indicates that gesture-based interaction could be a suitable input method for older adults. At least not a hindrance - maybe even a help.

Keywords: Gestural interfaces, aging psychology, human factors.

1 Introduction

Recent years have seen the dissemination of gestural interface technology in mass consumer products, pioneered most notably by products such as the Apple iPhone, or the Nintendo Wii video game console. Since then, manufactures of consumer electronics have included gesture control elements in a whole range of mobile electronic devices, such as laptops, cell phones, PDAs or digital cameras. While these interfaces are generally considered to provide a very direct, natural and intuitive way of interacting with a device, it remains unclear whether they also meet the needs and match the capabilities of a user group that is growing more and more important: the elderly. Demographic, structural and societal changes in most industrialized countries are leading to a dramatic increase of the percentage of elderly among the population. Even though there is not a unitary concept of *the elderly*, we refer to older adults in the following as individuals aged 60 years and above. The interaction with technology often confronts elderly people with particular problems, because devices are not designed to accommodate their special needs.

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1.1 Problems of an Aging User Related to Technology

The normal aging process is typically accompanied by sensory, perceptual and cognitive changes (see e.g. [1], for a detailed review), as well as a decline in motor skills [2]. These changes take place not only at high ages, but rather gradually across the whole life span [3], and they affect how elderly perceive and interact with the world, including technology.

All too often, unfortunately, elderly users are facing serious problems when trying to use technical devices. For instance, older users report problems related to displays that are too small and difficult to see, buttons and characters that are too small or crammed too closely together, oversupply of functions, non-intuitive menu arrangements or unclear instructions how to find certain functions and services [4]. Thus, while technology in principle could help to compensate parts of their changing physical, social and cognitive resources and enhance their quality of life, the elderly in many cases get frustrated by and disinterested in too complicated technology.

1.2 Can Gesture Technology Facilitate Technology Use?

What can be done to improve this situation and grant the older adults a better access to technology? In our view, there are different strategies that complement each other to accomplish this goal, e.g. *motivation* of the older users to bridge their initial disinclination towards technology, *training* older users with specific adaptive training concepts, or *build devices* tailored to the older user's abilities. While the best results in alleviating the use of technology for elderly users are surely achieved by a combination of these strategies, our research is centered on the problem of interface design for the older user. Finding solutions to this problem is a tightrope walk between two pitfalls: On one hand, if technology is designed only with respect to the older users' deficiencies, it runs the risk of stigmatizing them and thus being hardly accepted by the older users. On the other hand, following strictly a philosophy of "Universal Design", "Design-for-All" or "Inclusive Design" might not properly address the *specific* problems of the elderly, or lead to design compromises which are neither favored by the elderly nor by younger generations. Solutions to this predicament could emanate from new technologies, which, on one side, are sufficiently simple and intuitive to be used by the elderly, and on the other side sufficiently efficient and aesthetically pleasing to be used by a broader user community. Gesture based interaction, in our view, might be such a candidate. It remains unclear, however, how these technologies fit the needs and abilities of the elderly, and under which circumstances older adults might be able to effectively use them. Key questions that have to be addressed in this respect are:

1. **What are the requirements of gesture technologies regarding motor control and manual dexterity?** Do they match the sensory and motor control abilities of the older users? Under which boundary conditions could a match be achieved?

2. **To what extent, or under which circumstances, is gesture technology intuitive for the older user?** Is there a set of gestures which are self-descriptive, easy to understand, easy to learn and easy to remember for the older users?
3. **Does gesture technology provide a benefit for the older users?** Does it compare to (or even out-perform) traditional input methods with respect to usability metrics, like efficiency, effectiveness and satisfaction?
4. **Is this technology accepted by older users?**

1.3 The Pros and Cons of Gesture Technology

Gestures, in everyday human to human interaction, are a natural and powerful tool of nonverbal communication and engulf everything from speech accompanying gesticulations to highly structured sign languages. In the context of human-technology interaction, we define a gesture as *"a coordinated and intended movement of body parts to achieve communication. The information which it contains is specified by the configuration of body parts, the speed and direction of the movement and must be interpretable by its receiver"*. By this definition, we separate gesture input from simple key presses or mouse clicks where the button press itself carries no information. Gestural interfaces are implemented on a huge range of technical systems and classified roughly into *2D gestures*, operating through finger or hand movements on touchscreens or interactive surfaces, and *3D gestures*, operating through free-form movements in space [5]. We focus our research on mobile devices, as there exist already many devices on the market that make use of 2D finger gesture input, and present the most accessibly gesture technology for elderly at the moment.

