Published in final edited form as:
IIE Trans Occup. 2015 ; 3(1): 1–8. doi:10.1080/21577323.2015.1027638.

Occupational Macroergonomics: Principles, Scope, Value, and Methods

Richard J. Holden[1,*], **A. Joy Rivera**[2], and **Pascale Carayon**[3,4]

[1]Department of BioHealth Informatics, School of Informatics and Computing, Indiana University, Walker Plaza – WK319, 719 Indiana Avenue, Indianapolis, IN 46202, USA

[2]Children's Hospital of Wisconsin, Milwaukee, Wisconsin, USA

[3]Department of Industrial and Systems Engineering, University of Wisconsin-Madison, Madison, Wisconsin, USA

[4]Center for Quality and Productivity Improvement, University of Wisconsin-Madison, Madison, Wisconsin, USA

This year marks the 35th anniversary of Hal Hendrick's (1980) report to the US Human Factors Society, considered by some as the origin of macroergonomics as a formal subdiscipline of human factors/ergonomics (HFE) (Hendrick, 2002). The report itself dealt with future trends in work and implications for HFE, but importantly it sparked a discourse on the critical importance of considering factors beyond the human, machine, or human-machine interface. Nowadays, the macroergonomic dicta to "think big(ger)" and "think systems" are embraced by the global HFE community and are arguably principles shared by all HFE professionals (Dul et al., 2012; Wilson, 2014).

In 2012, the HFE community lost a dear friend and colleague, Professor Ben-Tzion (Bentzi) Karsh, a champion of macroergonomics and systems-thinker who "thought big(ger)" and inspired others to do the same. This special issue is dedicated to the late Professor Karsh. It reflects his passion and insight, echoing several of Karsh's most significant scientific publications. In particular, the included articles collectively examine macroergonomics as an indispensable whole-systems perspective on human work; a source of practical tools, methods, and approaches; and an evolving science and practice that draws on other fields but is developing its own identity.

1. The fundamental principles of macroergonomics

Macroergonomics, also known as organizational ergonomics, shares many of the principles of HFE at large (Dul et al., 2012):

- It takes a systems approach: performance results from interactions in a sociotechnical system, of which the person is one component.

*Corresponding author. rjholden@iupui.edu.

In memory of Professor Ben-Tzion (Bentzi) Karsh, 1971–2012

- It is design driven: performance is improved by designing and redesigning systems to accommodate and support humans' capabilities and activities.
- It has a dual goal of improving performance and wellbeing: outcomes to balance include "productivity, efficiency, effectiveness, quality, innovativeness, flexibility, (systems) safety and security, reliability, sustainability, …health and safety, satisfaction, pleasure, learning, [and] personal development" (Dul et al., 2012, p. 379).

The systems perspective includes the concept of interactions between components of the system. Wilson (2000) argued that expertise in assessing and designing these interactions is a unique competence of the HFE discipline and Hendrick (1991) noted that a strength of macroergonomics is understanding these interactions in the context of a broader sociotechnical system, such as an organization or a community. The definition of sociotechnical systems varies from model to model (Carayon, 2006), yet it is noteworthy that several models of systems include high-level community, political, regulatory, and sociocultural factors (Carayon et al., 2014; Holden et al., 2013; Kleiner, 2006; Moray, 2000). For instance, in depicting the healthcare system, Karsh et al (Holden & Karsh, 2009; Karsh, Holden, Alper, & Or, 2006) depicted people nested in work units, nested in organizations, nested in an external environment of industry and workforce factors and extra-organizational rules, standards, legislation, and enforcement (see Figure 1). Karsh and colleagues' (2006) model and others like it (e.g., Moray, 2000) illustrate another fundamental principle of macroergonomics, which can be summarized as "context matters": lower-level systems are nested in and shaped by higher-level systems. Karsh wrote about the cross-level effects that describe the influence of context on a system and vice versa (Holden & Karsh, 2007, 2009; Karsh, 2006; Karsh, Waterson, & Holden, 2014). The concepts of nesting and cross-level effects actually reveal a subtle point about the definition of macroergonomics: it is not concerned purely with high-level factors such as organizational safety culture but rather with multiple factors *including* high-level ones and the interactions within and between these multiple layers (Karsh et al., 2014). This is illustrated in Figure 2 using the metaphor of the *matryoshka* Russian nesting doll.

