An Evaluation of Finger-Gesture Interaction on Mobile Devices for Elderly Users

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Abstract

Recent years have seen the dissemination of gesture-based interaction elements to an increasing number of mass consumer products, most notably finger-gesture interaction on small touchscreen devices. In the present study we investigate whether this new way of interacting with technical devices could be a means of facilitating human technology interaction, particularly for older users. This user group is known to frequently face problems when trying to use technical devices, many of them being associated with interfaces which are not tailored to their needs and abilities. In order to find out whether finger-gesture interaction could be a suitable input method also for senior-friendly devices, we compared a group of older and younger users on a set of thirty single-finger gestures on a mobile device regarding speed and accuracy measurements. Furthermore, we investigated the effect of different device postures. Results show that older users take more time to perform the gestures, but are in general as accurate as the younger ones. The single-handed operation mode proved to be the most difficult, irrespective of age group.

Introduction

"Tap is the new click – we've entered a new era of interaction design…", is claimed boldly by Dan Saffer in his recent book "Designing Gestural Interfaces" (Saffer, 2008, p. 3). He points to the fact that in recent years a new way of interacting with technical systems – by means of interactive gestures – is being implemented on a steadily growing number of devices. Whether these new possibilities really will affect the way we interact with technology so drastically is yet to be seen. However, there is no denying the fact that since the advent of pioneering devices such as the Apple iPhone or the Nintendo Wii, it is today already well established to interact with a mobile device by moving the fingers over the display (or trackpad) in certain patterns, or by shaking and turning a device to trigger a particular function. Even though there is no exact definition of what counts as gesture-based interaction, and the boundaries to physical manipulation are fluent, we can categorize it roughly into 2-dimensional gestures – usually carried out through finger movements on a touchscreen – and 3-dimensional gestures – usually carried out through hand movements with a device or in front of a camera (Saffer, 2008). Gesture-based interaction engulfs all technical devices which can be operated (even if only partly) by means of interactive gestures. As a gesture, in the context of HCI, we understand 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."*

In our research we focus primarily on finger-gesture input, as this technology is already well established on a huge variety of electronic devices, ranging from mobile phones, PDAs, MP3-Players, digital cameras and navigation systems to laptop and desktop computers. Today, many touchscreen devices can recognize movement patterns of one, or sometimes also several fingers, which are then interpreted by the devices and used to trigger functions. For example, by moving two fingers in opposite directions, the user can enlarge pictures or screen sections on the Apple iPhone. While manufacturers don't hesitate to advertise such systems as being highly intuitive to use, the scientific basis for such claims is still lacking. In particular, this prospect of a potentially easier interaction with electronic devices is interesting for those users, who often struggle to use existing devices: the elderly.

Older users

The importance of designing new technology also with respect to older users becomes undoubtedly clear if one brings to mind the demographic changes which are taking place in most industrialized countries: for example in Germany, the percentage of over 65-years old citizens will rise to over 1/3 of the total population within the next 30 years (Statistisches Bundesamt, 2006). The problems which older users of technical systems are facing nowadays are manifold, and can in parts be attributed to the changing physical, cognitive and social resources that accompany the normal aging process (Fisk, Rogers, Charness, Czaja, & Sharit, 2004). 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, nonintuitive menu arrangements or unclear instructions how to find certain functions and services (Kurniawan, 2008). A couple of studies comparing input devices for older adults have already shown that direct, touchscreen input is generally advantageous for older users (e.g. Murata & Iwase, 2005). However, most of the studies concerned with senior-friendly input devices focus on efficiency rather than effectiveness of input, and tracing meaningful gesture patterns brings about still different requirements than just tapping a button on the screen. The literature on motor control documents a general decline of motor skills with age (Vercruyssen, 1997), and also specific observations like a reduced wrist flexibility (Chaparro et al., 2000) which put the suitability of gesture-based interaction for older users into question.