Studies comparing direct input devices (without translation or gain, e.g. touchscreen) with indirect input devices (e.g. mouse or trackball), with respect to older users have shown a general benefit of direct input devices over indirect ones (e.g.[6,7]). The direct nature of gesture input thus might facilitate interaction for older users. However, the literature on motor control of the aging adult has documented a couple of observations which might put the suitability of finger gesture input for elderly into question: Chaparro et al. [8] found that in comparison to younger subjects (25-35), older adults (60-69) have a reduced wrist flexion and extension by 12% and 14%, respectively. As gesture input demands even more wrist flexibility than mouse input or simple button presses, these results might become important when deciding whether and how gestural technology can be a suitable input mechanism for the elderly. Other studies report that older adults have less efficient perceptual feedback systems and lack the force to produce very rapid movements [9], they make more submovements than younger ones [10], and have difficulties with continuous movements or the coordination of movements [2]. As gesture input usually demands relative precise execution of a continuous movement pattern, these findings are important when designing gesture interfaces for older users: they must be tolerant against imprecise execution of gestures, they have to provide some obvious and immediate feedback and avoid relying on fast and jerky movements.

1.4 Aim of the Study

The aim of this study is to provide a user-centered approach towards gesture technology, and targets especially the older users' abilities. This study focuses particularly on how older users meet the motor demands of finger gesture input. In order to establish boundary conditions under which this technology works for elderly, we devised an experiment to investigate how the available screen space as well as the complexity of the gesture pattern influences performance on a stationary touchscreen device. A younger and an older user group were compared with respect to velocity and accuracy measures in an imitation task of previously presented gesture patterns.

2 Methods

2.1 The Gesture Set

For the first experiment, we devised a set of 42 simple one-finger gestures. The gesture set was developed along the following goals: Overall simplicity of the gesture shapes, coverage of simple symbolic and geometric patterns which are already in use in finger gesture applications, and systematization regarding the complexity of the shape. The gesture set was inspired (among others) by Microsoft Application Gestures [11] and Apple's Trackpad Gestures [12]. The complexity of the gestures varies systematically according to the number of line segments it contains: single-line, double-line or multi-line gestures (Figure 1).

2.2 Participants and Apparatus

In total 38 participants volunteered in this experiment. The younger participants (9m, 9f), were 21-33 years old (mean 26 years; SD: 3.4 years), while the older ones (9m, 9f) were aged between 60-71 years (mean 63 years; SD: 3.2 years). All participants were right-handed, had normal or corrected-to-normal vision and no pathological condition that diminished arm, hand or finger movements on self-report. The participants were seated in front of a 15" touch screen (Eizo

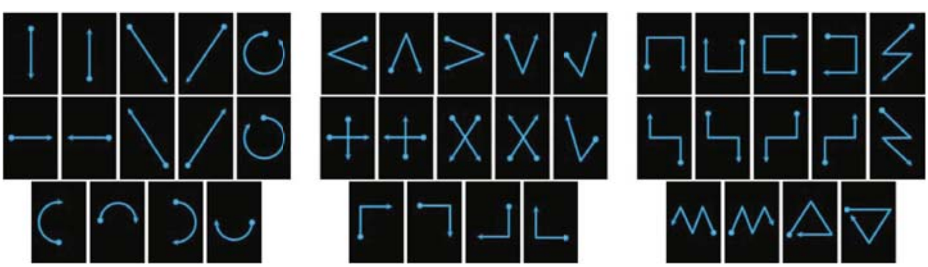

Fig. 1. Set of finger gestures used in the experiment: single-line gestures (left), double-lines gestures (middle) and multi-line gestures (right)