Wilson (2014) argues that, when context is considered, the breadth and complexity of most systems of interest to HFE professionals cannot be replicated in the laboratory. Consistent with this, it is fair to say that most macroergonomic endeavors take place in the field of practice, where the complexity of systems is preserved and even embraced by researchers or practitioners. Furthermore, macroergonomic research and practice generally follows the principle of "multiple" (Haims & Carayon, 1998): using multiple methods including qualitative and quantitative ones, considering multiple levels of analysis, examining multiple actors and their multiple perspectives, designing a system for multiple users and tasks, measuring at multiple time points, and drawing on multiple disciplines. Finally, macroergonomics gives due concern to how HFE and other innovations are both designed *and* implemented; this is observed in the subdiscipline's development of participatory ergonomics approach (Brown Jr., 2002; Vink, Imada, & Zink, 2008; Zink, Steimle, & Schröder, 2008).

2. The scope of macroergonomics

The scope of macroergonomics is large, as illustrated by the special issue articles. They span the domains of construction (Ghosh & Dickerson, 2015), healthcare (Fray, Waterson, & Munro, 2015), and manufacturing (Larson, Wick, Hallbeck, & Vink, 2015). Kubek, Fischer, and Zink (2015) implicate entire international supply chains in their conceptualization of macroergonomics for sustainable work systems. The papers also address a wide range of topics:

- Larson et al (2015) evaluate the nature of successful HFE interventions with implications for assessing and promoting corporate ergonomic programs.
- Weidman, Dickerson, and Koebel (2015) develop a conceptual model and survey instrument for assessing the factors that influence industry adoption of a national macroergonomic initiative.
- Sznelwar and Hubault (2015) examine workers' goal-directed activity as a guiding principle and resource for the participatory design of work organization.
- Ghosh and Dickerson (2015) adapt a measurement approach for interpersonal interactions to describe communication in construction project meetings.
- Fray et al. (2015) study the relationship between patient handling and patient safety climate in a UK hospital.
- Kubek et al. (2015) consider the concept of a sustainable work system as a potential paradigm for HFE and macroergonomics.

This range of topics is not unusual in macroergonomic research and practice. For comparison, a recent review of macroergonomic research in healthcare (Carayon et al., 2013) included the following topics:

- Job design (job stress and burnout, workload, interruptions).
- Patient-centered care and the design of "patient work" (see Valdez, Holden, Novak, & Veinot, in press).
- Health information technology and medical devices.
- Violations and patient safety.
- Care coordination across the continuum of care.
- Healthcare system design and redesign.
- Usability in the organizational context.
- Organizational learning and resilience.
- Healthcare quality and patient safety.

Consistent with the above, Karsh's work often noted the importance of addressing multiple aspects of complex phenomena, for example, both the usability of an information system's interface and its implementation (Karsh, 2004, 2009; Karsh, Weinger, Abbott, & Wears, 2010), both workers' performance and their wellbeing (Holden et al., 2011; Karsh, Beasley,

& Hagenauer, 2004), both errors and violations as inputs into safety (Alper et al., 2012; Koppel, Wetterneck, Telles, & Karsh, 2008), both the positive and negative side of interruptions (Rivera & Karsh, 2010), and both social and technical aspects of technology (Carayon & Karsh, 2000).

The level of analysis in the special issue papers ranges from individual to team to activity system to organization to global system. In a series of papers, Karsh argued both for examining phenomena at various levels of analysis and applying theories and multilevel statistical methods to understand the relationships between these levels (Holden et al., 2013; Holden & Karsh, 2009; Karsh, 2006; Karsh & Brown, 2010; Karsh, Escoto, Beasley, & Holden, 2006; Karsh et al., 2014). He described the value of doing so for theory, measurement, analysis, interpretation, and interventions, concluding that "more robust macroergonomic theories may emerge … which in turn may lead to more efficacious solutions in the workplace" (Karsh, 2006, p.4). Following suit, Fray et al. (2015) use Karsh et al.'s (2014) mesoergonomics paradigm to examine cross-level effects between work-related musculoskeletal disorders (WMSDs) and organizational safety climate at the hospital ward level.

Furthermore, the papers address phenomena that are physical, social, organizational, and often some combination of these. The distinction of above-the-neck (cognitive) and below-the-neck (physical) ergonomics (Hollnagel, 1997) is not as clear in macroergonomics because cognitive and physical factors should be considered when using a whole-systems perspective (Figure 1), and are inter-related and influence each other (Carayon, Smith, & Haims, 1999). Indeed, Larson et al. (2015) describe a variety of successful physical ergonomics programs that address system usability, automation, task and process redesign, quality control, supply chain, and more, casting doubt on a clear distinction between physical, cognitive, and organizational. Ghosh and Dickerson (2015) situate an ostensibly cognitive phenomenon of team communication in the broader social context governed by politics, status, and relationships. Sznelwar and Hubault (2015) provides another excellent example, noting that the work of a bus driver is not all about driving a vehicle: s/he must also ensure the safety of passengers and others on the road, remain on schedule, answer questions, assist others, deal with violence, and cope with unique events. Therefore, macroergonomics provides the conceptual frameworks and approaches for understanding the whole system to be designed, not just its individual components.

