Accident Analysis and Prevention 68 (2014) 16–24

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

The next generation of macroergonomics: Integrating safety climate

Lauren A. Murphy[a,b,*], Michelle M. Robertson[b], Pascale Carayon[c]

[a] Harvard School of Public Health, Boston, MA, USA
[b] Liberty Mutual Research Institute for Safety, Hopkinton, MA, USA
[c] University of Wisconsin, Madison, WI, USA

ARTICLE INFO

Article history:
Received 1 May 2013
Received in revised form 30 October 2013
Accepted 25 November 2013
Available online 9 December 2013

Keywords:
Macroergonomics
Safety climate
Sociotechnical systems theory
Mesoergonomics

ABSTRACT

To date little research has examined safety climate in relation to macroergonomics and how the two distinct sub-disciplines can be integrated to affect safety outcomes. The purpose of macroergonomics is to design a fully "harmonized" work system that improves numerous aspects of organizational performance and effectiveness, and this is accomplished by incorporating the foundational theoretical framework of sociotechnical systems theory (STS). Two broad subsystems within such a system are the personnel subsystem, the ways *individuals* perform tasks, and the technological subsystem, the *tasks* to be performed. Management is an important aspect of the personnel subsystem, and there is a growing body of research regarding supervisors' influence over employee safety. One such area of research is safety climate, which is based on the perception of workers regarding safety and organizational practices. Two major factors of safety climate are management commitment to safety and communication pertaining to safety as a true priority from both top management and direct supervisors. This article describes the conceptual overlaps of macroergonomics and safety climate in order to present a conceptual model that integrates these domains using the framework of mesoergonomics. In conclusion, we discuss how this model can serve as a framework to guide the analysis and design of work systems and subsequent organizational interventions.

1. Introduction

Macroergonomics, related to sociotechnical systems theory (Karsh et al., 2014), and safety climate are robust areas in safety and ergonomics research, each having its unique strengths and weaknesses while sharing some conceptual overlap. The strength of research on safety climate is its emphasis on the workers' perspective; workers observe occurrences and activity in the work environment and interact with others in the organization, and, with such information, form their safety perceptions. Those perceptions lead to behaviors and actions that determine the overall level of safety in an organization. The limitation of current safety climate research is the assumption that most safety issues can be solved by improving communication between workers and supervisors. While communication is very important, there may be technical issues within an organization that cannot be solved through communication alone. Macroergonomics has a more holistic approach to safety through sociotechnical systems theory where good communication is necessary but not sufficient in creating a safe, productive work environment. Safety is an outcome of a work system with components that cooperate (i.e., joint optimization) so that one subsystem (e.g., personnel, technological) is not bearing all the responsibility of keeping the entire system and its workers safe. However, one limitation of macroergonomics is the lack of specified mechanisms through which the system disperses the responsibility of safety across different subsystems. Given the conceptual overlaps between macroergonomics and safety climate, we argue that strengths in one area can be utilized while compensating for weaknesses in the other area.

The purpose of this article is to review the description and history of macroergonomics and to identify areas of overlap with safety climate and other areas where unique principles of safety climate can be used to enhance the systems approach in macroergonomics. In order to bridge to the gap between the different subdisciplines, a mesoergonomic framework will be utilized (Karsh et al., 2014). A conceptual model will then be presented to illustrate how macroergonomics and safety climate can be integrated to improve safety outcomes. We will then expand the discussion with suggestions for analyzing a work system and designing future organizational systems interventions that use the theoretical underpinnings of macroergonomics in conjunction with safety climate.

* Corresponding author at: Center for Behavioral Sciences, Liberty Mutual Research Institute for Safety, 71 Frankland Road, Hopkinton, MA 01748, USA. Tel.: +1 508 497 0200; fax: +1 508 435 0482.
E-mail addresses: Lauren.Murphy@LibertyMutual.com, lamurphy@hsph.harvard.edu (L.A. Murphy).

0001-4575/$ – see front matter
http://dx.doi.org/10.1016/j.aap.2013.11.011

2. Macroergonomics

Human factors and ergonomics (HF/E) is defined as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance" (International Ergonomics Association, 2000, "What is Ergonomics"). In particular, focusing on ergonomics can affect a number of outcomes, including safety, health, comfort, quality, productivity, and satisfaction (Hendrick, 2002). Human/machine interface technology is the first generation of ergonomics, user/interface technology is the second generation, and macroergonomics is the third generation (Hendrick, 1997; Kleiner, 2006). Macroergonomics is a subdiscipline of ergonomics concerned with organization/machine interface technology and ways to research, develop, and apply ergonomic and organizational design principles at a macro-level to work systems design (Hendrick, 1995, 1997, 2002; Hendrick and Kleiner, 2001).

Macroergonomics is integrative in that it focuses on the entire organization by utilizing knowledge, methods, and tools from a number of research areas, including sociotechnical systems, industrial/organizational psychology, cognitive ergonomics, physical ergonomics, systems engineering, and social psychology (Carayon, 2009; Karwowski et al., 2002; Kleiner, 2002; Zink, 2002). For example, organizational psychology provides principles for improving motivation and job satisfaction, enhancing organizational climate and leadership, and fostering teamwork. By using those constructs and numerous others, macroergonomics seeks to design work systems that are compatible with an organization's sociotechnical system characteristics and "then to ensure that micro-ergonomic elements are designed to harmonize with the overall work system structure and processes" (Hendrick, 2002, p. 5). When the work environment is suboptimal and misaligned, the following can be expected to be somewhat deficient: (a) adherence to safety standards and procedures that can result in lost time accidents and injuries; (b) quality; (c) productivity; and (d) motivation, job satisfaction, and perceived quality of work life (e.g., perceived stress, psychosocial discomfort; Hendrick, 2002).

2.1. Sociotechnical systems theory

Macroergonomics follows a clear and established theoretical framework: Sociotechnical systems (STS) theory. Sociotechnical systems can range from a single individual using a hand tool to a multinational organization, but a work system usually consists of two or more people interacting with some form of: (a) *job design*, (b) *software* and/or *hardware*, (c) *internal environment*, (d) *external environment*, and/or (e) *organizational design* (Hendrick, 2002). *Job design* consists of work modules, knowledge, tasks, skill requirements, opportunity for social interaction, and also factors from Hackman and Oldham's (1976) job characteristics model (i.e., autonomy, feedback, and meaningfulness obtained from skill variety, task identity, and task significance). With over 30 years of research conducted in relation to job design, a bridge has been built between theory and practice, including clear and robust guidelines to be used to design work to promote employee performance and well-being (Grant et al., 2010b). All this available information has mitigated researchers' interest in investigating issues in job design (Ambrose and Kulik, 1999; Grant et al., 2010b). Yet, new issues have emerged because of changes in the nature of work, such as a shift from manufacturing to service, an increase in task interdependence and the use of teams, and the implementation of breakthrough technology and flexible work methods like telework and virtual teams (Grant et al., 2010b; Grant and Parker, 2009; Rousseau and Fried, 2001). Newer areas of job design research include proactivity (Thomas et al., 2010), job crafting (Wrzesniewski and Dutton, 2001), and idiosyncratic deals (Rousseau et al., 2006).

