Task Dependent Analysis of Handheld Positions on Touchscreen Devices

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Abstract: Due to technical progress, the use of touchscreens has become more essential. This may have far-reaching consequences as recent studies have shown that visual information close to the hands is perceived in a different way as information farther away from the hands. (for reviews see (Abrams, Weidler, & Suh, 2015; Bloesch, Davoli, & Abrams, 2013; Goodhew, Edwards, Ferber, & Pratt, 2015; Tseng, Bridgeman, & Juan, 2012)). The aim of the present research was to gain a basic understanding of how people interact with handheld devices and how this interaction changes depending on task context. Therefore, five different hand positions were evaluated with regard to three different tasks: typing short text, typing long text and reading. To gain a large sample size, the study was administered via an online questionnaire. Results show that there are significant differences in handheld positions with regard to different tasks and in dependence on interacting with a smartphone or a tablet-pc.

Keywords: Human-computer interaction, hand positions, ergonomic design

1. Introduction

Due to technical progress, the use of touchscreen devices has become more essential during the last decades. The number of private households in Germany that own a mobile phone has increased from 30% in 2000 to 90% in 2012 (Federal Statistical Office of Germany, 2013). Considering the global market, more than half of the world's population has accessed mobile internet via smartphone or tablet in 2015. In 2014, the number of mobile internet usage has been greater than the use of the internet by desktop PC for the first time (statista, 2016). In summary, the statistics show that the interaction with mobile technologies is becoming more ubiquitous.
The design of human-computer interaction with regard to ergonomics raises a great need for research. Thereby, this process may be iteratively, starting with the prototypical development and implementation of ergonomic design concepts, the empirical evaluation involving potential users and the integration of the evaluated results into new technologies. In this context, the focus of many studies is the evaluation of different input devices. As the diversity of mobile devices is constantly growing, interacting with input devices through direct hand input is on the rinse. This may have far-reaching consequences as recent studies have shown that visual information close to the hands is perceived in a different way as information farther away from the hands. (for reviews see (Abrams et al., 2015; Bloesch et al., 2013; Goodhew et al., 2015; Tseng et al., 2012)). Therefore, it is of particular use to evaluate how people interact with mobile devices.

Touchscreen devices can be operated either vertically or horizontally, with one or both thumbs, or one or more fingers of the same or the other hand. Thereby, it is essential to differentiate between tablets and smartphones since they differ with regard to size, weight and shape and so different requirements are laid down on the design of user interfaces (Odell & Chandrasekaran, 2012). Research conducted so far investigated approaches of finger placement and hand grasp during touchscreen interaction. With regard to the interaction with tablets Oulasvirta et al. (2013) recommended a symmetric bimanual grip while holding a tablet in landscape orientation as being most appropriate for ergonomic text input. Odell and Chandrasekaran (2012) examined this position in order to measure the thumb reachable areas for two different grips and for different anthropometrical measures. What those researchers found was that the reachable distance of the thumb on the tablet is larger in the side grip than in the corner grip and therefore it can be inferred that the grip of the hands on the sides should be preferred to the position of the hands at the corners. With regard to smartphone interaction Wobbrock, Myers, and Aung (2008) studied in total eight different postures, four different two-handed postures and four different one-handed postures. They found that the posture of the hand has a significant effect on users' touch performance and that interaction with the device should not only take place by fingers on the front of the device but also back-of-device performance should be investigated as a feasible means for interaction which enables a richer set of finger and thumb interactions. This idea was studied by Le, Mayer, Wolf, and Henze (2016). Specifically, those researchers analyzed how users naturally position their hands for three different tasks aiming to develop ergonomic back-of-device interaction techniques. The studied tasks were derived from Böhmer, Hecht, Schöning, Krüger, and Bauer (2011) and involved writing a text message, reading a text and watching a video. Thereby, the writing and the reading tasks were conducted in the portrait mode of the device, while the task of watching a video was conducted in the landscape mode. The sample consisted of ten right-handed subjects. Over all tasks, it was found that the right hand touched the phone the most. Furthermore, a higher number of different hand positions were found for the landscape mode in comparison to the portrait mode which let the researchers conclude that people might be less used to the landscape mode.