These broad-spanning, multiple-level combinations and connections of the social, technical, cognitive, physical, organizational, and super-organizational add to an ongoing debate about whether it is appropriate to divide HFE into physical, cognitive, social, micro-, meso-, macro-, cultural, community, sustainable or any other type of ergonomics, (Holden, 2012; Hollnagel, 1997; Smith-Jackson, Resnick, & Johnson, 2014; Smith et al., 2002; Wilson, Jackson, & Nichols, 2003). As an alternative, we could embrace all of these areas as the primary colors of HFE that blend in different proportions in each HFE endeavor. In general, we use the term macroergonomics as a reminder to "think big(ger)" and "think systems"; at the same time, we look forward to a day when this distinction is obsolete and HFE professionals worldwide "think big(ger)" and "think systems" by default.

3. The value of (macro)ergonomics

Hal Hendrick (1996) famously stated, “good ergonomics is good economics.” Others have urged evaluations of the value of HFE in general and macroergonomics in particular, on economic and other dimensions (Dul et al., 2012; Dul & Neumann, 2009; Tompa, Dolinschi, & Natale, 2013). There are many complexities to measuring the value of macroergonomics and specific challenges for evaluating the financial cost-benefit (Kerr, Knott, Moss, Clegg, & Horton, 2008; Neumann & Dul, 2009). Among them are defining value, linking value to macroergonomic interventions and specific intervention components, and measuring value —especially across settings. Moreover, when macroergonomics is incorporated early in the design process to eliminate future hazards or difficulties, it can be hard to estimate what could have gone wrong (Bias & Mayhew, 2005). An additional challenge is identifying *for whom* macroergonomics has value (Hancock & Drury, 2011). Fischer et al (2015) address this topic and ask, for example, are employee, organizational, and environmental stakeholders equal recipients of value and at whose expense is value created? In an ambitious evaluation of the 3M Corporation’s HFE intervention programs submitted for an internal ergonomics innovation award, Larson et al (2015) attempt to assess the nature of successful ergonomic interventions. They conclude that ergonomic interventions appear associated with both operational efficiency and WMSD reduction. This is a promising evaluation that bears repeating.

It is important to demonstrate and document value to key stakeholders, especially for a discipline that may not be a household name. Weidman et al.’s (2015) rigorous survey development paper gives one reason why: even for a well-publicized and large-scale national macroergonomic program, adoption and acceptance are not guaranteed and depend on stakeholder perceptions of the programs usefulness, and cost – i.e., value.

4. Macroergonomic methods and approaches

Methods and measures should be at least as diverse and complex as the phenomena they attempt to address (cf. Ashby, 1956). Having described the broad scope of macroergonomic and the complex sociotechnical systems where marcroergonomic phenomena occur, it is no surprise that macroergonomic methods are diverse, evolving, draw on many other fields of science and practice, and are often combined in a given project. Macroergonomic methods also range from broad approaches such as participatory ergonomics (Brown Jr., 2002) to step-by-step procedures for analyzing the structures and processes of work systems (Hendrick & Kleiner, 2001; Karsh & Alper, 2005; Robertson, Kleiner, & O'Neill, 2002). Several papers in the special issue have a methods focus. Some adapt approaches from other fields, such as Ghosh and Dickerson’s (2015) demonstration of the Interaction Process Analysis for analyzing communication during construction projects. Fray et al. (2015) use the Safety Culture Survey, developed by safety scientists. Weidman et al. (2015) leverage multiple useful theories and a standard scale development process to produce a measurement tool of large potential value for macroergonomics. Other papers describe the use of methods and approaches originating in macroergonomics, such as the Ergonomic Work Analysis in Sznelwar and Hubault (2015), the mesoergonomic paradigm and the Tool for Risks Outstanding in Patient Handling Interventions (TROPHI) in Fray et al. (2015) or the

Ergonomics Job Analysis (EJA) and Engineering Design Criteria (EDC) tools used in the 3M Corporation's risk reduction program in Larson et al. (2015).

We encourage both approaches: adapting what exists and developing and testing new methods, tools, and theories. Cognitive work analysis (Vicente, 1999) and many forms of cognitive task analysis (Hoffman & Militello, 2009) are already well suited to macroergonomic pursuits. Other useful approaches are being newly developed, such as the Prevention by Design approach described by Weidman et al. (2015) and the Intervention Design and Analysis Scorecard (IDEAS) (Robertson et al., 2013). Future macroergonomic methods could focus on product design and evaluation, teamwork, virtual environments, and adaptive human activity (see also Sznelwar & Hubault, 2015).