Given that macroergonomics pertains to the design of work systems and focuses on organization-system interaction, it is important to discuss the influences of the design more extensively. Regarding organizational theory, both the Classical School (from the early 1900s, e.g., supervision, hierarchy, span of control, reward systems) and the Human Relations School (from the 1950s, e.g., motivation, teams) have been prominent (Kleiner, 2006). In the 1970s and 1980s, automation strongly influenced industry because of the technology being developed, and designers were promoting a "factory of the future" where the human factor, considered as disruptive and costly, was replaced with a computer-integrated, workerless system (Kleiner, 2006). Conversely, Total Quality Management was utilized by some organizations in the 1980s to develop teams and create a human-driven culture without considering technology and its methods or operations (Kleiner, 2006). Macroergonomics, conceptualized during the 1980s, integrates both the Classical and Human Relations Schools, as outlined in Smith and Carayon-Sainfort's (1989) Balance Theory and Kleiner (2006).

The work system model is the basis of the Balance Theory, and the original purpose of the Balance Theory was to improve the physical and mental health, stress, and working life of employees (Smith and Carayon-Sainfort, 1989). A work system is where an individual performs tasks using tools and technologies, and works in a physical environment that is under the control of an organization with its own policies, practices, and procedures (Carayon, 2009; Carayon and Smith, 2000; Smith and Carayon-Sainfort, 1989). All the components of a work system interact so that a change in one element of the work system can affect any other element in the work system (Carayon, 2006). The Balance Theory enhances the work system model by providing guidelines about job design and redesign (Carayon, 2009), and there are two core principles. The first principle is to remove the negative aspects found in each work system model, which can be done using knowledge from job/organizational design, job stress, and human factors and ergonomics. The second principle is to balance the work system (Smith and Carayon-Sainfort, 1989). Removing all negative aspects of a work system may not be practical or possible, but either the well-functioning aspects can be used to compensate for the negative aspects or a balance can be achieved by having positive aspects counteract the negative aspects in a work system (Carayon, 2009). A balanced system leads to individual outcomes such as high safety and well-being, good health, low stress, and optimal performance (Carayon, 2009).

One such case is reported in Robertson et al. (2008) where the effects of a office ergonomics intervention, conducted in a field setting with office and computer knowledge workers as participants, were examined longitudinally. This study found overall positive, significant effects on outcome variables of psychosocial factors, workspace satisfaction, musculoskeletal health, and performance for the two intervention groups compared to the control group. The intervention group that was exposed to a change in workstation design and participated in office ergonomics training showed significant improvements by reporting a higher sense of community (communicating corporate culture) and ergonomic climate than the workstation-only and control group over time. Improvements in the musculoskeletal health were revealed for both the workstation-only and workstation + training intervention groups compared to a control group; however, the magnitude of change for the workstation + training group was relatively larger. Results of the business process analyses revealed the impact that the flexible workspace and training had on reducing process cycle time costs. The workstation + training group demonstrated almost double the reduction in process time compared to the workstation-only group, indicating that the training had additional positive effects on process time beyond the effects of the workspace itself. Regression analysis showed that the flexible workspace and training were significant predictors of these process cycle time reductions. The trained group also reported a higher sense of belonging to the organization and a more positive sense of community with the organization than the workstation-only group, indicating that the driving force may not have been only the workspace redesign, but these important values being conveyed by management as delivered in the training. Together, these findings support the notion that workspace design and training influence psychosocial factors and can have positive effects on quantitative measures of organizational output.

In the macroergonomics approach, *software* refers to management-based factors (i.e., policies/rules, procedures, manuals) and *hardware* is typically tools, equipment, machines, workspaces, and buildings (Robertson et al., 2002). Management plays a key role in safety climate theory, and a major concept in the safety climate literature is the discrepancy between formal and informal policies and practices; the more consistency there is between the formal policies written by top management and the informal practices established by the supervisors of an organization, the stronger the consensus among employee climate perceptions (Huang et al., 2013). Hardware is given less attention by safety climate researchers, but both the software and hardware interactions, as work systems elements, can greatly affect safety outcomes.

The *internal environment* can be thought of as psychosocial factors (e.g., cognitive complexity) and physical parameters (i.e., noise, temperature, air quality, humidity, illumination, and vibration). The culture of an organization is also included as part of the internal environment (Haro and Kleiner, 2008; Kleiner, 2006, 2008). Culture and climate are distinct constructs, and there are varying definitions for each. Some researchers view culture and climate in a layered model where culture is at the core and includes basic values, principles, convictions, and assumptions. The outer layers of that layered model are climate and they are the more visible expressions of culture like artifacts and rituals (Guldenmund, 2000; Schein, 1992). Cox and Flin (1998) used personality as an analogy; culture is a trait that is fixed and climate is mood that is more variable. Numerous recent meta-analyses have shown safety climate to be a leading indicator of accidents and injuries (Beus et al., 2010; Christian et al., 2009; Nahrgang et al., 2011). The importance of safety climate as an antecedent of accidents and injuries sets it apart from other aspects of the internal environment and has led to safety climate's prominence in safety research.

The *external environment* consists of elements that can permeate an organization and to which an organization must be responsive in order to be successful (Hendrick, 2002). The degree of stability or change of cultural, economic, and political factors is particularly important for an organization to be aware of when it comes to the external environment. *Organizational design* is comprised of organizational structure and processes (Hendrick, 2002). According to Leveson (2011), "...any open-system hierarchy (either biological or man-made) will require a set of processes in which there is communication or information for regulation or control" (p. 66). Having a good safety climate, in which the value and priority of safety are communicated, will lead to fewer accidents and injuries (Zohar, 1980, 2010).

The work system is composed of people in the form of a personnel subsystem (also referred to as a social subsystem) and technology in the form of a technological subsystem (also referred to as a technical subsystem). The personnel subsystem defines the ways *individuals* perform tasks and the technological subsystem defines the *tasks* to be performed (Hendrick, 2002; Kleiner, 2008). A key component of the personnel subsystem is management, and there is a growing body of research concerning the influence of supervisors in the safety literature, with the major construct being safety climate (Zohar, 2003). Safety climate is important because it is about the true priority of safety in an organization. As Deborah Hersman stated during her opening statement at the National Transportation Safety Board Forum in September 2013:

> If safety is truly a core value, it resonates at all levels and permeates into the practice of every single individual so that they do the right thing, even when nobody is watching because they believe it is the right thing. And it is about establishing and maintaining an atmosphere where safety is paramount and employees make the right decisions over profits, over time constraints, over obstacles...without fear of reprisal for doing the right thing.