Aim of the study

In order to establish a holistic evaluation of the suitability of gestural input for elderly users, we investigate the syntax, semantics and pragmatics of gesture-based interaction. Before we ask which gestures *should* older users use, and which systems *will* they use, we have to answer the question which gestures *can* they use. In other words, it is of equal importance to determine the *understanding* of gesture-based interaction, its *usefulness* and *acceptance* among older users, as it is of value to establish the boundary conditions of gesture complexity and use contexts that satisfy their *motor constraints*. For the latter purpose we tested a group of older and younger users on a set of thirty single-finger gestures on a mobile device (iPod Touch) with respect to speed and accuracy measurements. The aim of the study was to investigate whether any age-related differences in gesture input performance can be observed, whether is it possible to differentiate between more and less suited gestures, and how stable these observations are across different device postures. This last point is of interest as younger users might have totally different usage patterns (e.g. a comparably high proficiency in using the thumb to single-handedly operate a mobile device) than older people do. A previous experiment we conducted using a similar set of gestures on a stationary touchscreen showed that elderly users were generally slower in performing the gestures. However, there was no significant loss in accuracy (Stößel, Wandke, & Blessing, 2009).

Method

We tested gesture performance within a group of 20 younger (aged 20-32, mean 26, 10m/10f) and 19 older (aged 60-79, mean 67, 9m/10f) users. Participants were asked to perform finger-gestures on the touchscreen of a mobile device (iPod Touch) as fast and accurately as possible. All participants were right-handed, had normal or corrected-to-normal vision and no pathological condition to impede hand or finger movement. In each trial, a random gesture was displayed in form of an arrow for 1.5 seconds (figure 1). Subsequently, participants had to retrace it on the screen without visual feedback. Every gesture was repeated three times in each of the three posture conditions: the device was either placed stable on the table and operated with the right hand, or it was held in the left hand while being operated by the right hand, or held in the right hand and operated by the thumb of the right hand (figure 2). Furthermore, the gestures differed in their complexity, but this aspect will not be elaborated on within the scope of this article. The gesture set had been 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 movement trajectory was sampled at 50Hz. Analysis was conducted with repeated measures ANOVAs, with AGE (younger users, older users) as between-subjects factor, and POSTURE of the device (table, hand, thumb) as within-subjects factor.