Implementing macroergonomic methods, whatever their origin, can be its own challenge. There are many way of doing it, as Larson et al.'s (2015) paper clearly shows. In the field, even basic techniques such as audio or videorecording can be difficult or impossible (Ghosh & Dickerson, 2015). A decade ago, Karsh reflected on the challenges of conducting macroergonomic research in the field, the politics and social issues related to these studies, and the potential disruptiveness. He likened a macroergonomic project to any other change process, even when no intervention is introduced. Karsh concluded that if macroergonomic research is an organizational change, it can be managed as an organizational change. Thereafter, Karsh and colleagues described the principles of sociotechnical change management and practical considerations for ensuring the success of a macroergonomic research project (Holden, Alper, Rivera, Or, & Karsh, 2008; Holden, Or, Alper, Rivera, & Karsh, 2008). The 'change management framework for macroergonomic field research' has since been used to describe the challenges of conducting macroergonomic research in people's homes and communities, as opposed to institutional settings (Holden, McDougald Scott, Carayon, Hoonakker, & Hundt, 2014; Holden, McDougald Scott, Hoonakker, Hundt, & Carayon, in press). Other models can be helpful to think about how macroergonomics and macroergonomic projects are innovations that must be diffused, accepted, and sustained (Carayon, 2010; Weidman et al., 2015).

5. Concluding remarks

Despite the challenges of "doing" macroergonomics, we have no doubt that macroergonomics can and should be "done." We have noted that its fundamental principles overlap with those of HFE generally and urge for the uptake of additional principles such as the "multiple" approach and the importance of field research. There appears to be value added by the use of macroergonomic approaches, theories, tools, and methods, for local and global change (Scott, 2008). There is also much opportunity to clearly and rigorously determine and document this value (Hendrick, 1996) in a variety of domains, e.g., healthcare (Xie & Carayon, 2015). We see much promise in the ongoing adaptation and new development of theories and methods for conducting macroergonomic projects.

All in all, as we reflect on the past, present, and future of macroergonomics, we are reminded of Professor Bentzi Karsh's profound contributions to HFE and macroergonomics. We aspire to continue what he started with an equal level of passion, intelligence, and pride.

Acknowledgements

This article and special issue are dedicated to Professor Ben-Tzion Karsh, PhD (1971–2012).

Funding

Author RJH is supported by an award from the National Institute on Aging (NIA) of the US National Institutes of Health (NIH) (K01AG044439).

References

Alper SJ, Holden RJ, Scanlon MC, Patel NR, Kaushal R, Skibinski K, Karsh B. Self-reported violations during medication administration in two pediatric hospitals. BMJ Quality & Safety. 2012; 21:408–415.

Ashby, WR. An Introduction to Cybernetics. London: Chapman & Hall; 1956.

Bias, RG.; Mayhew, DJ. Cost-Justifying Usability: An Update for the Internet Age. 2nd ed. San Francisco, CA: Morgan Kaufmann; 2005.

Brown, O, Jr. Macroergonomic methods: Participation. In: Hendrick, HW.; Kleiner, BM., editors. Macroergonomics: Theory, methods and applications. Mahwah, NJ: Lawrence Erlbaum Associates; 2002. p. 24-44.

Carayon P. Human factors of complex sociotechnical systems. Applied Ergonomics. 2006; 37:525–535. [PubMed: 16756937]

Carayon P. Human factors in patient safety as an innovation. Applied Ergonomics. 2010; 41(5):657–665. [PubMed: 20106468]

Carayon P, Karsh B. Sociotechnical issues in the implementation of imaging technology. Behaviour & Information Technology. 2000; 19(4):247–262.

Carayon P, Karsh B, Gurses AP, Holden RJ, Hoonakker P, Hundt AS, Wetterneck TB. Macroergonomics in healthcare quality and patient safety. Reviews of Human Factors and Ergonomics. 2013; 8:4–54.

Carayon P, Smith MJ, Haims MC. Work organization, job stress, and work-related musculoskeletal disorders. Human Factors. 1999; 41(4):644–663. [PubMed: 10774134]

Carayon P, Wetterneck TB, Rivera-Rodriguez AJ, Hundt AS, Hoonakker P, Holden RJ, Gurses AP. Human factors systems approach to healthcare quality and patient safety. Applied Ergonomics. 2014; 45(1):14–25. [PubMed: 23845724]

Dul J, Bruder R, Buckle P, Carayon P, Falzon P, Marras WS, van der Doelen B. A strategy for human factors/ergonomics: Developing the discipline and profession. Ergonomics. 2012; 55:377–395. [PubMed: 22332611]

Dul J, Neumann WP. Ergonomics contributions to company strategies. Applied Ergonomics. 2009; 40(4):745–752. [PubMed: 18775532]

Fray M, Waterson, Munro. Macro and micro ergonomic outcomes in healthcare: Unravelling the relationship between patient handling performance and safety climate. IIE Transactions on Occupational Ergonomics and Human Factors. 2015

Ghosh, Dickerson DE. Modified Interaction Process Analysis as a Macroergonomic Method of Analyzing Communication Patterns in Construction. IIE Transactions on Occupational Ergonomics and Human Factors. 2015

Haims MC, Carayon P. Theory and practice for the implementation of 'in-house', continuous improvement participatory ergonomic programs. Applied Ergonomics. 1998; 29:461–472. [PubMed: 9796792]

Hancock PA, Drury CG. Does human factors/ergonomics contribute to the quality of life? Theoretical Issues in Ergonomics Science. 2011; 12:1–11.