In order to achieve a high safety climate where safety is paramount, the system elements and levels must be aligned so that all aspects, including equipment, production/work processes, policies, and communication, fulfill the goal of creating a safe, productive work environment.

The technological subsystem is defined as "the techniques used by an organization or its subunits to transform inputs into outputs" (Billings et al., 1977, p. 319). The technological subsystem can be mistaken for aspects relating strictly to "technology," but technological (or technical) refers to "non-human," which includes structural aspects of work (Trist, 1981). Dimensions of job structure/design that are strongly related to work characteristics include autonomy, skill variety, and task significance (Brass, 1985; Morgeson et al., 2010).

The two subsystems are mutually interdependent and interact with each other in order to transform an input into an output, which is the functional task of a work system (Clegg, 2000; Trist, 1981). The effectiveness of a work system is determined by how well the personnel and technological subsystems are designed in relation to one another and the demands of the external environment (Pasmore, 1988). Examining safety climate in conjunction with macroergonomics allows researchers to use the rich information gathered in both literatures regarding the more social aspects of work to inform ways to improve the more technological aspects of the system and to align the subsystems for a harmonized work system design.

2.1.1. Theoretical strengths and weaknesses of STS theory

STS theory, as the theoretical framework for macroergonomics, is used to select a work system design that is compatible with both the characteristics of the relevant external environment and the psychosocial and skill characteristics of the workers, and to employ available technology that is congruent with each (Emery and Trist, 1960). There have been criticisms of STS theory, primarily because its propositions lack specificity (Grant et al., 2010a). Also, there have been few empirical tests and conceptual developments in the past two decades (Parker et al., 2001; Parker and Wall, 1998). However, the theory has informed past job design research (Friedlander and Brown, 1974; Rousseau, 1977), for example, and persists in presenting a meta-theoretical perspective that informs current job design research (Grant et al., 2010a). STS theory is most recognized for (Holman et al., 2002): (a) a set of design principles (Cherns, 1976, 1987), (b) a set of criteria for creating a well-designed job, and (c) the innovation of autonomous work groups (Emery, 1964). The design principles include: (a) variances in work processes should be dealt with at the source; (b) boundaries should not exist that hinder the sharing of information, knowledge, and learning; and (c) methods of working should be minimally specified (Holman et al., 2002). A well-designed job consists of social support, recognition, some level of decision-making owned by front line employees, opportunities for learning, and a reasonable level of demand (Holman et al., 2002). Given the meta-theoretical perspective of the STS model, and concern over the criticisms discussed previously (Torraco, 2005), mesoergonomics will be discussed as a supplement to address these issues. STS theory creates the structure of the work system by indicating the necessity of having social as well as technical components accounted for, but other theories like mesoergonomics may be needed to further explain the mechanism for how each system component interacts with or affects the others when viewing these interactions simultaneously.

2.1.2. Mesoergonomics

A complex system, like an organization, is composed of interrelated components, and the properties of those components will change if the system itself changes (Karsh et al., 2014). A systems approach emphasizes two aspects of social and organizational behavior: (a) movement in one part of the system leads in a predictable fashion to movement in other parts of the system and (b) a system's openness to environmental inputs leads to its continual state of flux (Katz and Kahn, 1966). As Karsh et al. (2014) state: "...adopting a systems ergonomics 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 organizational (e.g., safety culture/climate) levels of analysis (p. 2)." This is in line with Bronfenbrenner's (1994) description of a mesosystem in his ecological systems theory, with a mesosystem being defined as the linkages and processes between two or more settings (e.g., work and home, school and work) in which an individual lives.

The intention of this article is to demonstrate the importance of integrating macroergonomics and safety climate, and the concept of mesoergonomics is one proposed way to tie it all together. Mesoergonomics is an open systems approach where the relationship between variables in at least two different system levels is studied (Karsh et al., 2014). The mesoergonomic framework is based on House et al.'s (1995) meso paradigm, an organizational behavior concept in which two or more levels are examined simultaneously. Early sociotechnical systems research showed that individuals' work behavior is strongly influenced by the work organization (Cherns, 1976; Trist, 1981); human performance, including safety, is influenced by variables located higher than the level of front line workers in the organization (Karsh et al., 2014). Different models of human performance that pertain to safety and espouse mesoergonomic relationships include Reason (1995, 2000) and Rasmussen (1997), describing how national, industry, organization, department, and/or unit variables can directly or indirectly influence individuals' performance (Karsh et al., 2014). Karsh et al. (2014) identify safety climate as a good example of mesoergonomic research, explaining that variables are specifically measured at the organization, unit, and individual levels to determine cross-level relationships.

3. Safety climate

Safety climate has a considerable history of research (over 30 years) and a breadth of studies in different occupations, like manufacturing, health care, and offshore oil and gas (Brown and Holmes, 1986; DeJoy et al., 1998; Schaefer and Moos, 1996; Zohar, 1980, 2000; Zohar and Luria, 2005), and different cultures, including Western and Eastern (Felknor et al., 2000; Mearns et al., 2003; Siu et al., 2004). The study of safety climate is based on the perception of workers, with safety climate being defined as the shared perception workers form regarding their organization's policies, procedures, and practices in relation to the value and importance of safety within that organization (Griffin and Neal, 2000; Zohar, 1980, 2000, 2002, 2003). The top management of an organization determines the formal written policies, procedures, and practices to be followed by employees in that organization. However, supervisors are more closely positioned to employees in the hierarchy than top management, and supervisors do not always enact the formal policies as written. Given their place in the organization, workers form their safety climate perceptions based on the discrepancy between the *formal* and *enacted* policies, procedures, and practices. This discrepancy is what is measured by asking employees to fill out safety climate surveys.

There have been robust findings that safety climate is a leading indicator of accidents and injuries (Beus et al., 2010; Christian et al., 2009; Nahrgang et al., 2011), and the mechanism through which this occurs is the influence of safety climate on employees' motivation and knowledge to act in a safe manner, leading to safer behaviors that result in fewer accidents and injuries (Christian et al., 2009; Griffin and Neal, 2000). Zohar (1980) explained that the one most consistent factor that contributes to safety climate is a strong management commitment to safety. Such commitment is exhibited in a number of different ways, including: (a) top management being personally involved in safety activities regularly, (b) safety officers having high rank and status in the organization, (c) emphasis being placed on safety training, (d) open communication and frequent contact between management and workers, (e) a stable workforce (e.g., less turnover and (f) promotion of safety through guidance and counseling instead of enforcement and admonition, including recognizing or praising individual workers for high safety performance and enlisting workers' families in safety promotions (Zohar, 1980). Since this first article by Zohar (1980) was published, there have been numerous conceptualizations and scales constructed in relation to safety climate (Neal and Griffin, 2002, 2004). Yet, the priority (or value) of safety in an organization has remained at the core of safety climate's conceptualization (Griffin and Neal, 2000; Zohar, 2003).