While previous work provides some approaches of hand positions analyses, none of them takes a large group of users, a thorough differentiation of hand positions and an a comparison between smartphone and tablet into account. Therefore, the study presented in this paper provides an analysis of handholding positions while interacting with smartphones and tablet-pcs and differentiates between three different tasks. To gain a large sample size the study was administered via an online questionnaire. The obtained data enable UI designers to evaluate their designs with regard to physical user implications in order to gain a comfortable and intuitive interaction in handheld computing.

2. Method

2.1 Procedure

The questionnaire started with a short introduction of the study and questions with regard to demographical data. After that subjects were ask to specify how they would position their hands by choosing between five different positions:

1) Holding the device vertically and interacting with the thumb of the same hand.
2) Holding the device vertically with one hand and interacting with a finger of the other hand.
3) Holding the device vertically with both hands and interacting with both hands.
4) Holding the device horizontally and interacting with both thumbs.
5) Holding the device horizontally with one hand and interacting with a finger of the other hand.

The tasks that were studied were inspired by those used by Böhmer et al. (2011) and Le et al. (2016), although not fully identical. The tasks were: typing short text, typing long text and reading.

2.2 Participants

In total 289 subjects took part in the online study. The participants' age ranged from 20 to 65 years, with a mean age of M = 46.22 years (SD = 10.29). The age structure was not equally distributed, but showed a peak at the middle ages (figure 1). As people usually tend to use their dominant hand when operating their phone (Arif, 2012), all our subjects were right handed to avoid that influence.

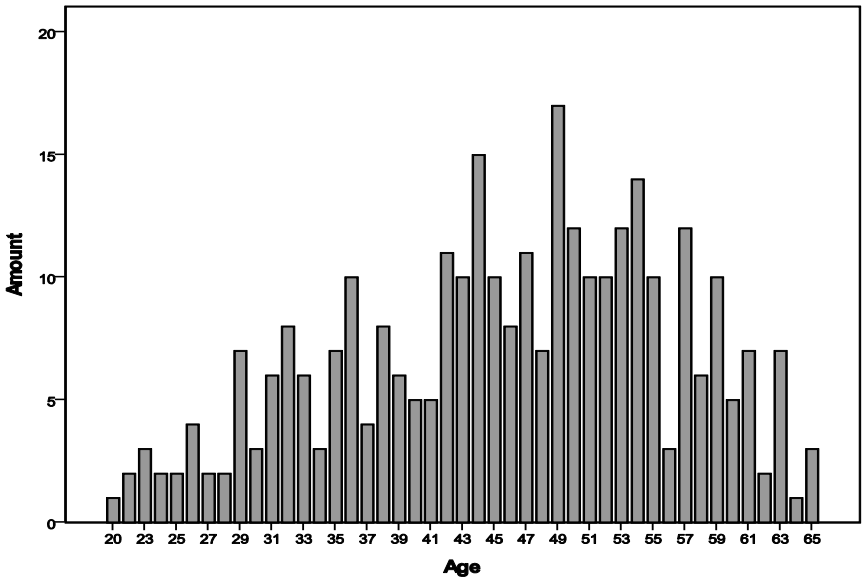

Figure 1: *Age distribution of participants*

3. Results

3.1 Smartphone Interaction

In order to analyze the data statistically, chi-square tests was performed to examine if there are differences in handheld positions for the three tasks when interacting with a smartphone. Results show significant differences for typing short text ((χ^2(4, N = 289) = 253.34, p = .00), typing long text ((χ^2(4, N = 289) = 222.92, p = .00) and reading text ((χ^2(4, N = 289) = 113.47, p = .00). The visual analysis of the bar graphs (figure 2) shows that for typing short text the most prominent position is

holding the smartphone in the one hand while interacting with the other hand, whereas interacting with the thumb is the second prominent position. For typing long text, interacting with a finger of the opposite hand is most favorable, while the remaining four positions are less favorable. For the task of reading text there is no clear result: Holding the smartphone in one hand while interacting with the thumb or a finger of the other hand almost yield the same amount of answers.