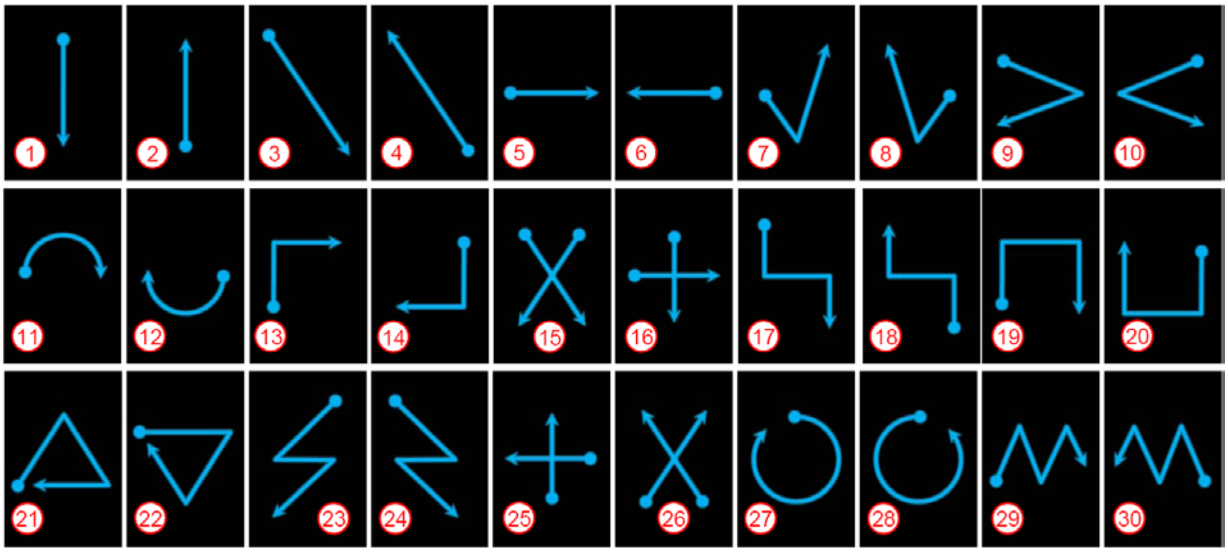


Fig. 1: Gesture set consisting of thirty different single-finger gestures

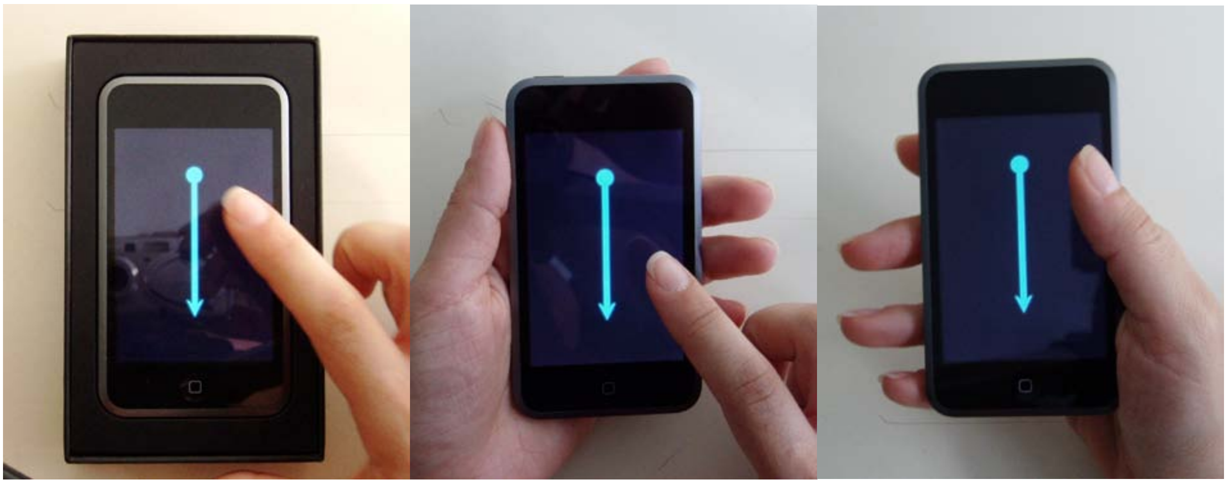
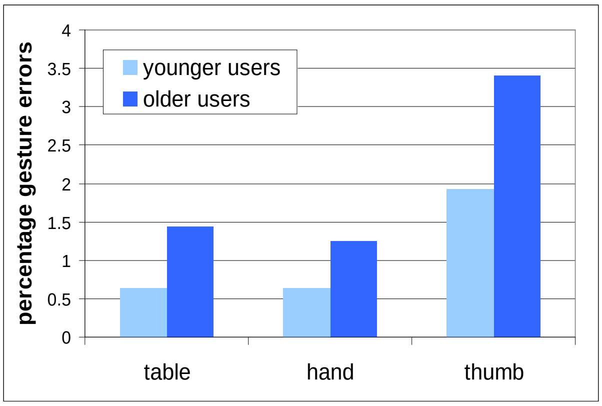


Fig. 2: Three different posture conditions: Device fixed on table, operated by right hand finger (left), device held in left hand and operated by right hand finger (middle), and device held in right hand and operated by right hand thumb (right)

The gesture performance is characterized by a couple of parameters which were computed from the logfiles: the *total drawing time*, the average drawing *velocity*, and the accuracy parameters of *form and line stability*, which were established differentially for linear and circular gestures. As indicators for the accuracy of gesture form served the angular deviation of geometrically fitted lines from reference lines or angles for the linear gestures, and the eccentricity of a geometrically fitted ellipse for the circular gestures (the smaller the eccentricity value, the closer the shape resembles an ideal circle). As indicators for the line stability (or uniformity and straightness of the trajectory) we used the average distance to the best fitted line or ellipse, respectively. All accuracy parameters were size- and position invariant. Three subjects had to be excluded from further analysis due to data logging irregularities (1) and problems related to too long fingernails, resulting in artefacts in the movement data (2). The remaining participants performed all less than 5% erroneous gestures, with an average of 1.5% errors.

