ELSEVIER

Applied Ergonomics 37 (2006) 525–535

APPLIED ERGONOMICS

www.elsevier.com/locate/apergo

Human factors of complex sociotechnical systems

Pascale Carayon*

Department of Industrial and Systems Engineering, Center for Quality and Productivity Improvement, University of Wisconsin-Madison, 610 Walnut Street 575 WARF, Madison, WI 53726, USA

Abstract

Increasingly products and services result from interactions among people who work across organizational, geographical, cultural and temporal boundaries. This has major implications for human factors and ergonomics (HFE), in particular, challenging the limits of the systems to be designed, and widening the range of system elements and dimensions that we need to consider. The design of sociotechnical systems that involve work across multiple boundaries requires better integration of the various sub-disciplines or components of HFE, as well as increased collaboration with other disciplines that provide either expertise regarding the domain of application or expertise in concepts that can enrich the system design.

In addition, 'customers' contribute significantly to the 'co-production' of products/services, as well as to their quality/safety. The design of sociotechnical systems in collaboration with both the workers in the systems and the customers requires increasing attention not only to the design and implementation of systems, but also to the continuous adaptation and improvement of systems in collaboration with customers.

This paper draws from research on human factors in the domains of health care and patient safety and of computer security.

Keywords: Organizational design and management (ODAM); Macroergonomics; Complex work system; Sociotechnical system; Health care and patient safety; Computer and information system security

1. Introduction

A number of changes are occurring in the business and socio-economic environment that contribute to increasing the complexity of work systems. Vicente (1999) lists several factors that contribute to work system complexity (see Table 1 for a list of the dimensions of work system complexity and their relevance to the healthcare and computer security domains). Increasing work system complexity poses unique challenges to the people involved in the design, implementation and maintenance of sociotechnical systems, including human factors and ergonomics (HFE) researchers and professionals. In this paper, we discuss two emerging trends that contribute to increased work system complexity: (1) working across organizational, geographical, cultural and temporal boundaries, and (2) the increasing role of the customer in product/service design.

The examples used in this paper draw from the healthcare/patient safety and computer security domains. Patient safety is a systemic problem of healthcare organizations worldwide. The issue of medical errors and harm caused by poorly designed healthcare systems made headlines in the US with the publication of the 1999 Institute of Medicine report, "To Err is Human: Building a Safer Health System" (Kohn et al., 1999). The World Health Organization has recognized patient safety as a strategic issue in order to improve health and health care worldwide (http://www.who.int/patientsafety). HFE has a long tradition of involvement in helping assess and solve performance, quality and safety problems in health care (Chapanis and Safrin, 1960).

The issue of computer security is also a global problem, but it has received considerably less attention and contributions from HFE as compared to health care and patient safety. The 2005 CSI/FBI [Computer Security

*Tel.: +1 608 265 0503/263 2520; fax: +1 608 263 1425.
E-mail address: carayon@engr.wisc.edu.

0003-6870/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apergo.2006.04.011

Table 1
Complexity of work systems[a]

Dimensions of complexity	Definitions	Application to health care	Application to computer security
Large problem spaces	Many different elements and forces	About 500,000 illnesses	Large number of computers and other technologies connected via a network
Social system	Composed of many people who must work together	Healthcare providers and staff Patients and their families	End users + creators–maintainers of computer security
Heterogeneous perspectives	Workers with different backgrounds and disciplines	Different disciplines and cultures/values	Usability versus security
Distributed system	People located in different places	Home healthcare Telemedicine	Networked system: people accessing the network from a remote location
Dynamic system	Delay in effects of actions	Preventive care	Networked system
Hazardous system	Catastrophic economic, public, social, environmental consequences	Medical errors	Security breaches leading to loss of business, reputation, etc…
Coupling	Highly coupled interacting sub-systems	Both tight and loose coupling	Both tight and loose coupling
Automation	Highly automated system	High automation in radiology and pharmacy	High automation
Uncertain data	Uncertainty in data available to workers	Patient characteristics	Data from intrusion detection software
Mediated interaction	System not observable directly by workers	Medical technologies (e.g., endoscopic technologies)	Computer security performance mediated by various technologies
Disturbances	Workers responsible for dealing with unanticipated events	Unanticipated events (e.g., changes in patient status, adverse drug events)	Unanticipated attacks

[a]The dimensions of complexity are further described by Vicente (1999).

Institute & Federal Bureau of Investigation] survey of 699 people representing various industries shows that 56% of the companies experienced some type of unauthorized use of computer systems within the past year (Gordon et al., 2005), including laptop or mobile theft, denial of service, telecom fraud, unauthorized access to information and virus. There is slow recognition among computer security specialists of the importance of non-technical (human and organizational) factors in ensuring and maintaining computer security. For instance, in the CSI/FBI 2005 survey, a large number of respondents (63–70%) identified awareness training in various areas of security (security policy, security management, access control systems and network security) as very important to their organizations. HFE can make a significant contribution to improving the design and implementation of computer security technologies, policies and management systems (Carayon et al., 2005a).

The domains of health care and computer security pose unique challenges to HFE because of their high complexity. Much patient care involves people (patients, their families, and healthcare providers and staff) who work across various boundaries. Patients (and their families and caregivers) have an increasingly important role in the quality and safety of the care provided to them. Computer security is becoming increasingly complex because of the (distributed, decentralized) Internet and other networked systems that involve people working across various boundaries. Those people have a critical role in computer security: they can directly or indirectly affect security through their behaviors and actions (e.g., writing down passwords), or they can alert computer security managers of possible security breaches (e.g., when experiencing slow response to computer network access).

In the remainder of the paper, the trend towards working across boundaries and the implications for a greater focus on system interactions and integration within and outside the HFE discipline are discussed. We then describe the increasing role of the customer in product/service design, and the subsequent need for developing more comprehensive models of HFE in system design.

2. Working across boundaries

Many people no longer work for a single organization or only with people belonging to the same organization. They work across *organizational, geographical, cultural and temporal boundaries* in a world that is 'flattening' (Friedman, 2005) (see Table 2 for examples of boundaries in the healthcare and computer security domains, and other domains of application). Products and services are created as outcomes of multiple entities/organizations that work together across boundaries. Working across organizational, geographical, cultural and temporal boundaries increases the number and type of interactions between systems, and therefore amplifies the complexity of work systems.

Example in health care: The creation of virtual intensive care units (ICUs) is an example of 'working across organizational, geographical and temporal boundaries' in the healthcare domain that poses important HFE challenges. In a virtual ICU system, a patient is cared for by on-site ICU nurses and physicians located in hospital A