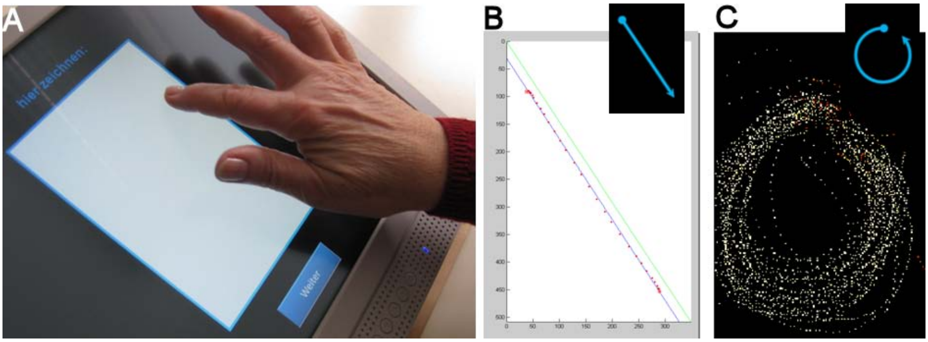

Fig. 2. A) Experimental Setup. B) Example single line gesture path, with original data (red dots), linear fit (dark blue line), and reference line (light green line). C) Example circular gesture patterns: all older users collapsed.

L353T-C) which was mounted on a supporting rack at an oblique angle (30°) and placed on a desk. (Figure 2A). The finger movements on the screen were sampled with a frequency of 50 Hz.

2.3 Procedure and Design

The task was to retrace visually presented gestures on the touch surface. The gestures were depicted as arrows (cf. Figure 1) and presented centrally on the screen at different sizes. Each gesture instruction was displayed for 1.5 seconds, and afterwards an equally sized rectangular white square appeared on the screen on which the gesture had to be retraced. The participants received no visual feedback of their drawn trajectory in order to measure original patterns without corrective movements. They were instructed to copy the presented gesture within the boundaries of the drawing area as fast and accurate as possible. The task was structured into nine blocks of 42 gestures with short breaks in between. The experiment was conducted as a 2 (AGE) x 3 (SIZE) x 3 (COMPLEXITY) factorial design. AGE varied as a between-subjects variable (younger vs. older), while SIZE (small, medium, large) and COMPLEXITY (single line, double line, multiple line) varied as within-subject variables. The three different sizes were chosen so that the medium size equals the display size of an Apple iPhone, the small size corresponded to 1/4 of this size, and the large one to four times that size. That way, the smallest size was conceived as a lower bound for possible gesture input, the medium size as a reference size for gesture input on modern mobile devices, and the largest size as an example of stationary touch screen applications. The number of lines making up the gesture was chosen as a simple means to differentiate gesture complexity. Each of the 42 different gestures was repeated 3 times per size, resulting in a total of 378 trials, organized in 9 blocks. Within each block the size was held constant while the sequence of gestures was randomized. The sequence of blocks was permuted across participants.

2.4 Analysis

The performance of gesture execution was measured through a couple of different parameters: *Errors* (when the gesture was not retraced correctly) and *boundary violations* (when the finger surpassed the designated drawing space) provided measures of task fulfillment. The *average velocity* of gesture execution was calculated between the first touch down and the last touch up event. Measures of gesture accuracy can be divided in parameters of *form stability* (e.g. how accurate was the form of the gesture preserved), and *directional stability.* These were measured differentially for linear and circular gestures. For linear gestures, the measure of *form stability* was *angular deviation* from one or more reference angles. For circular gestures, form stability was measured through the *eccentricity* value of the best ellipse fit to the data (a value of 0 denotes a perfect circle, and increasing values denote increasing asymmetry of the ellipse). *Directional stability* was measured as the average deviation from the best fitted reference line. This was an orthogonal least squares linear fit (for each line segment) for all non-circular gestures, and a geometrically fitted ellipse otherwise. The derived measures were *linear deviation* and *ellipse deviation.* All measures of velocity, form- and directional stability were analyzed only on non-erroneous gestures. For each dependent variable, a separate repeated measures analysis of variance (ANOVA) was calculated, with the between-subjects factor AGE, and the within-subjects factors SIZE and COMPLEXITY. For some analyses, the assumption of sphericity was not met, and the degrees of freedom were adjusted using the Greenhouse-Geisser estimate of sphericity.

3 Results

A summary of descriptive results can be found in tables 1 and 2. The separate parameters will be discussed more closely in the following.

Errors and Boundary Violations. For both parameters, there were no significant effects for age or complexity. The elderly performed 1.9 % more errors than the younger group, but due to huge individual differences within each group, no group effects could be observed. There was, however, a stable influence of size (=the available space to draw the gesture) on the amount of errors $[F(1.4, 48.5) = 12.94, p < .01]$ and boundary violations $[F(1.26, 43.05) = 12.96, p < .01]$: the larger the available space, the less frequent were errors observed, and, naturally, the less frequent the boundaries of the gesture space were crossed with the finger.