Hendrick, HW. Human factors in management. Presented at the symposium on professional planning, 1980–2000; Human Factors Society 24th Annual Meeting; Los Angeles, CA. 1980.

Hendrick HW. Ergonomics in organizational design and management. Ergonomics. 1991; 34:743–756.

Hendrick, HW. Good ergonomics is good economics. Santa Monica, CA: Human Factors and Ergonomics Society; 1996. Available at: http://www.hfes.org/Web/PubPages/goodergo.pdf.

Hendrick, HW. An overview of macroergonomics. In: Hendrick, HW.; Kleiner, BM., editors. Macroergonomics: Theory, methods and applications. Mahwah, NJ: Lawrence Erlbaum Associates; 2002. p. 1-23.

Hendrick, HW.; Kleiner, BM. Macroergonomics : An Introduction to Work System Design. Vol. 2. Santa Monica, CA: Human Factors & Ergonomics Society; 2001.

Hoffman, RR.; Militello, LG. Perspectives on Cognitive Task Analysis : Historical Origins and Modern Communities of Practice. New York: Psychology Press; 2009.

Holden RJ. Social and personal normative influences on healthcare professionals to use information technology: Towards a more robust social ergonomics. Theoretical Issues in Ergonomics Science. 2012; 13:546–569. [PubMed: 23066349]

Holden, RJ.; Alper, SJ.; Rivera, AJ.; Or, CKL.; Karsh, B. Macroergonomic field research reframed: What can be (and has been) learned by field researchers from change management theory; Paper presented at the 9th International Symposium on Human Factors in Organizational Design and Management; São Palo, Brazil. 2008.

Holden RJ, Carayon P, Gurses AP, Hoonakker P, Hundt AS, Ozok AA, Rivera-Rodriguez AJ. SEIPS 2.0: A human factors framework for studying and improving the work of healthcare professionals and patients. Ergonomics. 2013; 56(11):1669–1686. [PubMed: 24088063]

Holden RJ, Karsh B. A review of medical error reporting system design considerations and a proposed cross-level system research framework. Human Factors. 2007; 49:257–276. [PubMed: 17447667]

Holden RJ, Karsh B. A theoretical model of health information technology usage behaviour with implications for patient safety. Behaviour & Information Technology. 2009; 28:21–38.

Holden RJ, McDougald Scott AM, Carayon P, Hoonakker P, Hundt AS. Macroergonomics in the wild: research challenges in community settings. Human Factors in Organizational Design and Management – XI. 2014:613–614.

Holden RJ, McDougald Scott AM, Hoonakker PLT, Hundt AS, Carayon P. Data collection challenges in community settings: Insights from two field studies of patients with chronic disease. Quality of Life Research. (in press).

Holden RJ, Or CKL, Alper SJ, Rivera AJ, Karsh B. A change management framework for macroergonomic field research. Applied Ergonomics. 2008; 39:459–474. [PubMed: 18417095]

Holden RJ, Scanlon MC, Patel NR, Kaushal R, Escoto KH, Brown RL, Karsh B. A human factors framework and study of the effect of nursing workload on patient safety and employee quality of working life. BMJ Quality & Safety. 2011; 20:15–24.

Hollnagel E. Cognitive ergonomics: It's all in the mind. Ergonomics. 1997; 40:1170–1182.

Karsh B. Beyond usability for patient safety: designing effective technology implementation systems. Quality & Safety in Health Care. 2004; 13:388–394. [PubMed: 15465944]

Karsh, B. Meso-ergonomics: A new paradigm for macroergonomics research; Paper presented at the International Ergonomics Association; Maastricht, Netherlands. 2006.

Karsh, B. Clinical practice improvement and redesign: How change in workflow can be supported by clinical decision support. AHRQ Publication No. 09-0054-EF. Rockville, MD: Agency for Healthcare Research and Quality; 2009.

Karsh, B.; Alper, SJ. Advances in patient safety: From research to implementation. Rockville, MD: Agency for Healthcare Research and Quality; 2005. Work system analysis: the key to understanding health care systems; p. 337-348.