It continues to be the case that "while there is no single universally accepted definition of safety climate, fairly broad agreement exists that management support for safety and the overall importance of safety within the organization are key aspects of safety climate" (Dejoy et al., 2004, p. 82). Leveson (2004) and Checkland (1981) have also indicated that the activity of management in a system (i.e., organization) constrains/influences the activity of workers at lower hierarchical levels. The importance of understanding the work activities at different levels in the hierarchy is emphasized by the framework of mesoergonomics. Similarly in the macroergonomics literature, top management can identify and rectify variances, defined as deviations from standard operating conditions, specifications, or norms that are not anticipated or wanted, found at lower levels in the organization (Hendrick and Kleiner, 2001). Whereas safety climate uses employees' perceptions to measure discrepancies between formal and informal policies and practices, macroergonomics tries to explicitly identify such gaps using methods like Kleiner's (2004, 2006) Macroergonomic Analysis and Design (MEAD) and the Systems Engineering Initiative for Patient Safety (SEIPS) framework (Carayon et al., 2006, 2014; Holden et al., 2013), which will be reviewed during the discussion of analyzing and designing work systems and potential future organizational interventions.

In addition to management commitment to safety, another major safety climate factor is communication pertaining to safety as a true priority from both top management and direct supervisors. Communication is one mechanism through which safety climate is created in an organization. For example, Zohar and Luria (2003) conducted a safety climate intervention that utilized safety-related supervisory interactions (measured as frequency of safety-oriented communications with subordinates) to change managerial role definitions and found that when supervisors had higher frequencies of safety-oriented communications, their subordinates demonstrated fewer negative safety behaviors. Therefore, organizations that prioritize safety over other work and organizational competing demands will have effective communication channels through which important safety-related information can be easily transmitted from employees (at a lower level of the organization) to top management (at a higher level of the organization) just as easily as information is transmitted from top management down to employees.

While communication is central to safety climate theory, it is also an important aspect of STS theory. According to systems theory, systems are hierarchical structures with descending levels that impose constraints on the behavior of those workers in the levels below (Checkland, 1981). Accidents can be explained by the separation of workers from top managers because the greater the distance between those working on the front line and decision makers, the harder it is to communicate problems with equipment, policies, and other aspects of the work environment, which increases uncertainty and risk (Leveson, 2004). Specifically, macroergonomics highlights the gap between the operation of the actual work system (what workers have decided to do) and the expectations of how the ideal work system should function (what management believes is being done; Kleiner, 2004; Leplat, 1989). Kleiner (2004) has found that those gaps are usually gaps of perception, and communication between informed personnel and the organization is necessary to bridge those gaps. Macroergonomists seek to redesign the work system, with improving lines of communication as one example, so that the actual system reflects more of the ideal system.

Some safety improvement programs in the past have been based on communication and have been successful in changing workplace safety. As an example, maintenance resource management (MRM) programs are found in the field of aviation safety and are intended to influence the safety attitudes and behaviors of aviation workers and their supervisors (Robertson, 2000; Taylor and Thomas, 2003). A change in workers' cognition occurs as a result of MRM programs so that workers are more safety-oriented and more aware of safety issues, therefore creating a strong safety culture. MRM programs were designed to change workers' knowledge and skills regarding interpersonal behavior and communication between team members (Robertson and Taylor, 1996; Taylor and Patankar, 2000), and so the premise of MRM is that trust and open communication (part of the personnel subsystem) are necessary to improve technical communication (part of the technological subsystem; Taylor, 2000). Given that communication is the foundation of MRM and is necessary for the success of organizational change, Taylor (2000) stated: "(1) that systems are larger than individuals, but that people collaborating can succeed, (2) that individuals benefit from communication skill training, (3) that top management and union support are essential for a strong culture, and (4) that aviation safety can improve only if it is a central part of the organization's culture" (p. 212).

4. Integrating macroergonomics and safety climate

To date little research has examined safety climate in relation to other work system components and how they all influence safety and performance outcomes. While safety climate is a general measure of the overall importance of safety in a workplace and includes specific items that may provide a fine-grained analysis of particular issues like communication, it does not allow for a broader systems analysis that takes into account various deficits when safety climate is low or various strengths when safety climate is high. Macroergonomics allows for that broader analysis through an examination of all aspects of the work system without restrictions based on measuring only front line employees' perceptions. Mesoergonomics is important in this discussion because it emphasizes the necessity of examining issues that go between and simultaneously interact with multiple levels within the organization.

Specific items used to measure safety climate are limited in their ability to pinpoint the exact underlying causes of poor safety outcomes because they usually address global safety concerns. Even the more detailed items address only a small number of safety issues in system design. This is especially true given that a large number of the safety climate scales in the literature are general measures that have not been validated in a particular industry. Recently, Zohar (2010) called for researchers to develop valid and reliable scales that are specific to industries because the context of one industry is different from the context of another industry. As examples, Huang et al. (2013) developed a safety climate scale particular to lone workers using truck drivers as the exemplar, and Singer et al. (2007) developed a patient safety climate survey to be utilized in healthcare organizations.

While a strength of safety climate is its mesoergonomic examination of discrepancies between levels (e.g., top management, supervisors, employees), safety climate may be particularly deficient in the lack of direction that can be given to bridge the disconnectedness of work groups or departments in their view of safety climate. Different work groups (e.g., workers with different supervisors or in different departments) within one organization can perceive different levels of safety climate. Each decision may seem rational and safe within the context of an individual work environment (Leveson, 2004), which in safety climate research is classified as a department or work group within one organization. Yet, when the overall sociotechnical system is taken into consideration, some decisions may seem unsafe when they are dependent upon other decisions made in other areas of the organization (Leveson, 2004). However, since safety climate emphasizes workers' perception, such research can be used to enhance specific areas of STS theory. For example, Trist (1981), while describing one step in analyzing a work system, stated, "A separate inquiry is made into *social-system members' perception* [italics added] of their roles and of role possibilities as well as constraining factors" (p. 33). The work accomplished by safety climate researchers can inform work system design, especially in terms of considering workers' perception, just as STS theory can inform safety climate research.