Average Velocity. The velocity of gesture execution was clearly influenced by age: across all complexity levels and gesture sizes, the elderly performed consistently slower than the younger users $[F(1, 34) = 6.670, p = .014]$. In addition, there was a significant effect of size on gesture execution speed: the larger the

Table 1. Comparison of the dependent variables according to *AGE*. Asterisks mark significant main effects (** $p < .01$, * $p < .05$).

parameter		younger users		older users		
		M	SD	M	SD	
errors	(%)	2,65	3,08	4,54	5,87	
boundary violations	(%)	4,50	6,00	5,00	5,79	
average velocity	(cm/s)	1,39	0,44	1,07	0,37	*
angular deviation	(deg)	5,39	0,66	5,46	1,21	
eccentricity		0,60	0,04	0,62	0,07	
line deviation	(mm)	0,69	0,15	0,68	0,14	
ellipse deviation	(mm)	0,50	0,14	0,53	0,23	

Table 2. Comparison of the dependent variables according to different levels of *SIZE* and *COMPLEXITY*. Asterisks mark significant main effects (** $p < .01$, * $p < .05$).

size:		small		medium		large		
		M	SD	M	SD	M	SD	
errors	(%)	6,09	7,19	3,30	5,18	1,39	2,77	**
boundary violations	(%)	9,14	12,48	3,62	5,59	1,48	2,07	**
average velocity	(cm/s)	0,64	0,26	1,14	0,38	1,90	0,60	**
angular deviation	(deg)	6,53	1,09	5,02	1,03	3,93	0,85	**
eccentricity		0,65	0,06	0,61	0,06	0,57	0,07	**
line deviation	(mm)	0,46	0,10	0,65	0,15	0,94	0,22	**
ellipse deviation	(mm)	0,30	0,10	0,49	0,23	0,76	0,23	**

complexity:		single		double		multi		
		M	SD	M	SD	M	SD	
errors	(%)	3,27	4,82	3,72	4,76	3,79	4,48	
boundary violations	(%)	4,60	5,83	4,65	6,36	4,99	6,17	
average velocity	(cm/s)	1,29	0,46	1,30	0,43	1,09	0,34	**
angular deviation	(deg)	3,42	0,66	6,43	1,25	5,62	1,60	**
eccentricity		0,61	0,06					
line deviation	(mm)	0,67	0,14	0,70	0,17	0,68	0,16	
ellipse deviation	(mm)	0,52	0,18					

gesture that should be retraced, the faster it was performed [$F(1.1, 37.9) = 340.3, p < .01$]. Apart from the predicted slowing effect for age, we could observe an interesting interaction of the factors size and age [$F(1.1, 37.9) = 12.139, p < .01$]: even though younger and older users both increased their drawing speed with larger sizes, the younger users could take more advantage of the largest size.

Form Stability Measures. The form stability of gesture execution as measured by angular deviation was influenced by the size [$F(2, 68) = 232.5, p < .01$] and complexity [$F(1.64, 56.58) = 83.6, p < .01$] of the gesture, but no significant differences due to age could be observed. Across all participants, the angular deviation decreased with increasing gesture space, resulting in a more accurate reproduction of the gesture pattern. The same observation could be made for circular gestures: The larger the drawing space, the smaller the eccentricity of the best ellipse fit to the gesture, resulting in a closer approximation of a perfect circle [$F(2, 68) = 60.55, p < .01$]. For both form stability measures, contrast analysis revealed a highly significant linear trend for the factor size [$F_{angle}(1, 34) = 454.27, p < .01; F_{ecc}(1, 34) = 121.67, p < .01$], and pairwise comparisons (using Bonferroni correction) between the *small*, *medium* and *large* gesture spaces showed that performance means differed significantly across all comparisons. Comparing the angular deviation between the *single*, *double* and *multi-line* gestures revealed that all three different complexity levels differed significantly from one another, with the highest deviation values encountered at double-line gestures. Taken together, these results indicate that the form stability of gestures was not influenced by age, but it was clearly facilitated with larger screen sizes. How the complexity might have interacted with form stability is discussed below.