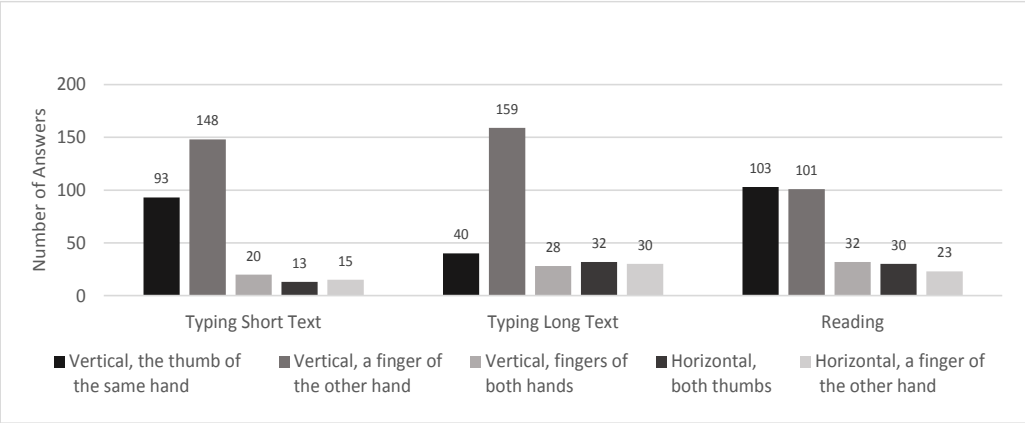

Figure 2: *Bar graph of subject's absolute numbers of answers for three different tasks*

3.2 Tablet-PC Interaction

Again chi-square tests were performed to examine if there are differences in handheld positions for three different tasks when interacting with a tablet-pc. Results show significant differences for typing short text (($\chi^2(4, N = 289) = 58.18, p = .00$), typing long text (($\chi^2(4, N = 289) = 71.12, p = .00$) and reading text (($\chi^2(4, N = 289) = 22.10, p = .00$). The visual analysis of the bar graphs (Figure 1) shows that with regard to typing short and long text the most favorable position is holding the tablet-pc vertically and interacting with a finger of the opposite hand of the one holding the tablet-pc. Subsequently, the position holding the tablet-pc horizontally and interacting with a finger of other hand is the second favorable position for both tasks. With regard to reading text on a tablet-pc the results are different: the most favorable position is again holding the tablet vertically and interacting with a finger of the opposite hand but when interacting with the tablet-pc horizontally, the most favorable position is holding the tablet-pc with both hands and interacting with both thumbs instead of interacting with a finger.

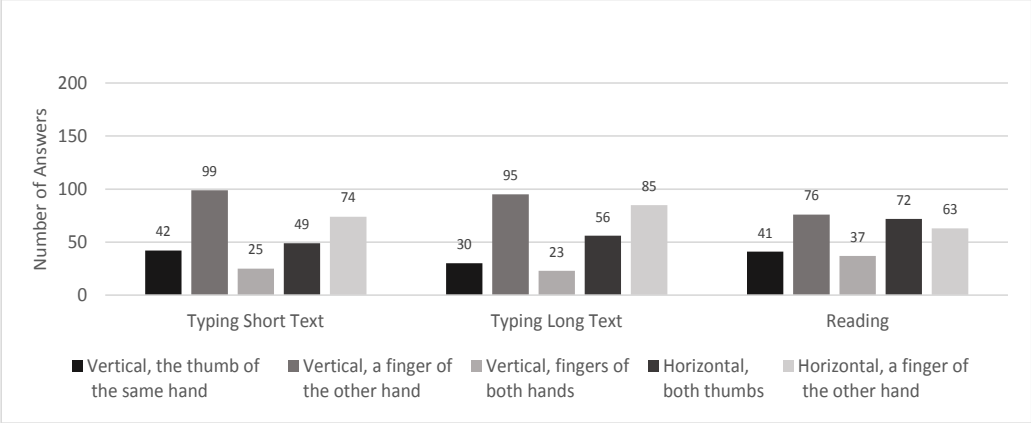

Figure 1 *Bar graph of subject's absolute numbers of answers for three different tasks*

4. Discussion

As the diversity of mobile devices is constantly growing, interacting with input devices through direct hand input is on the rinse. Developing ergonomic user interfaces requires to understand how users naturally hold their devices. The analyses presented in this paper show how users hold and interact with their smartphones and their tablet-pcs in three common tasks. Overall, results show differences in the way of interaction between smartphones and tablet-pcs. While the most prominent positions when interacting with a smartphone are holding the phone vertically and interacting with a thumb or a finger, there is more variability in the results of the analysis of the interaction with a tablet-pc. Specifically, results show that more subjects hold their tablet-pc horizontally in comparison to smartphone interaction. With regard to interface design this implies that in order to design the interaction with handheld devices ergonomically, software should be designed taking those handheld positions with regard to different tasks into account.

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