Karsh B, Beasley JW, Hagenauer ME. Are electronic medical records associated with improved perceptions of the quality of medical records, working conditions, or quality of working life? Behaviour & Information Technology. 2004; 23:327–335.

Karsh B, Brown R. The impact of levels on theory, measurement, analysis, and intervention in medical error research: the case of patient safety health information technology. Applied Ergonomics. 2010; 41:674–681. [PubMed: 20153456]

Karsh B, Escoto KH, Beasley JW, Holden RJ. Toward a theoretical approach to medical error reporting system research and design. Applied Ergonomics. 2006; 37:283–295. [PubMed: 16182233]

Karsh B, Holden RJ, Alper SJ, Or CKL. A human factors engineering paradigm for patient safety – designing to support the performance of the health care professional. Quality & Safety in Health Care. 2006; 15:i59–i65. [PubMed: 17142611]

Karsh B, Waterson PE, Holden RJ. Crossing levels in systems ergonomics: A framework to support 'mesoergonomic' inquiry. Applied Ergonomics. 2014; 45(1):45–54. [PubMed: 23706573]

Karsh B, Weinger MB, Abbott PA, Wears RL. Health information technology: Fallacies and sober realities. Journal of the American Medical Informatics Association. 2010; 17(6):617–623. [PubMed: 20962121]

Kerr MP, Knott DS, Moss MA, Clegg CW, Horton RP. Assessing the value of human factors initiatives. Applied Ergonomics. 2008; 39(3):305–315. [PubMed: 18096132]

Kleiner BM. Macroergonomics: Analysis and design of work systems. Applied Ergonomics. 2006; 37:81–89. [PubMed: 16226212]

Koppel R, Wetterneck TB, Telles JL, Karsh B. Workarounds to barcode medication administration systems: Their occurrences, causes, and threats to patient safety. Journal of the American Medical Informatics Association. 2008; 15:408–423. [PubMed: 18436903]

Kubek, Fischer K, Zink KJ. Sustainable work systems: A challenge for macroergonomics? IIE Transactions on Occupational Ergonomics and Human Factors. 2015

Larson N, Wick, Hallbeck, Vink. Corporate Ergonomics Programs: Identifying value through a company award process. IIE Transactions on Occupational Ergonomics and Human Factors. 2015

Moray N. Culture, politics and ergonomics. Ergonomics. 2000; 43:858–868. [PubMed: 10929822]

Neumann, WP.; Dul, J. A systematic review of ergonomics' benefits for HR & engineering; Paper presented at the International Ergonomics Association (IEA) Congress; Beijing, China. 2009.

Rivera AJ, Karsh B. Interruptions and distractions in healthcare: Review and reappraisal. Quality & Safety in Health Care. 2010; 19(4):304–312. [PubMed: 20378621]

Robertson MM, Henning R, Warren N, Nobrega S, Dove-Steinkamp M, Tibirica L, Bizarro A. The Intervention Design and Analysis Scorecard: a planning tool for participatory design of integrated health and safety interventions in the workplace. J Occup Environ Med. 2013; 55(12 Suppl):S86–S88. [PubMed: 24284761]

Robertson, MM.; Kleiner, BM.; O'Neill, MJ. Macroergonomic Methods: Assessing Work System Processes. In: Hendrick, HW.; Kleiner, BM., editors. Macroergonomics: Theory, methods and applications. Mahwah, NJ: Lawrence Erlbaum Associates; 2002. p. 67-96.

Scott PA. Global inequality, and the challenge for ergonomics to take a more dynamic role to redress the situation. Applied Ergonomics. 2008; 39(4):495–499. [PubMed: 18384753]

Smith-Jackson, TL.; Resnick, ML.; Johnson, HT., editors. Cultural Ergonomics: Theory, Methods, and Applications. Boca Raton, FL: CRC Press; 2014.

Smith, JH.; Cohen, WJ.; Conway, FT.; Carayon, P.; Derjani-Bayeh, A.; Smith, MJ. Community ergonomics. In: Hendrick, HW.; Kleiner, BM., editors. Macroergonomics: Theory, Methods, and Applications. Mahwah, NJ: Lawrence Erlbaum; 2002. p. 289-309.

Sznelwar LI, Hubault. Work activities as a resource for work organization design and for strategic decisions? IIE Transactions on Occupational Ergonomics and Human Factors. 2015

Tompa E, Dolinschi R, Natale J. Economic evaluation of a participatory ergonomics intervention in a textile plant. Applied Ergonommics. 2013; 44(3):480–487.

Valdez RS, Holden RJ, Novak LL, Veinot TC. Transforming consumer health informatics through a patient work framework: Connecting patients to context. Journal of the American Medical Informatics Association. (in press).

Vicente, KJ. Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work. Mahwah, NJ: Erlbaum; 1999.