Direction Stability Measures. For both circular and linear gestures, we found a main effect of gesture size: with increasing gesture space, there were significantly larger deviations from the best linear fit [$F(1.4, 46.4) = 232.7, p < .01$] or ellipse fit [$F(2, 68) = 155.54, p < .01$] respectively. A polynomial contrast revealed clear linear trends [$F_{ellipse}(1, 34) = 324.80, p < .01; F_{line}(1, 34) = 281.27, p < .01$] and pairwise comparisons (Bonferroni corrected) showed that all three size levels differed significantly from one another. The larger the gesture movement itself, the larger was also the movement jitter. No main effect of complexity could be found. Importantly, there was again no main effect of age, meaning that across all gestures and sizes, older and younger users did not differ in directional stability. Most interestingly, the measure of linear deviation revealed an age x size interaction effect [$F(1.4, 46.4) = 5.535, p = .015$], with significant differences between small and medium ($p = .04$) as well as small and large ($p = .01$) gesture space conditions. While in the smallest gesture space the younger users were more accurate, in the medium sized space both groups are roughly equal, and in the largest gesture space the older users are more accurate than the younger users. A significant three-way interaction between *age*, *complexity* and *size* on this measure [$F(4, 136) = 5.479, p = .001$] further differentiates the previous interaction. Contrast and pairwise comparisons analyses showed that the accuracy advantage on small screen sizes for younger users was independent of gesture complexity, but with bigger screen sizes, also the influence of complexity became stronger. It can be seen that the accuracy advantage at the largest screen size for the older users is modulated by complexity, such that the more complex the gesture gets, the bigger the direction stability difference between older and younger users.

4 Discussion

4.1 How Do Gesture Space and Gesture Complexity Influence Performance?

Across all participants of the study, it could be observed that the available space given to retrace a gesture influenced strongly the way the gesture was performed with respect to errors and boundary violations (cf. Table 2). The effects on errors and boundary violations should not raise too much concern, because first, the smallest screen size in this experiment was deliberately chosen to provide a lower bound estimate, and second, the observed overshooting of the gesture frame is most likely an artifact of our setup and cannot be generalized to physically bounded screens.

The variation of gesture space had also an effect on the average velocity with which the retracing was performed: The participants were about double as fast for the medium sized gestures, and triple as fast for the large gestures as compared to the smallest size. Thus, execution speed correlates highly with the spatial extend of the gesture. From a psychological point of view this outcome is in line with kinematic laws that describe basic principles of human motor pattern generation. It reflects a principle referred to as *"Gesetz der konstanten Figurzeit"* (Derwort, 1938, cited from [13]), which postulates that the time needed to trace identical figures of different size is constant.

With regard to accuracy, we observe that the measures of form stability and directional stability have been affected differentially by gesture size: with increasing drawing space, the form stability increased, while directional stability decreased. This seems surprising at a first glance, but can be explained in the light of a speed-accuracy tradeoff: If the user, during gesture execution, detects a deviation from the optimal path and readjusts the motor pattern, overshoots and further readjustments are more likely at higher velocities and result in a decreased directional stability. On the contrary, form stability is preserved better with larger gestures. In the case of angular deviation, this becomes obvious from the fact that the same small displacement of the finger can result in large angular deviations if the reference gestures itself is small, but results in smaller angular deviations if the reference gesture is comparably large.

The manipulation of gesture complexity as a variation of the number of lines did not result in a systematic effect across our measurements. A decrease in average velocity with increasing number of line segments is explained well by the fact that users have to decelerate and accelerate again at each turning point of the pattern. More interesting is the effect of gesture complexity on angular deviation: the highest angular deviation was found for double-line gestures, followed by multi-line gestures and single-line gestures. This pattern could be explained by the geometric properties of the gestures that make up the groups: the double-line gesture group consisted of many gestures which included an acute angle (see Figure 1, the multi-line group included more rectangular gestures, while the reference angles in the single-line group were only 90° or 45°. It seems that especially right-angled patterns can be replicated more accurate than patterns that include more arbitrary acute angles. Finally, the reason why we did not find a systematic effect of gesture complexity might be due to the fact that the initial division of single-line, double-line and multi-line gestures did not reflect the actual difficulty of the gesture. It can be easily conceived that a circular gesture poses a much higher demand on motor control than a single horizontal line, even though these appeared in the same category. Our classification was a simple one-dimensional classification approach, but the qualitative data we obtained hints at a multi-dimensional account, including for example also curvature, symmetry, direction, or familiarity of the gesture.

