Applied Ergonomics 45 (2014) 45–54

Contents lists available at SciVerse ScienceDirect

Applied Ergonomics

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

Crossing levels in systems ergonomics: A framework to support 'mesoergonomic' inquiry

Ben-Tzion Karsh [a,†], Patrick Waterson [b,*], Richard J. Holden [c]

[a] Department of Industrial and Systems Engineering, University of Wisconsin-Madison, Madison, WI, USA
[b] Human Factors and Complex Systems Group, Loughborough Design School, Loughborough University, Loughborough LE11 3TU, UK
[c] Departments of Medicine and Biomedical Informatics, Vanderbilt University, Nashville, TN, USA

ARTICLE INFO

Article history:
Received 26 February 2013
Accepted 24 April 2013

Keywords:
Systems ergonomics
Macro/micro integration
Organizational ergonomics

ABSTRACT

In this paper we elaborate and articulate the need for what has been termed 'mesoergonomics'. In particular, we argue that the concept has the potential to bridge the gap between, and integrate, established work within the domains of micro- and macroergonomics. Mesoergonomics is defined as an open systems approach to human factors and ergonomics (HFE) theory and research whereby the relationship between variables in at least two different system levels or echelons is studied, and where the dependent variables are human factors and ergonomic constructs. We present a framework which can be used to structure a set of questions for future work and prompt further empirical and conceptual inquiry. The framework consists of four steps: (1) establishing the purpose of the mesoergonomic investigation; (2) selecting human factors and ergonomics variables; (3) selecting a specific type of mesoergonomic investigation; and (4) establishing relationships between system levels. In addition, we describe two case studies which illustrate the workings of the framework and the value of adopting a mesoergonomic perspective within HFE. The paper concludes with a set of issues which could form part of a future agenda for research within systems ergonomics.

1. Introduction

The International Ergonomics Association (IEA, 2000) identifies three broad categories of ergonomic specialization: physical ergonomics, cognitive ergonomics and organizational ergonomics. These three specializations can be further grouped into micro-ergonomics and macroergonomics (Meshkati, 1989; Morel et al., 2009; Scott and Charteris, 2006; Zink, 2000). Physical and cognitive ergonomics comprise what is thought of as microergonomics, as research and practice in physical and cognitive ergonomics traditionally focuses on the human-machine system interactions. Organizational ergonomics, also known as macroergonomics and related to sociotechnical systems theory (Waterson, 2013), is by contrast concerned with the design of larger sociotechnical systems. Hendrick (1986, 1991; Hendrick and Kleiner, 2000) defines macroergonomics as a top down sociotechnical systems approach to the design of work systems such that micro-system interfaces (e.g., human-machine, human-software) are aligned with macro-systems interfaces (e.g., human-job, human-organization). The goal of the approach is the design of work systems that allow for the simultaneous achievement of individual employee and organizational goals. In such a situation, individual employees are able to achieve high performance in a safe work environment while the organization is able to grow market share and profitability. Some have referred to organizations that achieve this feat as healthy work organizations (Murphy and Cooper, 2000; Sauter et al., 1996).

1.1. Systems theory and human factors and ergonomics

Much of the background theory and motivation for macro-ergonomics derives from systems theory and the application of the systems approach to understanding safety, well-being, and a range of other ergonomic variables within work environments. Wilson (2012) for example, has argued that a defining characteristic of research in human factors and ergonomics is that is explicitly adopts a 'systems view':

"… it is tempting to be hard-nosed and suggest that any study, investigation or analysis or development which does not take a systems view is, in fact, not ergonomics at all… So, a musculo-skeletal disorder investigation or improvement which does not account for psychological/emotional/social influences, on MSD

* Corresponding author. Tel.: +44 1509 228478; fax: +44 1509 223940.
E-mail address: p.waterson@lboro.ac.uk (P. Waterson).
† Deceased.

0003-6870/$ – see front matter © 2013 Elsevier Ltd and The Ergonomics Society. All rights reserved.
http://dx.doi.org/10.1016/j.apergo.2013.04.021

causation or success of solutions, is not fully ergonomics" (Wilson, 2012, p. 3861).

A central idea of the systems approach is that complex systems, for example organisations, teams and types of technology, are composed of interrelated components, the properties of which are changed if the system is dissembled in any way. The approach also emphasises two specific aspects of social and organisational behaviour: (1) their systems character, so that movement in one part leads in a predictable fashion to movement in other parts; and, (2) their openness to environmental inputs, so that they are continually in a state of flux (Katz and Kahn, 1966, p. 3). In addition, adopting a systems ergonomic point of view often affords insights into how actions or occurrences at one level (e.g., an error made by a process operator) collectively interact with phenomena at team (e.g., situation awareness) and organisational (e.g., safety culture/climate) levels of analysis.