As prominent safety researchers have argued, efficient accident models need to emphasize mechanisms and factors that shape human behavior, which Leveson (2004) explained as "performance-shaping mechanisms and context in which human actions take place and decisions are made" (p. 9). Safety climate can be thought of as a mechanism that shapes workers' decisions and performance concerning safety and both a systems perspective and safety climate should be considered simultaneously when trying to reduce accidents and injuries in an organization and to enhance performance. Again, communication is a key way to impose constraints on lower levels, referred to as reference channels by Leveson (2004), and also as a way to give feedback to higher levels as to what is working in regard to the constraints of the system, referred to as measuring channels (Leveson, 2004). The context in which a decision is made by anyone in the system and the influences that may shape behavior must be evaluated to ascertain why unsafe decisions were made in the first place (Leveson, 2004). Similarly, safety climate shapes safety-related behavior through the shared perception of workers that is formed by observing the context of their environment in terms of safety.

Context is also important in macroergonomics as it allows for the examination of what specifically can cause accidents and injuries that occur as a result of the interface between workers and their environments (Imada, 2002), whereas safety climate assesses the overall perception of workers as they interact with their work environments. It has been shown that the macroergonomics approach involves comprehensive methodology for analyzing, designing, and evaluating work systems, and has led to 60% to 90% reported reductions in accidents, injuries, and work-related musculoskeletal disorders (Hendrick, 2004; Kleiner, 2006). These impressive outcomes are in part because macroergonomics is a human-centered approach in which workers' professional and psychosocial characteristics are systematically considered in relation to the entire work system. As Imada (2002) stated, "A more robust model acknowledges that accidents and human error have multiple causal factors that extend well beyond the scene of the event" (p. 151).

5. Conceptual model

A conceptual model, adapted from Carayon et al.'s (2006) SEIPS Model, Hendrick and Kleiner (2001), and Karsh et al.'s (2014) mesoergonomic framework, is shown in Fig. 1. This model can be used to determine influences of organizational performance and safety outcomes within a work system.

We are viewing this model with a feedback mechanism that begins with the subsystems and components of a work system. The design of the work system consists of the technological and personnel subsystems and their joint optimization, as well as the organizational design and the physical environment. The technological subsystem defines the tools and technologies of how work is performed (including the "non-human" structural aspects of work) and the personnel subsystem defines who performs the work. The organizational design includes the structural design and hierarchy of an organization (complexity, formalization and centralization; Bedeian and Zammuto, 1991), and processes. Nested in the middle is the worker as well as the activity s/he performs and the effort put forth to accomplish the activity. The design and characteristics of the work system influence the level of safety climate, which then impacts the workers' individual attitudes and behaviors and their shared perceptions of work practices. Encircling the work system and safety climate are boxes to depict the influence of the internal and external environments. Since sociotechnical systems are viewed as dynamic, open, with permeable boundaries, and continually evolving in response to multiple internal and external influences, the model includes these internal and external elements. In this model, the internal environment is comprised of the psychosocial factors (e.g., job design, job demands, decision latitude), team and social interactions, and the organizational culture. The external environment consists of elements, such economics, culture, and politics, which can permeate the boundaries of an organization. Ultimately, the collective interrelationships among these factors influence the organization's performance and safety.

If a work system is poorly designed and subsystems are misaligned, safety climate will be negatively impacted. As the outcomes of an organization are measured and used to provide feedback to the organization, this creates a mechanism for continuous improvement of processes as well as a process leading to redesign efforts and/or interventions, as depicted by the feedback loop. In order to systematically understand the multiple levels and their relationships, we emphasize the need to include a multilevel analysis that simultaneously studies the impact of the work system design interfaces, such as those proposed by the mesoergonomic framework that integrates a sociotechnical system model.

6. Analysis and design of future work system interventions

Currently, the first two authors, along with colleagues, are developing a methodology that extends the construct of safety climate beyond the safety climate scores themselves. We propose to integrate safety climate and STS theory in order to elucidate organizational/communication patterns associated with specific safety climate scores in specific companies. This project will be guided by the following specific aim: Design a methodology that extends the construct of safety climate beyond the safety climate scores themselves in order to explore the organizational context relating to those scores using a STS approach. Two companies will be recruited based on overall safety climate scores that have already been collected, one with a low safety climate score and one with a high safety climate score. Data collection will be conducted within the framework of proven macroergonomic methodology (i.e., Kleiner's Macroergonomic Analysis and Design (MEAD) framework).

The MEAD framework involves "formal company statements about mission (i.e., purpose), vision, and principles [that] are identified and evaluated with respect to their components in an effort to assess variances between what is professed and what is practiced" (Kleiner, 2004, p. 90–92). Kleiner (2004, 2006) proposed the MEAD framework to be used to achieve a safe and productive work system. The MEAD framework allows for the integration of existing tools from different disciplines to achieve a comprehensive system evaluation (Haro and Kleiner, 2008). Phase 1 involves the initial scanning of the organization in which the main elements of the system are identified, and those main elements include inputs, outputs, boundaries, environment interaction, stakeholders, and objectives (Haro and Kleiner, 2008; Trist, 1981). Also within this first phase is the identification of the stated goals of the system, which are later compared to the actual behavior found within the system to determine variances between the ideal and actual systems (Haro and Kleiner, 2008). Specifically, those stated goals are the mission, vision, and principles provided by the organization. It is often the case that there is a gap between what the organization recognizes as defining characteristics (e.g., safety) and how those in the organization actually behave (Hendrick and Kleiner, 2001; Kleiner, 2004). Likewise in the safety climate literature, top management may formally decide the way supervisors should implement safety rules and procedures but, in reality, the way supervisors implement safety rules and procedures is based on their own values, beliefs, and opinions. It is these values, beliefs, and opinions that workers observe and try to understand when actively forming their safety climate perceptions. Macroergonomics offers methods of collecting information regarding gaps or discrepancies between formal and enacted policies, like the contextual inquiry technique (Holtzblatt and Jones, 1993; O'Neill, 1998), that are not utilized in the safety climate literature. Other systems analysis techniques, such as the Systems Analysis Tool (SAT), have shown to be effective in providing a systematic, participatory process to analyze organizational problems, define objectives to solve these issues, and to generate and evaluate potential viable intervention alternatives to address identified problems (Robertson et al., 2002). Therefore, safety climate can be used to determine the overall level of safety in an organization, with a low safety climate score indicative of gaps between management commitment to safety and actual safety procedures, and MEAD (or SAT) can be used to determine specific system components of an organization (e.g., miscommunication, outdated equipment) that contribute to those gaps.

