Applied Ergonomics 61 (2017) 116–143

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Review article

Touchscreen interfaces in context: A systematic review of research into touchscreens across settings, populations, and implementations

Andreas K. Orphanides [a], Chang S. Nam [b, *]

[a] User Experience Department, North Carolina State University, Raleigh, NC 27695 USA
[b] Edward P. Fitts Department of Industrial and Systems Engineering, North Carolina State University, Raleigh, NC 27695 USA

ARTICLE INFO

Article history:
Received 4 September 2016
Received in revised form
19 December 2016
Accepted 22 January 2017

Keywords:
Touchscreen interface
Human factors and ergonomics
User-centered design

ABSTRACT

Although many studies have been conducted on the human factors and ergonomics (HFE) of touchscreens, no comprehensive review has summarized the findings of these studies. Based on a schema (three dimensions of understanding critical for successful display selection) presented by Wickens et al. (2004), we identified three dimensions of analysis for touchscreen implementations: touchscreen technology, setting and environment of implementation, and user population. We conducted a systematic review based on the PRISMA protocol (Moher et al., 2009), searching five article databases for relevant quantitative literature on touchscreens. We found that all three dimensions of analysis have a significant effect on the HFE of touchscreens, and that a selection for or against touchscreens must take into consideration the specific context of system interaction in order to maximize safety, performance, and user satisfaction. Our report concludes with a set of specific recommendations for systems designers considering touchscreens as input/output devices, and suggestions for future study into the HFE of touchscreens.

Contents

* Corresponding author.
E-mail addresses: akorphan@ncsu.edu (A.K. Orphanides), csnam@ncsu.edu (C.S. Nam).

http://dx.doi.org/10.1016/j.apergo.2017.01.013
0003-6870/

1. Introduction

1.1. Background and motivation

A touchscreen interface is a combined display/input device; the screen displays a graphical interface, and a user's physical touching of the screen is interpreted as an input or interaction with the interface, at the point of contact. Touchscreen interfaces were proposed over 50 years ago (Johnson, 1965), were first put into practice for use in the “Conseil Européen pour la Recherche Nucléaire”, or European Council for Nuclear Research (CERN) particle accelerator in 1976 (Beck and Stumpe, 1973), and were in commercial production by 1983 (Hewlett-Packard, 2012). Since that time touchscreens have been implemented in a variety of devices and using an assortment of technologies, but in many ways, the release of the Apple iPhone in 2007 (Apple, 2007) heralded a new age for touchscreens, both as a milestone in touchscreen-based personal ubiquitous computing, and also as a hallmark of the possibilities that touchscreen interfaces permit in industrial and aesthetic design. As a result, in the last decade touchscreens have become ubiquitous across industrial, commercial, and consumer applications, in devices as diverse as industrial controls, medical equipment, photocopiers, refrigerators, home thermostats, desktop computers, and, of course, smartphones.

Touchscreens have obvious appeal from a systems design perspective, as they combine display and input affordances (thus providing space and design efficiency), while simultaneously offering human factors and ergonomics (HFE) benefits, such as the direct mapping of inputs to targets. However, the decision to use a touchscreen as a system input results in certain HFE compromises as well, including concerns such as a lack of tactile input affordances, ergonomic compromises leading to fatigue and discomfort (Kang and Shin, 2014; Shin and Zhu, 2011; Young et al., 2012), and factors that compromise the quality of direct mapping of inputs and targets such as the “fat finger problem” (e.g., Siek et al., 2005) and parallax concerns due to physical separation of the input and display layers of the device (Leahy and Hix, 1990). This suggests that choosing a touchscreen as an input device may incur a tradeoff from an HFE perspective, which may influence the safety, task performance, and satisfaction of the users of the system. Further, the precise effect of touchscreen-as-input may depend on the context of the system, in particular the system's setting, the user population interacting with the system, and touchscreen implementation selected.

Despite the current dominance of touchscreens in contemporary systems engineering, and despite extensive human factors research into touchscreen interfaces in a multitude of contexts, there has been to date no comprehensive review of formal research into the human factors and ergonomics of touchscreens. Such a review would be an invaluable asset to a system designer, allowing her or him to make a determination about whether and how to integrate a touchscreen into the system, given the system's environment and tasks, the properties of the system's users, and the possible touchscreen implementations available. For this reason, we present a review of the human factors and ergonomics of touchscreens, examining the HFE concerns of touchscreens and touchscreen systems through the lenses of system setting, user population, and touchscreen implementation. We intend this review to serve two purposes: (1) for the system practitioner described above, to inform the process of evaluating whether to integrate a touchscreen interface into a system, based on the system's settings and tasks, the users of the system, and the touchscreen implementations under consideration; and (2) for the human factors researcher, to identify the contexts (i.e., settings and tasks, populations, and touchscreen implementations) that have been well-studied, those that have had promising initial studies conducted and may hold opportunities for additional research, and (through their absence) contexts that are ripe for new research.

1.2. Review objectives

This review is concerned with evaluative studies of touchscreen interfaces from a HFE perspective. Of specific concern are the effects of touchscreen interfaces on safety, task performance, and user satisfaction in relation to their contexts of use. We consider contexts of use along three dimensions: the implementation of the touchscreen, the task the touchscreen is serving, and the characteristics of the user interacting with the touchscreen. We base these