1.2. Integrating macro- and microergonomics

Over the years there have been calls to better integrate microergonomic and macroergonomic research and practice (Porter, 1977; Scott and Charteris, 2006; Zink, 2000), and some would argue that macroergonomics as originally defined by Hendrick is in fact a call to integrate organizational-level and human-machine level concerns for the joint improvement of the organization and its operators. At the same time, there is an acknowledgement that integrating macro- and microergonomics is challenging. Over twenty years ago for example, Wilson and Grey (1990) listed what they perceived to be some of the main issues in work redesign. Some of the issues they listed included: delineating the boundaries of what constitutes a work redesign initiative (i.e., task, role, job, organisational levels); identifying the key factor at each level and how these factors function; and, the intervening effects of individual differences and organisational structures on work redesign initiatives.

Even though macroergonomics is about the design of entire work systems, and models have been proposed to help guide researchers in identifying salient job and organizational level variables to study (Hendrick and Kleiner, 2002; Smith and Sainfort, 1989), few theories or models explicitly provide causal pathways and mechanisms between levels of the work system. In this paper, we promote the idea of *Mesoergonomics* (Karsh, 2006) as a way to specify macro and microergonomic integration. The specific objectives of the paper are to:

1. To provide a definition and context for mesoergonomic research;
2. To outline a framework for mesoergonomic research which integrates micro- and macro-levels of analysis and guides the conduct of research investigations (e.g., formulating research questions, choice of ergonomic variable under investigation).
3. To provide some examples from our own research of the framework in action;
4. To outline a set of future issues for mesoergonomic research and consider implications for theory, measurement and design in human factors and ergonomics.

2. The concept of 'mesoergonomics'

Karsh (2006) defined mesoergonomics as "an open systems approach to ergonomic theory and research whereby the relationship between variables in at least two different levels or echelons is studied, where the dependent variables are human factors and ergonomic constructs". This is in contrast to how others have used the idea of "meso" to refer to an explicit level in an organization. The term 'meso' is often applied using a traditional 'levels of analysis' approach, where 'macro' refers to organisational system influences, 'meso' group or team processes, and 'micro' influences which derive from individual (e.g., cognitive) factors. Within the field of patient safety research for example, Friesdorf and Glende (2007) describes macro-level influences on standards of patient care as referring to clinical pathways, meso-levels factors are interpreted as referring to variations in delivering treatment, and micro-level factors refer to standard operating procedures within the larger clinical context. By contrast, Greenhalgh and Russell (2010) in their discussion of the high failure rates involved in implementing eHealth programs describe macro-level factors in regard to economic or political factors, meso-level factors as the influence of specific organisational or professional group influences and micro-level factors as the influence of individual clinicians or service users.

The concept of mesoergonomics was borrowed directly from House, Rousseau, and Thomas-Hundt (House et al., 1995) who proposed the "meso paradigm" for organizational behavior research as a means for integrating micro and macro organizational behavior. In organizational behavior, issues of levels have a long and growing tradition (Mathieu and Taylor, 2007), for example in the study of leadership (Avolio and Bass, 1995; Yammarino and Bass, 1990; Yammarino and Dubinsky, 1994; Yammarino et al., 1998). The idea, as proposed by House et al. (House et al., 1995) was that meso theory and research involved the simultaneous study of at least two levels.

3. Mesoergonomics in context

In human factors and ergonomics there are many studies that are implicitly mesoergonomic in nature. Studies and communities of practice within human factors and ergonomics for example, have concluded for decades that many types of human performance and safety variables are influenced by variables that exist at levels higher than that of the individual, front line worker. Results of early sociotechnical systems research made clear the strong influence that work organisation could have on individual worker behaviour (Cherns, 1976; Trist, 1981; Trist et al., 1977). The proposed causal mechanism explaining how work organisation affected individual worker behaviour was self-regulation. Karoly (1993, p. 25) defines self-regulation as: "processes, internal and/or transactional, that enable an individual to guide his/her goal-directed activities over time and across changing circumstances (contexts). Regulation implies modulation of thought, affect, behavior, or attention via deliberate or automated use of specific mechanisms and supportive meta-skills". The US National Institute of Occupational Safety and Health demonstrated, through a series of reports, that a variety of organizational variables including safety culture appeared to impact employee injury experience (Cohen et al., 1975; Smith et al., 1978). Multiple causal mechanisms were hypothesized, including employee motivation and ownership. The then emerging field of cognitive systems engineering and 'joint cognitive systems' (Hollnagel and Woods, 1983) further pushed the notion that context was key to understanding human-automation performance.

Many well-known models of human performance also espouse mesoergonomic relationships. Models of human performance with respect to safety by Reason (1995, 2000), Rasmussen (Rasmussen, 1997) and others (e.g., Amalberti, 2001; Karsh et al., 2006; Carayon et al., 2006), all depict that national, industry, organization, department and/or unit variables can, directly or indirectly, influence individual performance. Rasmussen's models (Rasmussen, 1997) has been used several times to describe how higher level system variables can impact human performance (Cassano-Piche et al., 2008; Cook and Rasmussen, 2005; Vicente, 2003; Vicente