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Effects of button design characteristics on performance and perceptions of touchscreen use

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A B S T R A C T

Touchscreen technology has gained increasing popularity in both personal and public settings. However, button design characteristics that may affect touchscreen use have not been fully investigated. The aim of this study was to examine the effects of button design characteristics (i.e., button size, button spacing, visual feedback and button shape) on users' touchscreen performance, mental workload and preference. Twenty participants participated in an experiment in which they performed both digit and letter input tasks. Button sizes ranged from 7.5 to 27.5 mm with 5-mm increments, while button spacing was absent, 1 mm or 3 mm. Two types of visual feedback (presence and absence) and three button shapes (square, horizontal and vertical rectangles) were examined. Results indicated that button size, button spacing and button shape yielded significant effects on touchscreen performance, while visual feedback had no effect. It is also found that users performed better with medium-to-large size (17.5 mm and larger), square buttons. Mental workload was comparable across button shapes. Users generally preferred button design characteristics that could yield optimal input performance.

Relevance to industry: The findings could facilitate the optimal design of usable touchscreen technology.

1. Introduction

Touchscreen technology has gained increasing popularity over the last decade due to its natural and convenient human-technology interaction (Im et al., 2015; Travis and Murano, 2014; Wu and Xi, 2016). It is widely used for a variety of consumer electronic devices (Chen et al., 2014) and by a wide range of users (Piotrowski and Krcmar, 2017; Xiong and Muraki, 2016). Touchscreen technology is also commonly encountered in varied public settings, including banks, airports, train stations and healthcare facilities (Chourasia et al., 2013; Hu and Ning, 2016; Or and Tao, 2016; Robinson and Brewer, 2016). The use of touchscreen technology has many advantages. For example, touchscreen allows easy operations even by inexperienced and disabled users, requiring less training than other input devices such as the mouse, keyboard and trackball (Ahearne et al., 2016; Kwon et al., 2011; Ng et al., 2013; Sesto et al., 2012). In addition, touchscreen can minimize dimensions of a device, as physical buttons can be replaced by on-screen virtual buttons (Holzinger, 2003). Moreover, the design of touchscreen interface can be easily adjusted in terms of button size, spacing, shape and the presence of on-screen elements (Colle and Hiszem, 2004).

In spite of its convenience and potential benefits, the use of touchscreen technology has several significant limitations, such as reduced precision, finger occlusion, and the lack of clear feedback on the state of interaction (Benko and Wigdor, 2010). These limitations may prevent users from effective interaction with the technology. To address the limitations, the design of touchscreen technology should be with full consideration of factors that may affect the use of the technology and provide usable touchscreen interfaces (Wu and Xi, 2016).

Several important design factors, such as button size and spacing between buttons, have been investigated (Chen et al., 2013; Chourasia et al., 2013; Colle and Hiszem, 2004; Hara et al., 2015; Jin et al., 2007; Kim et al., 2014a, b; Park and Han, 2010; Pitts et al., 2012; Sears, 1991; Sears et al., 1993; Sesto et al., 2012; Xiong et al., 2014). However, evidence on optimal touchscreen design is still mixed, as indicated by varied recommendations from several international standards (e.g., 9.5 mm button size and 3.2 mm gap

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recommended by ANSI/HFES 100–2007 (Human Factors and Ergonomics Society, 2007), the breadth of distal finger joint dimension from 95th percentile male as minimal button size suggested by ISO 9241-9 (Greiner, 1991), and 19.05 mm button size and 6 mm gap by other standards (Monterey Technologies, 1996)). The inconsistent recommendations may come from varied usage contexts, which are unclearly specified. Thus, more efforts are required to clarify the scenario where the evidence is obtained.

In addition, some touchscreen design factors, such as button shape and visual feedback, may also exert important impacts on user performance and perceptions (Duarte et al., 2013; Han et al., 2004; Meyer et al., 1990), but are seldom investigated. Likewise, relationships between these understudied factors and previously widely examined ones (e.g., button size and spacing) have not been well reported, evidence from which might help explain inconsistency in existing design standards and provide more specific design guidelines. In addition, previous studies mostly examined digit input tasks with a simple digit keyboard (Chen et al., 2013; Chourasia et al., 2013; Colle and Hiszem, 2004). However, a letter keyboard that comprises much more buttons than a digit keyboard is used more often in practice. While the letter keyboard performance may differ from that of a digit keyboard, little research has examined whether design characteristics yield consistent effects between digit and letter tasks.