A current example in the literature of a model integrating different organizational levels to affect safety is the Systems Engineering Initiative for Patient Safety (SEIPS) model (Carayon et al., 2006, 2014). Production and service processes such as care processes are influenced by the work system design. For instance, the patient care process in a hospital can be characterized by the people who intervene in the process (e.g., patient, physician, nurse, pharmacist, receptionist), the various tasks performed by the people and the tools and technologies used to perform these tasks, the specific physical environment in which the tasks take place (e.g., patient room, nursing station), and the organizational structure and design

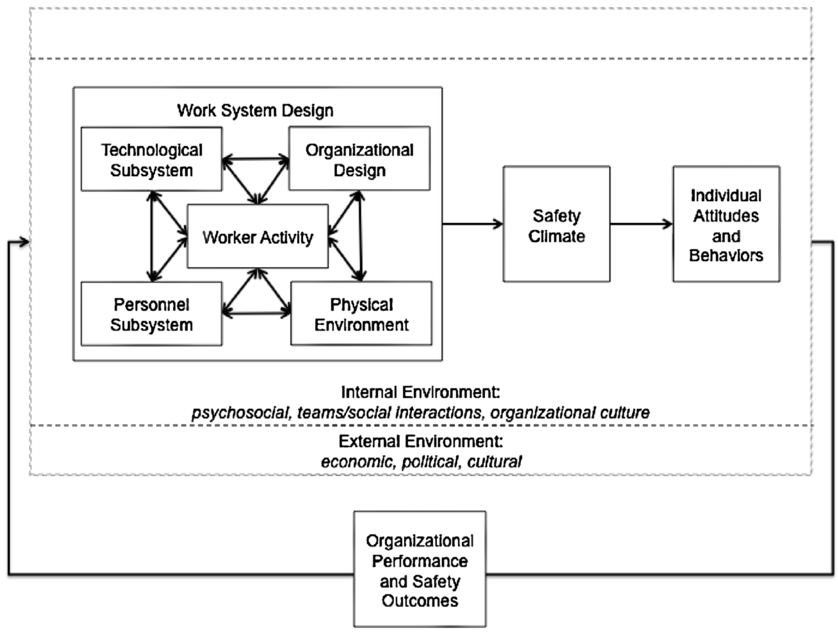

Fig. 1. A conceptual model of safety; adapted from Carayon et al. (2006), Karsh et al. (2014), Hendrick and Kleiner (2001), Robertson et al. (2008), and Zohar (2010) using different systems-based and safety climate theories.

that influence the process and its performance (e.g., collaboration between physician and nurse in making decisions about treatment, schedule of medication administration). The SEIPS model was specifically created to describe the impact of the work system on care processes and outcomes, including patient outcomes and worker outcomes (Carayon et al., 2006). A key aspect of the SEIPS model is to demonstrate how the design of work can affect care processes. Several research studies provide empirical evidence for the impact of work system design on care processes, such as the medication administration process and its safety (Carayon et al., 2007). Any production and service processes, including patient care processes, can be, therefore, influenced by the work system, and influence worker outcomes such as safety climate, as described in the proposed model (see Fig. 1).

7. Conclusion

Examining safety climate with regards to a systems approach is an area of research that is burgeoning. While safety climate is a leading indicator of safety, it is used more often to gauge the level of general safety in an organization and not to determine where safety problems occur. Therefore, the concept needs to be supplemented with a macroergonomics approach to design work systems so that we can identify specific human-technology-organization interfaces within an organization that negatively and positively affect the safety perception of workers' in that organization.

Acknowledgements

The authors would like to thank Marvin Dainoff, Lawrence Hettinger, Yueng-hsiang Huang, and Susan Jeffries of the Liberty Mutual Research Institute for Safety for their support of the first author's postdoctoral work. The authors would also like to thank Denis Murphy for his valuable assistance in editing this article.

References

Ambrose, M.L., Kulik, C.T., 1999. Old friends, new faces: motivation research in the 1990s. Journal of Management 25, 231–292.
Beus, J.M., Payne, S.C., Bergman, M.E., Arthur, W., 2010. Safety climate and injuries: an examination of theoretical and empirical relationships. Journal of Applied Psychology 95, 713–727.
Bedeian, A.G., Zammuto, R.F., 1991. Organizations: Theory and Design. Dryden Press, Chicago.
Billings, R.S., Klimoski, R.J., Breaugh, J.A., 1977. The impact of a change in technology on job characteristics: a quasi-experiment. Administrative Science Quarterly 22, 318–339.
Brass, D.J., 1985. Technology and the structuring of jobs: employee satisfaction, performance, and influence. Organizational Behavior and Human Decision Processes 35, 216–240.
Bronfenbrenner, U., 1994. Ecological models of human development. International Encyclopedia of Education, vol. 3., 2nd ed. Elsevier, Oxford.
Brown, R.L., Holmes, H., 1986. The use of a factor-analytic procedure for assessing the validity of an employee safety climate model. Accident Analysis and Prevention 18, 455–470.
Carayon, P., 2006. Human factors of complex sociotechnical systems. Applied Ergonomics 37, 525–535.
Carayon, P., 2009. The balance theory and work system model. . .twenty years later. International Journal of Human-Computer Interaction 25, 313–327.
Carayon, P., Smith, M.J., 2000. Work organization and ergonomics. Applied Ergonomics 31, 649–662.
Carayon, P., Hundt, A.S., Karsh, B.-T., Gurses, A.P., Alvarado, C.J., Smith, M., Brennan, P.F., 2006. Work system design for patient safety: the SEIPS model. Quality and Safety in Health Care 15, i50–i58.
Carayon, P., Wetterneck, T.B., Hundt, A.S., Ozkaynak, M., DeSilvey, J., Ludwig, B., Ram, P., Rough, S.S., 2007. Evaluation of nurse interaction with Bar Code Medication Administration (BCMA) technology in the work environment. Journal of Patient Safety 3, 34–42.
Carayon, P., Wetterneck, T.B., Rivera-Rodriguez, A.J., Hundt, A.S., Hoonakker, P., Holden, R., Gurses, A.P., 2014. Human factors systems approach to healthcare quality and patient safety. Applied Ergonomics 45, 14–25.
Checkland, P., 1981. Systems Thinking, Systems Practice. John Wiley & Sons, New York.
Cherns, A.B., 1976. The principles of socio-technical design. Human Relations 29, 783–792.
Cherns, A., 1987. Principles of socio-technical design revisited. Human Relations 40, 153–162.
Christian, M.S., Bradley, J.C., Wallace, J.C., Burke, M.J., 2009. Workplace safety: a meta-analysis of the roles of person and situation factors. Journal of Applied Psychology 94 (5), 1103–1127.
Clegg, C.W., 2000. Sociotechnical principles for system design. Applied Ergonomics 31, 463–477.
Cox, S., Flin, R., 1998. Safety culture: philospher's stone or man of straw? Work and Stress 12, 202–216.
DeJoy, D.M., Gershon, R.R.M., Murphy, L.R., 1998. Minimizing the risk of occupationally acquired HIV/AIDS: universal precautions and health-care workers. In: Feyer, A.M., Williamson, M. (Eds.), Occupational Injury: Risk, Prevention, and Intervention. Taylor & Francis, London, pp. 106–116.
Dejoy, D.M., Schaffer, B.S., Wilson, M.G., Vandenberg, R.J., Butts, M.M., 2004. Creating safer workplaces: assessing the determinants and role of safety climate. Journal of Safety Research 35, 81–90.