Vink P, Imada AS, Zink KJ. Defining stakeholder involvement in participatory design processes. Applied Ergonomics. 2008; 39(4):519–526. [PubMed: 18417096]

Weidman, Dickerson DE, Koebel. Prevention through Design (PtD): A macro-ergonomic conceptual approach to risk reduction. IIE Transactions on Occupational Ergonomics and Human Factors. 2015

Wilson JR. Fundamentals of ergonomics in theory and practice. Applied Ergonomics. 2000; 31:557–567. [PubMed: 11132041]

Wilson JR. Fundamentals of systems ergonomics/human factors. Applied Ergonomics. 2014; 45:5–13. [PubMed: 23684119]

Wilson, JR.; Jackson, S.; Nichols, S. Cognitive work investigation and design in practice: The influence of social context and social work artefacts. In: Hollnagel, E., editor. Handbook of Cognitive Task Design. Mahwah, NJ: Lawrence Erlbaum; 2003. p. 83-97.

Xie A, Carayon P. A systematic review of human factors and ergonomics (HFE)-based healthcare system redesign for quality of care and patient safety. Ergonomics. 2015; 58(1):33–49. [PubMed: 25323570]

Zink KJ, Steimle U, Schröder D. Comprehensive change management concepts: Development of a participatory approach. Applied Ergonomics. 2008; 39(4):527–538. [PubMed: 18395184]

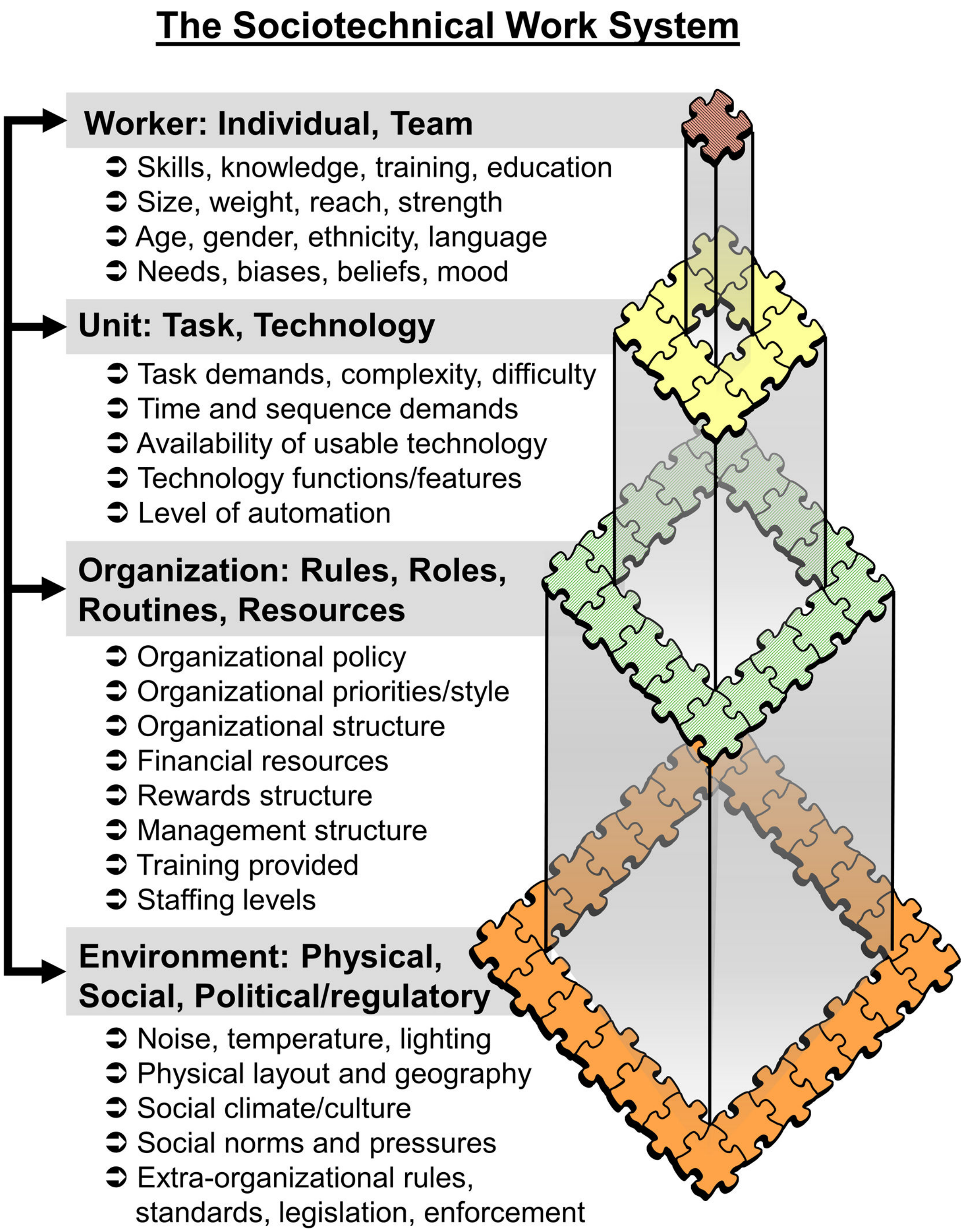

Figure 1.