The purpose of this study was therefore to examine the effects of button size, spacing, shape and visual feedback on user performance and perceptions in touchscreen tasks. While many of previous studies focused on small, handheld touchscreen devices (Conradi et al., 2015; Jung and Im, 2015) and tested digit tasks only, this study was based on a relatively large touchscreen interface that is commonly used in public settings, and examined both letter and digit input tasks.

1.1. Button size and spacing

It has been suggested that larger button sizes are associated with better performance in touchscreen use (Beaton and Welman, 1985; Beringer, 1990; Hara et al., 2015; Martin, 1988; Wilson and Liu, 1995). However, in many cases, button sizes should be kept optimal minimal and be traded off with spacing due to limited screen space. Some earlier studies found that an acceptable accuracy level in touchscreen kiosk tasks could be achieved with a minimal square button size ranging from 20 mm to 26 mm (Beringer, 1990; Hall et al., 1988; Sears, 1991). Later, researchers reported that button sizes of 20 mm (Colle and Hiszem, 2004) and 19.05 mm (Jin et al., 2007) could yield optimal user performance across varied levels of button spacing. Both studies indicated that button spacing had no measurable effects (Colle and Hiszem, 2004; Jin et al., 2007), but they did not consider scenarios where there is no spacing between buttons.

Recent studies have extended previous research in varied usage contexts and suggested that the effects of button size and spacing differed across personal and environmental conditions. For example, Chen et al. (2013) found that user performance from a non-disabled group plateaued at a button size of 20 mm, while performance from a disabled group continued to improve as button size increased. Chourasia et al. (2013) suggested that posture affected user performance in touchscreen number entry tasks. In particular, they found standing yielded worse performance than sitting at smaller button sizes (<20 mm), while both postures produced similar performance at larger button sizes. While Chen et al. (2013) and Chourasia et al. (2013) confirmed the non-effect of button spacing on touchscreen performance, they both reported that users indeed preferred larger button spacing. More recently, Kim et al., (2014a) have found that the usability of an in-vehicle touchscreen information system increased as the touch-key size increased up to 17.5 mm across a variety of simulated driving speeds.

1.2. Visual feedback

The provision of feedback is essential to touchscreen interface design as it can help check whether users' input has been recognized (Duarte et al., 2013; Meyer et al., 1990). This is likely to reduce efforts and minimize confusion, and might help avoid users' negative perception of usability towards the touchscreen interface. There are varied types of feedback, such as visual, auditory and tactile feedback, among which visual feedback is the most widely used one (Park et al., 2015; Pitts et al., 2012). This may be because that auditory and tactile feedback does not always work well, especially in moving and noisy environment, and in situations where quietness is required. In contrast, visual feedback is less sensitive to surrounding environment. Several studies have been conducted to compare different types of feedback (Lee et al., 2009; Lee and Spence, 2008; Park et al., 2015; Pitts et al., 2012), and confirmed the effectiveness of visual feedback in improving touchscreen performance. However, knowledge of the effects of visual feedback in relation to button size and spacing is lacking.

1.3. Button shape

Most of previous studies focused on square buttons (Chen et al., 2013; Chourasia et al., 2013; Colle and Hiszem, 2004; Jin et al., 2007; Pitts et al., 2012), and their results may not be applicable to non-square ones. In fact, button shape is not necessarily square. Non-square buttons, such as rectangle buttons, are commonly employed in personal and public touchscreen devices. Rectangle buttons have advantages over square ones with the same length in that they help achieve a smaller keyboard area and can be employed in cases where touch area is limited and not square. However, button shape has not been well investigated so far. Whether different shapes have comparable effects is unknown. The lack of evidence regarding button shape, especially in relation to button size and spacing, leaves designers without clear guidance of what to do when button shape should be considered in touchscreen design.

1.4. Study hypotheses

This study investigated the effects of button size, spacing, shape and visual feedback on touchscreen performance and perceptions in both letter and digit input tasks. The following hypotheses were proposed:

Hypothesis 1. A medium-to-large button size (17.5 mm and larger) will achieve better touchscreen performance than smaller button sizes;

Hypothesis 2. The presence of button spacing will lead to better touchscreen performance than its absence;

Hypothesis 3. The presence of visual feedback will lead to better touchscreen performance than its absence;

Hypothesis 4. Rectangle buttons will yield non-inferiority performance and mental workload compared with square buttons;

Hypothesis 5. Users will prefer button design characteristics that achieve better touchscreen performance.

Hypotheses 1 and 2 were formulated based on evidence regarding the effects of button size and spacing from the literature. Hypotheses 3 and 4 were proposed according to our expectations on potential benefits of visual feedback and rectangle buttons in touchscreen use. Hypothesis 5 was proposed based on the