Emery, F., 1964. Report of the Hunfoss Project. Tavistock Document Series, London.
Emery, F.E., Trist, E.L., 1960. Socio-technical systems. In: Churchman, C.H., Verhulst, M. (Eds.), Management Science, Models and Techniques, vol. 2. Peragmon, New York, pp. 83–97.
Felknor, S.A., Aday, L.A., Burau, K., Delclos, G., Kapadia, A.S., 2000. Assessment of safety climate and its association with injuries and safety practices in public hospitals in Costa Rica. International Journal of Occupational and Environmental Health 6, 18–25.
Friedlander, F., Brown, L.D., 1974. Organization development. Annual Review of Psychology 25, 313–341.
Grant, A.M., Fried, Y., Juillerat, T., 2010a. Work matters: job design in classic and contemporary perspectives. In: Zedeck, S. (Ed.), APA Handbook of Industrial and Organizational Psychology, vol. 1. American Psychological Association, Washington, DC, pp. 417–453.
Grant, A.M., Parker, S.K., 2009. Redesigning work design theories: the rise of relational and proactive perspectives. Academy of Management Annuals 3, 317–375.
Grant, A.M., Fried, Y., Parker, S.K., Frese, M., 2010b. Putting job design in context: introduction to the special issue. Journal of Organizational Behavior 31, 145–157.
Griffin, M.A., Neal, A., 2000. Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. Journal of Occupational Health Psychology 5, 347–358.
Guldenmund, F.W., 2000. The nature of safety culture: a review of theory and research. Safety Science 34, 215–257.
Hackman, J.R., Oldham, G.R., 1976. Motivation through the design of work: test of a theory. Organizational Behavior and Human Performance 16, 250–279.
Haro, E., Kleiner, B.M., 2008. Macroergonomics as an organizing process for systems safety. Applied Ergonomics 39, 450–458.
Hendrick, H.W., 1995. Future directions of macroergonomics. Ergonomics 38, 1995.
Hendrick, H.W., 1997. Organizational design and macroergonomics. In: Salvendy, G. (Ed.), Handbook of Human Factors and Ergonomics. , 2nd ed. Wiley, New York, pp. 594–636.
Hendrick, H.W., 2002. An overview of macroergonomics. In: Hendrick, H.W., Kleiner, B.M. (Eds.), Macroergonomics: Theory, Methods, and Applications. Lawrence Erlbaum Associates, Mahwah, NJ, pp. 1–23.
Hendrick, H., 2004. Macroergonomics methods. In: Stanton, N.A., Hedge, A., Brookhuis, K., Salas, E., Hendrick, H.W. (Eds.), Handbook of Human Factors and Ergonomics Methods. CRC Press, New York, pp. 75-1–75-4.
Hendrick, H.W., Kleiner, B.M., 2001. Macroergonomics: An Introduction to Work System Design. Human Factors and Ergonomics Society, Santa Monica, CA.
Hersman, D.A.P., 2013, September. Opening Remarks. Speech presented at the National Transportation Safety Board Safety Forum: Enhancing Transportation Safety, Washington, DC.
Holden, R.J., Carayon, P., Gurses, A.P., Hoonakker, P., Hundt, A.S., Ozok, A.A., Rivera-Rodriguez, A.J., 2013. SEIPS 2.0: a human factors framework for studying and improving the work of healthcare professionals and patients. Ergonomics 56, 1669–1686.
Holman, D., Clegg, C., Waterson, P., 2002. Navigating the territory of job design. Applied Ergonomics 33, 197–205.
Holtzblatt, K., Jones, S., 1993. Contextual inquiry: a participatory technique for system design. In: Schuler, D., Namioka, A. (Eds.), Participatory Design: Principles and Practices. Lawrence Erlbaum, Hillsdale, NJ, pp. 177–210.
House, R., Rousseau, D.M., Thomas-Hunt, M., 1995. The meso paradigm: a framework for the integration of micro and macro organizational behavior. Research in Organizational Behavior 17, 71–114.
Huang, Y.H., Zohar, D., Robertson, M.M., Garabet, A., Lee, J., Murphy, L.A., 2013. Development and validation of safety climate scales for lone workers using truck drivers as exemplar. Transportation Research Part F: Traffic Psychology and Behavior 17, 5–19.
Imada, A.S., 2002. A macroergonomics approach to reducing work-related injuries. In: Hendrick, H.W., Kleiner, B.M. (Eds.), Macroergonomics: Theory, Methods, and Applications. Erlbaum, Mahwah, NJ, pp. 151–171.
International Ergonomics Association, 2000. Retrieved December 5, 2010. http://www.iea.cc/01_what/What is Ergonomics.html
Karsh, B.-T., Waterson, P., Holden, R.J., 2014. Crossing levels in systems ergonomics: a framework to support 'mesoergonomic' inquiry. Applied Ergonomics 45, 45–54.
Karwowski, W., Kantola, J., Rodrick, D., Salvendy, G., 2002. Macroergonomic aspects of manufacturing. In: Hendrick, H.W., Kleiner, B.M. (Eds.), Macroergonomics: Theory, Methods, and Applications. Lawrence Erlbaum Associates, Mahwah, NJ, pp. 223–248.
Katz, D., Kahn, R.L., 1966. The Social Psychology of Organizations. John Wiley & Sons, New York, NY.
Kleiner, B.M., 2002. Computer-aided macroergonomics for improved performance and safety. Human Factors and Ergonomics in Manufacturing 12, 307–319.
Kleiner, B., 2004. Macroergonomic analysis and design (MEAD). In: Stanton, N.A., Hedge, A., Brookhuis, K., Salas, E., Hendrick, H.W. (Eds.), Handbook of Human Factors and ergonomics methods. CRC Press, New York, pp. 90-1–90-7.
Kleiner, B.M., 2006. Macroergonomics: analysis and design of work systems. Applied Ergonomics 37, 81–89.
Kleiner, B.M., 2008. Macroergnomics: work system analysis and design. Human Factors: The Journal of the Human Factors and Ergonomics Society 50, 461–467.
Leplat, J., 1989. Error analysis, instrument and object of task analysis. Ergonomics 32 (7), 813–822.
Leveson, N., 2004. A new accident model for engineering safer systems. Safety Science 42, 237–270.
Leveson, N.G., 2011. Engineering a Safer World: Systems Thinking Applied to Safety. MIT Press, Cambridge, MA.
Mearns, K., Whitaker, S.M., Flin, R., 2003. Safety climate, safety management practices and safety performance in offshore environments. Safety Science 41, 641–680.
Morgeson, F.P., Dierdorff, E.C., Hmurovic, J.L., 2010. Work design *in situ*: understanding the role of occupational and organizational context. Journal of Organizational Behavior 31, 351–360.
Nahrgang, J.D., Morgeson, F.P., Hofmann, D.A., 2011. Safety at work: a meta-analysis investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. Journal of Applied Psychology 96, 71–94.
Neal, A., Griffin, M.A., 2002. Safety climate and safety behavior. Australian Journal of Management 27, 67–75.
Neal, A., Griffin, M.A., 2004. Safety climate and safety at work. In: Frone, M.R., Barling, J. (Eds.), The Psychology of Workplace Safety. American Psychological Association, Washington, DC, pp. 15–34.
O'Neill, M., 1998. Ergonomic Design and Organizational Effectiveness. Lewis Publishers, Boston, MA.
Parker, S.K., Axtell, C.M., Turner, N., 2001. Designing a safer workplace: importance of job autonomy, communication quality, and supportive supervisors. Journal of Occupational Health Psychology 6, 211–228.
Parker, S.K., Wall, T.D., 1998. Job and Work Design: Organizing Work to Promote Well-being and Effectiveness. Sage, Thousand Oaks, CA.
Pasmore, W.A., 1988. Designing Effective Organizations: The Sociotechnical Systems Perspective. Wiley, New York.
Rasmussen, J., 1997. Risk management in a dynamic society: a modeling problem. Safety Science 27, 183–213.
Reason, J., 1995. A systems approach to organizational error. Ergonomics 38, 1708–1721.
Reason, J., 2000. Human error: models and management. British Medical Journal 320, 768–770.
Robertson, M.M., 2000. Using a participatory ergonomics design to develop a human factors training program for aviation maintenance. In: Proceedings of the International Ergonomics Association and the 44th Annual Human Factors and Ergonomics Society, July 29–August 4, San Diego, CA.
Robertson, M.M., Kleiner, B.M., O'Neill, M.J., 2002. Macroergonomic methods: assessing work system processes. In: Hendrick, H.W., Kleiner, B.M. (Eds.), Macroergnomics: Theory, Methods, and Applications. Lawrence Erlbaum Associates Publishers, New Jersey, pp. 67–96.
Robertson, M.M., Taylor, J.C., 1996. Team training in an aviation maintenance setting: a systematic evaluation. In: Hayward, B., Lowe, A. (Eds.), Applied Aviation Psychology: Achievement, Change and Challenge. Avebury, Sydney, Australia, pp. 373–383.
Robertson, M.M., Huang, Y.H., O'Neill, M.J., Schleifer, L.M., 2008. Flexible workspace design and ergonomics training: impacts on the psychosocial work environment, musculoskeletal health, and work effectiveness among knowledge workers. Applied Ergonomics 39, 482–494.
Rousseau, D.M., 1977. Technological differences in job characteristics, employee satisfaction, and motivation: a synthesis of job design research and sociotechnical systems theory. Organizational Behavior and Human Performance 19, 18–42.
Rousseau, D.M., Fried, Y., 2001. Location, location, location: contextualizing organizational research. Journal of Organizational Behavior 22, 1–13.
Rousseau, D.M., Ho, V.T., Greenberg, J., 2006. I-deals: idiosyncratic terms in employment relationships. Academy of Management Review 31, 977–994.
Schaefer, J.A., Moos, R.H., 1996. Effects of work stressors and work climate on long-term care on staff's job morale and functioning. Research in Nursing and Health 19, 63–73.
Schein, E.H., 1992. Organizational Culture and Leadership, 2nd Ed. Jossey Bass, San Francisco, CA.
Singer, S., Meterko, M., Baker, L., Gaba, D., Falwell, A., Rosen, A., 2007. Workforce perceptions of hospital safety culture: development and validation of the patient safety climate in healthcare organizations survey. Health Services Research 42, 1999–2021.
Siu, O., Phillips, D.R., Leung, T., 2004. Safety climate and safety performance among construction workers in Hong Kong: the role of psychological strains as mediators. Accident Analysis and Prevention 36 (3), 359–366.
Smith, M.J., Carayon-Sainfort, P., 1989. A balance theory of job design for stress reduction. International Journal of Industrial Ergonomics 4, 67–79.
Taylor, J.C., 2000. The evolution and effectiveness of Maintenance Resource Management (MRM). International Journal of Industrial Ergonomics 26, 201–215.
Taylor, J.C., Patankar, M.C., 2000. The role of communication in the reduction of human error. In: Proceedings of the 14th Annual Human Factors in Aviation Maintenance Symposium, Vancouver, BC, pp. 1–27.
Taylor, J.C., Thomas III, R.L., 2003. Toward measuring safety culture in aviation maintenance: the structure of trust and professionalism. The International Journal of Aviation Psychology 13, 321–343.
Thomas, J.P., Whitman, D.S., Viswesvaran, C., 2010. Employee proactivity in organizations: a comparative meta-analysis of emergent proactive constructs. Journal of Occupational and Organizational Psychology 83, 275–300.
Torraco, R.J., 2005. Work design theory: a review and critique with implications for human resource development. Human Resource Development Quarterly 16, 85–109.
Trist, E., 1981. The evolution of sociotechnical systems. In: Van de Ven, A., Boyce, W. (Eds.), Perspectives on Organization and Design. Wiley, New York, pp. 19–75.
Wrzesniewski, A., Dutton, J.E., 2001. Crafting a job: revisioning employees as active crafters of their work. Academy of Management Review 26, 179–201.