Results: Performance data

The gesture execution was counted as erroneous if one or several of the following criteria held true: a) the gesture was not recorded at all or consisted of less than 10 samples (subjects pressed "proceed" without performing the gesture), b) the wrong gesture pattern was performed, c) the gesture pattern was performed incompletely, d) more than one finger trace was recorded simultaneously, e) the trajectory was discontinued, f) more than one gesture pattern was drawn before "proceed" was pressed, g) the ellipse fitting algorithm did not converge within the given computational settings. These incorrectly performed gestures were found significantly more often [F(1,34)=4,362, p=0.044] among the older users (2,03%) than among younger users (1,07%), and also significantly more often in the thumb operation mode than in the two other conditions. (Figure 3a).



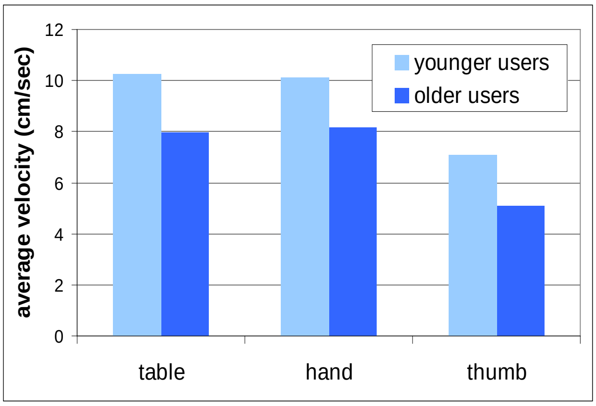


Fig. 3: a) Percentage of errors in gesture performance; b) Average velocity (cm/sec)

The speed of gesture execution was found to be significantly slower [F(1,34)=7.686, p<.01] for older participants (7.1 cm/s) compared to younger participants (9.2 cm/s). This observation is reflected also in the total drawing time (from the first touch-down to the last touch-up of the finger), which increased from an average of 1.03 seconds for the younger group to 1.44 seconds for the older group [F(1,34)=9.205, p<.01]. Furthermore, a main effect of device posture could be observed [F(1.37,46.44)=126.64, p<.01], where contrast analysis proved that gestures were performed significantly slower when they had to be drawn with the thumb compared to the other posture conditions.

The measures of *form stability* did not show any influence of age on the accuracy of the gesture performance. Neither for the angular deviation, nor for the eccentricity parameter could a main effect of age or interaction of age with device posture be substantiated. For both parameters it could be shown that the thumb conditions was more difficult than the other two conditions, resulting in significantly greater angular deviations [$F_{table-thumb}(1,34)=111.93$, $p<0.01$, $F_{hand-thumb}(1,34)=103.6$, $p<0.01$], and more egg-shaped circles (larger eccentricity) [$F_{table-thumb}(1,34)=10.31$, $p<0.01$, $F_{hand-thumb}(1,34)=5.32$, $p=0.027$]. The measures of *direction stability* showed similar results. Also here we found main effects of device posture [$F_{line}(1.29,43.71)=331.32$, $p<.01$, $F_{circle}(2,68)=21.91$, $p<.01$] which in both cases can be attributed to the greater deviations in the thumb conditions. No age effects were found for the linear gestures, while a slightly more shaky trajectory could be observed for older users with regard to the circular gestures [F(1,34)=4.439, p=0.043]. Interestingly, these results suggest that while there were no differences between age groups concerning the "overall roundness" of circular gestures, the older users achieved this result probably by employing more corrective movements, while the younger users drew a smoother line. No interactions for device posture with age could be observed for the *direction stability* parameters.

Results: Preferred posture

After the drawing task, participants were asked to indicate their preferred posture of the device (figure 4). The thumb operation mode was preferred least of all by older as well as younger users. While the younger users preferred to hold the device in their left hand rather than have it fixed on the table [$\chi^2(2) = 12.4$, p=.002], the elderly users were indifferent in this respect [$\chi^2(2) = 5.38$, p=.076].