Depiction of the multiple-level sociotechnical work system. Adapted from (Holden & Karsh, 2009; Karsh, Holden, et al., 2006)

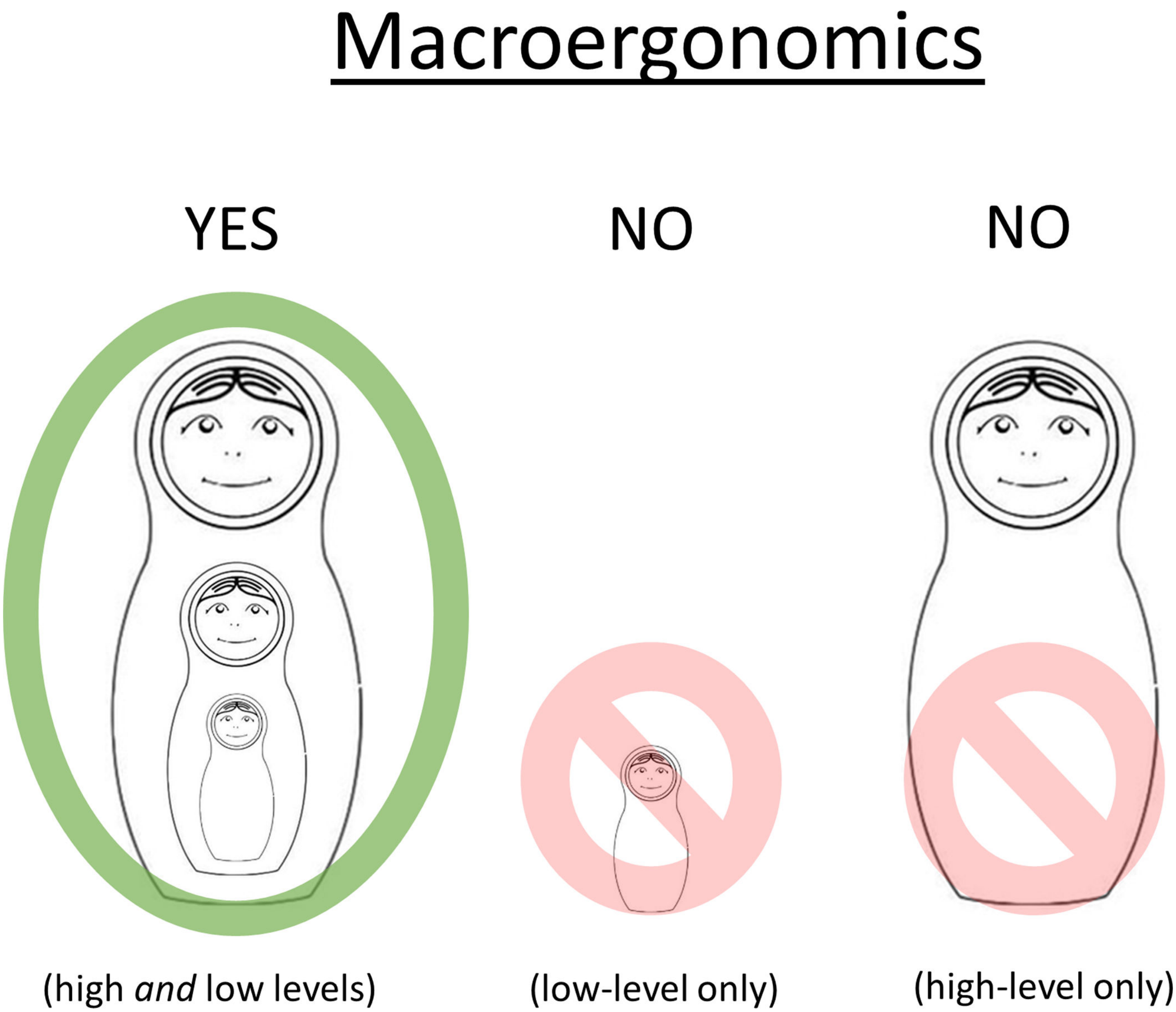

Figure 2.
Macroergonomics as a subdiscipline concerned with both systems and phenomena across levels (left) not at lower levels (middle) or higher levels (right) alone.