Understanding One Handed Use of Mobile Devices

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Karlson, A., Bederson, B. B. (2007) **Understanding One Handed Use of Mobile Devices**. Lumsden, Jo (Ed.), Handbook of Research on User Interface Design and Evaluation for Mobile Technology, Idea Group Reference, 86-101.

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ABSTRACT

Mobile phones are poised to be the world's most pervasive technology, already outnumbering land lines, personal computers and even people in some counties! Unfortunately, solutions to address the usability challenges of using devices on the move have not progressed as quickly as the technology or user distribution. Our work specifically considers situations in which a mobile user may have only a single hand available to operate a device. To both motivate and offer recommendations for one-handed mobile design, we have conducted three foundational studies: a field study to capture how users currently operate devices; a survey to record user preference for the number of hands used for a variety of mobile tasks, and an empirical evaluation to understand how device size, interaction location, and movement direction influence thumb agility. In this chapter we describe these studies, their results, and implications for mobile device design.

INTRODUCTION

The handheld market is growing at a tremendous rate; the technology is advancing rapidly and experts project that annual mobile phone sales will top 1 billion by 2009 (Pittet et al., 2005). To meet customer demand for portability and style, device manufacturers continually introduce smaller, sleeker profiles to the market. Yet advances in battery power, processing speed and memory allow these devices to come equipped with increasing numbers of functions, features, and applications. Unfortunately these divergent trends are at direct odds with usability: richer content accessed via shrinking input and output channels simply makes devices harder to use. The unique requirements for mobile computing only compound the problem, since mobile use scenarios can involve to unstable environments, eyes-free interaction, competition for attention resources, and varying hand availability (Pascoe, Ryan, & Mores, 2000). While each of these constraints requires attention in design, we are currently interested in issues of usability when a user only has only one hand available to operate a mobile device.

Devices that accommodate single-handed interaction can offer a significant benefit to users by freeing a hand for the host of physical and attentional demands common to mobile activities. But there is little evidence that current devices are designed with this goal in mind. Small, light phones that are easy to control with one hand are unfriendly to thumbs due to small buttons and crowded keypads. Larger devices are not only harder to manage with a single hand, they tend to feature more (rather than larger) buttons, as well as stylus-based touchscreens whose rich interface designs maximize information content, but offer targets too small, and/or too distant, for effective thumb interaction.

While it may seem obvious which features inhibit single-handed use, there has been relatively little systematic study of enabling technologies and interaction techniques. Most commercial and research efforts in one-handed device interaction have focused primarily on either a specific technology or task. For example, accelerometers have been explored to support tilt as a general input channel for handheld devices (Dong, Watters, & Duffy, 2005; Hinckley, Pierce, Sinclair, & Horvitz, 2000; Rekimoto, 1996), while media control (Apple, 2006; Pirhonen, Brewster, & Holguin, 2002) and text entry (Wigdor & Balakrishnan, 2003) have been popular tasks to

consider for one-handed device operation. But in the varied landscape of mobile devices and applications, one-handed design solutions must ultimately extend to a wide range of forms and functions. We began our investigation of this problem by looking at the fundamental human factors involved in operating a device with a single hand.

In this chapter, we report on three studies conducted to understand different aspects of one-handed mobile design requirements. We first ran a field study to capture the extent to which single-handed use is currently showing up "in the wild". Second, we polled users directly to record personal accounts of current and preferred device usage patterns. The results from these studies help motivate one-handed interface research, and offer insight into the devices and tasks for which one-handed techniques would be most welcomed. Finally, we performed an empirical evaluation of thumb tap speed to understand how device size, target location, and movement direction influence performance. From these results we suggest hardware-independent design guidelines for the placement of interaction objects. Together our findings offer foundational knowledge in user behavior, preference, and motor movement for future research in single-handed mobile design.

BACKGROUND

The physical and attentional demands of mobile device use was perhaps first reported for fieldworkers (Kristoffersen & Ljungberg, 1999; Pascoe, Ryan, & Mores, 2000), from which design recommendations for minimal-attention and one-handed touchscreen interface designs emerged (Pascoe et al., 2000). Though well suited to the directed tasks of fieldwork, the guidelines do not generalize to the varied and complex personal information management tasks of today's average user. Research of the effects that mobility has on attention and user performance continues (Oulasvirta, Tamminen, Roto, & Kuorelahti, 2005), as well as how these factors can be replicated for laboratory study (Barnard, Yi, Jacko, & Sears, 2005).

Several approaches for one-handed device interaction have been proposed. Limited gestures sets have been explored for mobile application control with both the thumb (Apple, 2006; Karlson, Bederson, & SanGiovanni, 2005; Pascoe et al., 2000) and index finger (Pirhonen et al., 2002), but none have specifically considered ergonomic factors. Since text entry remains the input bottleneck for mobile devices, many are working on improvements, and some targeting one-handed use. Peripheral keyboards for one-handed text entry are available, such as the Twiddler (Lyons et al., 2004), but the mobile device itself must be supported by another hand, desk or lap, which violates our definition of one-handed device control. Text entry on phone keypads is generally performed with a single thumb, but methods to improve input efficiency have focused on reducing the number of key presses required, such as T9 word prediction, rather than by improving ergonomics by optimizing button sizes, locations, or movement trajectories. Accelerometer-augmented devices allow for the device's spatial orientation to serve as an input channel, and have been shown to support one-handed panning (Dong, Watters, & Duffy, 2005), scrolling (Rekimoto, 1996), and text entry (Wigdor & Balakrishnan, 2003). However, the coarse level of control tilt offers, and the potential for confusion with the normal movements of mobile computing necessarily limit the viability of tilt for generalized input.