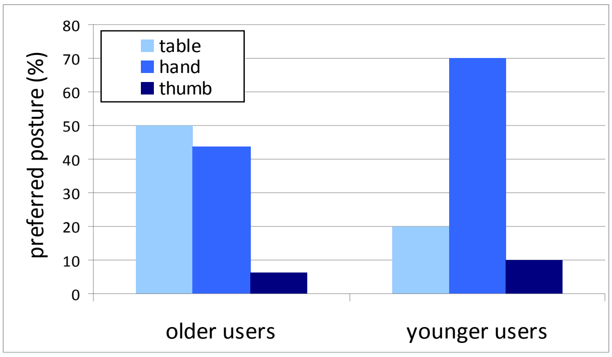


Fig. 4: Device posture preference by age group

Discussion

The present experiment was conducted in order to shed some light into the performance of finger gesture execution of younger and older users on a mobile device. Generalized over all tested gestures, we found that older users perform the gestures slower, and therefore take more time to complete them. We also found that gestures were drawn incorrectly significantly more often by older users than by younger users. However, if a gesture was drawn in principal correctly, no general disadvantage in accuracy could be observed for older compared to younger users. Only for circular gestures it seemed to be the case that younger users could draw the line a little more smoothly, but both user groups achieved similar results in the overall goodness of the circular pattern. Bearing in mind our limited gesture set and the rather small sample size, this pattern of results suggests that the elderly users *can* – if just a little slower – perform single-finger input gestures as accurately as younger users; they are not even worse when the device has to be operated single-handedly. It thus does not seem to be a problem of motor control that would fully account for the significantly increased number of incorrectly performed gestures. Some of the errors that occurred can be attributed to imprecise gesture execution such as when there are jumps in the trajectory, or when an attempted circular motion resulted in an angled pattern. Others, like a rather common proceed-button press without having drawn the gesture, or the (less frequent) drawing of multiple gestures on top of each other, hint at an inadequate mental model of the experimental task. Even though all participants received a training covering 10 gestures of varying complexity, older participants seemed to have been puzzled more by the lack of feedback on whether their movement was already registered and they could proceed to the next gesture. We conclude that even though a particular gesture *pattern* can be adequately reproduced by older users, and might even be familiar for them and intuitive to use in a given context, the basic *mode* of gesture input needs to be thoroughly explained and trained with older users to avoid confusion. We deliberately abstained from visual feedback in this experimental setup in order to measure the original movement trajectory without many explicit corrective movements. Providing any kind of feedback (visual, auditory, or even haptic) will surely help to decrease the frequency of erroneous gesture input, especially among older users for whom the absence of feedback seems to have been the larger problem.

The comparison of different device postures yielded a clear result: the single-handed operation condition proved to be the most difficult, as observed through increased incorrect gesture input, lower execution speed, and less accurate gesture execution. As we did not find any interaction effects between age group and device posture, this effect seems to hold generally for younger and older users. Thus our hypothesis that younger users would outperform older users in the thumb condition was not supported. Taking into account the low preference rating for older and younger users alike for the single-hand operation mode, it was probably experienced as being difficult irrespective of age. A gesture-level analysis seems promising to reveal which gestures suffer particularly from one–handed operation and which gestures could be operated by the thumb without major drawbacks. It has already been shown that for example the NW ↔ SE movement direction is especially difficult for right handed users (Karlson, Bederson, & Contreras-Vidal, 2006), but so far the research has concentrated largely on taps and text entry and could be enriched with gesture input data. When designing future mobile devices that rely on finger gestures as input modality, is has already become clear that care has to be taken whether the employed gestures can only be handled bimanually, or whether they support also the wish of the majority of users (Karlson et al., 2006) to be handled also only with one hand.

Worth mentioning at the end is also that older users showed no difference in execution speed or accuracy between the table and hand condition. The table condition, where the device was kept immobile in a shell had been conceived as a baseline condition, to see whether the fact that the device had to be held in one hand while being manipulated by the other hand had any effect on gesture performance. Even though the table and hand conditions were roughly equally preferred by the older users, it made no difference in terms of gesture performance, and thus they can use devices with similar gestures as effectively holding them in their hand as when they seek support (e.g. a table) for stabilization.

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