Zink, K.J., 2002. A vision of the future of macro-ergonomics. In: Hendrick, H.W., Kleiner, B.M. (Eds.), Macroergonomics: Theory, Methods, and Applications. Lawrence Erlbaum Associates, Mahwah, NJ, pp. 347–358.
Zohar, D., 1980. Safety climate in industrial organizations: theoretical and applied implications. Journal of Applied Psychology 65, 96–102.
Zohar, D., 2000. A group-level model of safety climate: testing the effects of group climate on microaccidents in manufacturing jobs. Journal of Applied Psychology 85, 587–596.
Zohar, D., 2002. Modifying supervisory practices to improve subunit safety: a leadership-based intervention model. Journal of Applied Psychology 87 (1), 156–163.
Zohar, D., 2003. Safety climate: conceptual and measurement issues. In: Quick, J.C., Tetrick, L.E. (Eds.), Handbook of Occupational Health Psychology. American Psychological Association, Washington, DC, pp. 123–142.
Zohar, D., 2010. Thirty years of safety climate research: reflections and future directions. Accident Analysis and Prevention 42, 1517–1522.
Zohar, D., Luria, G., 2003. The use of supervisory practices as leverage to improve safety behavior: a cross-level intervention model. Journal of Safety Research 34, 567–577.
Zohar, D., Luria, G., 2005. A multilevel model of safety climate: cross-level relationships between organization and group-level climates. Journal of Applied Psychology 90, 616–628.