4.2 How Does Age Influence Gesture Performance?

The central question of this research, however, was whether there are any age-related differences in gesture execution performance. Of particular interest was whether and how age interacts with the screen size and gesture complexity variations. The results showed an influence of age on the execution speed, but not on the accuracy of gesture performance. Bearing in mind the limitations of our user and gesture samples, this suggests that elderly users have no more problems than younger users in performing accurate gesture input, even on small screen devices. In our gesture retracing task we found a slowing factor of 1.3, which is at the lower end of reported efficiency drops in studies concerned with age effects on input device performance. These studies quantify performance decline by factors ranging from 1.3 to 3 over a range of input devices, including mouse, trackball, trackpoint and touchpad [10,14,15].

In the present study, age differences were smallest (0.15 cm/s) for the smallest screen size, and largest (0.58 cm/s) for the largest screen size. It thus seems to be the case that the speed advantage found for younger users is mainly generated by their increased velocity in the largest screen size. It is known from aging psychology research that older adults prefer accuracy over speed (Salthouse, 1985, in [16]). Sülzenbrück et al. note that older people even favor accuracy if they are instructed to perform as quickly as possible, which results in higher accuracy at the cost of slowing for all tasks that exhibit a speed-accuracy tradeoff [16]. In fact, this might be the reasons why there are no obvious drawbacks in gesture accuracy for older adults in the present study.

Interestingly, in their comparison of age-related slowing effects across different motor tasks, Sülzenbrück et al. found task contingent slowing effects, and even a performance advantage of elderly users for the line-tracing task, which resembles our gesture retracing task most closely [16]. The authors explain this observation with its close relation to handwriting, in which, as has been shown previously, older adults are stronger trained with. While their highly controlled line tracing task was still of quite a different nature and this might account for the divergent findings, their results are encouraging in two ways: First, if a large sample of older adults (N=180) can outperform a younger group on a lane-tracing task which is highly similar to performing an accurate gesture pattern on the touch screen surface, then gestures as input paradigm might indeed be suitable for elderly adults. Second, considering the fact that elderly have usually a high proficiency with handwriting, they might benefit from gesture patterns that are borrowed from or similar to patterns used in cursive writing.

5 Summary and Outlook

We presented a study which was designed to provide first insights of how effectively and efficiently elderly users can produce finger gestures pattern on a touchscreen. Of particular interest were the questions whether small screens impede their interaction, and whether performance among the elderly drops as the gesture patterns become more complex. Our results show no systematic influence of age on gesture accuracy. Furthermore, no consistent interaction of complexity or size with age could be observed. This means that even on small screens (e.g. the size of current mobile phones and smart phones), older users do not fall behind younger ones in terms of accuracy. In fact, the tendency of older users to prefer accuracy over speed might prevent them from performing a gesture too fast and negligent as was observed sometimes among younger users. These results support previous findings that direct interaction, and in particular touch screen interaction is beneficial to elderly users (e.g.[17]). However, we extend existing literature by showing that not only a single touch, but also more complex gestural patterns could be handled effectively by older users. With regard to suitable gesture patterns for elderly, gestures similar to the ones we tested should be feasibly for older adults. In addition, effects like the familiarity with handwriting, or a general bias for right angles, along with curvature, direction and symmetry effects, might influence gesture performance and should be accounted for when designing simple 2D gesture commands for older users. We further observed that older users are slower than younger users in performing finger gesture input patterns. However, the slowing factor is still comparably small with regard to other input technology comparisons, and, as accuracy is not affected, this should not impede actual device usage.

The present results were obtained on a stationary touchscreen and are not automatically generalizable to a handheld device. Therefore, a second experiment is currently being conducted to investigate to which extend these results can be replicated on a mobile device (iPod Touch), and extending this research by investigating also multi-finger gestures and the effects of device posture.

Taken together, we present a user-centered approach to gesture technology, asking not only what is feasible from a technical point of view, but also how gesture technology should be designed to suit the needs and abilities of the user, and in particular the older user. There are still many important questions to be answered, including the semiotics of gestures and the acceptance of this technology among elderly. However, by pursuing this line of research we hope to contribute to the development of technology which is better suited to the older users' abilities, empowering them to actually make use of it and help them to ease their daily routine.

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