Scientists in the medical community have studied the biomechanics of the thumb extensively for the purposes of both reconstruction and rehabilitation. The structure of the thumb is well

understood (Barmakian, 1992), but only now are scientists beginning to reliably quantify the functional capabilities of the thumb. Strength has been the traditional parameter used to assess biomechanical capabilities, and recent research has established the effect movement direction has on thumb strength (Li & Harkness, 2004). Unfortunately, only standard anatomical planes have been considered, which excludes movements toward the palm that are typical of mobile device interaction. As a complement to force capabilities, others have looked at range as a characteristic of thumb movement. Kuo, Cooley, Kaufman, Su and An (2004) have developed a model for the maximal 3D workspace of the thumb and Hirotaka (2003) has quantified an average angle for thumb rotation. The experimental conditions for these studies, however, do not account for constraints imposed by holding objects of varying size, such as alternative models of handheld device.

FIELD STUDY

One motivation for our research in single-handed mobile designs was our assumption that people already use devices in this manner. Since current interaction patterns, whether by preference or necessity, are predictive of future behavior, they are likely to be transferred to new devices. This suggests that designs should become more accommodating to single-handed use, rather than less, as the current trend seems to be. To capture current behavior, we conducted an *in situ* study of user interaction with mobile devices. The study targeted an airport environment for the high potential of finding mobile device users and ease of access for unobtrusive observation.

Field Study Method

We observed 50 travelers (27 male) at Baltimore Washington International Airport's main ticketing terminal during a six hour period during peak holiday travel. Because observation was limited to areas accessible to non-ticketed passengers, seating options were scarce. We expected to observe the use of both Personal Digital Assistants (PDAs) and cell phones since travelers are likely to be coordinating transportation, catching up on work, and using mobile devices for entertainment purposes. Since most users talk on the phone with one hand, we recorded only the cell phone interactions that included keypad interaction as well. All observations were performed anonymously without any interaction with the observed.

Note that while any subject observation without consent presents a legitimate question for ethical debate, in our research we follow the federal policy on the protection of human research subjects (Department of Health and Human Services, 2005) as a guideline. The policy states that the observation of public behavior is not regulated if the anonymity of the subjects is maintained and that disclosure of the observations would not put the subjects at risk in terms of civil liability, financial standing, employability, or reputation. Since we were interested in capturing natural behavior, did not record identifying characteristics, and consider phone use while standing, walking and sitting relatively safe activities, we did not obtain subject consent.

Field Study Measures

For each user observed, we recorded sex, approximate age, and device type used: candy bar phone, flip phone, Blackberry, or PDA. A "candy bar" phone is the industry term for a traditional-style cellular phone with a rigid rectangular form, typically about 3 times longer than

wide. For phone use, we recorded the hand(s) used to dial (left, right or both) and the hand(s) used to speak (left, right or both). We also noted whether users were carrying additional items, and their current activity (selected from the mutually exclusive categories: walking, standing, or sitting).

Field Study Results

Only two users were observed operating devices other than mobile phones - one used a PDA and the other a Blackberry. Both were seated and using two hands. The remainder of the discussion focuses on the 48 phone users (62.5% flip, 37.5% candy bar). Overall, 74% used one hand for keypad interaction. By activity, 65% of one handed users had a hand occupied, 54% were walking, 35% were standing, and 11% were sitting. Figure 1 presents the distribution of subjects who used one vs. two hands for keypad interaction, categorized by the activity they were engaged in (walking, standing, or sitting). The distribution of users engaged in the three activities reflects the airport scenario where many more people were walking or standing than sitting. It is plain from Figure 1 that the relative proportion of one handed to two handed phone users varied by activity; the vast majority of walkers used one hand, about two-thirds of standers used one hand, but seated participants tended to use two hands. However, we also recorded whether one hand was occupied during the activity, and found walkers were more likely to have one hand occupied (60%), followed by standers (50%), and finally sitters (25%), which may be the true reason walkers were more likely than standers to use one hand, as well as why standers were more likely than sitters to use one hand. Regardless of activity, when both hands were available for use, the percentage of one vs. two handed phone users was equal.

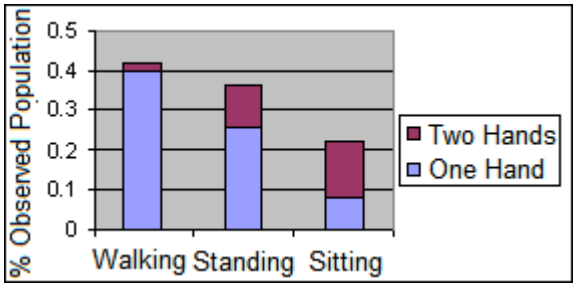

Figure 1. Airport Field Study - number of hands used for keypad interaction by activity.

Analysis of Field Study

Although Figure 1 suggests a relationship between user activity and keypad interaction behavior, it is unclear whether activity influences the number of hands used, or vice versa. Furthermore, since the percentage of users with one hand occupied correlates with the distribution of one-handed use across activities, hand availability, rather than preference, may be the more influential factor in the number of hands used to interact with the keypad. While use scenario certainly impacts usage patterns, the fact that users were as likely to use one hand as two hands when both hands were available suggests that preference, habit and personal comfort also play a role. Regardless of scenario, we can safely conclude that one-handed phone use is quite common, and thus is an essential consideration in mobile phone design.

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