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Safety climate and culture: Integrating psychological and systems perspectives

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Safety climate and culture: Integrating psychological and systems perspectives

Abstract

Safety climate research has reached a mature stage of development, with a number of meta-analyses demonstrating the link between safety climate and safety outcomes. More recently, there has been interest from systems theorists in integrating the concept of safety culture and to a lesser extent, safety climate into systems-based models of organizational safety. Such models represent a theoretical and practical development of the safety climate concept by positioning climate as part of a dynamic work system in which perceptions of safety act to constrain and shape employee behavior. We propose safety climate and safety culture constitute part of the enabling capitals through which organizations build safety capability. We discuss how organizations can deploy different configurations of enabling capital to exert control over work systems and maintain safe and productive performance. We outline four key strategies through which organizations to reconcile the system control problems of promotion versus prevention, and stability versus flexibility.

Keywords: safety capability, safety climate, safety culture, control theory, work systems

Safety climate and Culture: Integrating psychological and systems perspectives

It has been almost 40 years since the concept of safety climate was originally introduced by Zohar (1980). Broadly, safety climate refers to shared perceptions held by members of a team or organization about the way safety is managed within the organization (Griffin & Neal, 2000; Zohar, 1980). After a slow start, interest in the concept increased during the mid 1990's, and has grown rapidly since. According to Web of Science, only 11 articles included 'safety climate' in the title between 1980 and 1996. Since 1996, 429 articles included 'safety climate' in their title; of these, 70 were published between 1997 and 2006, and 359 were published between 2007 and 2016.

Research in safety climate has reached a mature stage of development within the psychological and management literature (Zohar, 2010). For example, a number of meta-analyses provide good evidence of the link between safety climate and safety outcomes (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006, 2010; Nahrgang, Morgeson, & Hofmann, 2011). These studies consistently demonstrate that people work more safely when there is a shared social context where safety is prioritized and valued. Consequently, safety climate is firmly established as an organizational antecedent of safety performance.

Despite the progress in understanding safety climate and its impact, there remain limitations that might be addressed in future research. Specifically, the construct domains of safety climate and the broader concept of safety culture are often blurred and overlapping (Cox & Flin, 1998; Guldenmund, 2000), with both researchers and practitioners conflating the meaning of culture and climate (Griffin & Curcuruto, 2016). Safety climate and culture also tend to be treated as static variables, which does not reflect the more dynamic orientation of contemporary systems-based models of organizational safety. Recently, Griffin et al. (2014) introduced the concepts of safety capability and enabling capitals, which although are more compatible with systems thinking, add further conceptual complexity to discussions of safety climate and culture. The net result is poor understanding of how climate, culture, and capability interrelate and evolve over time, as well as how these concepts contribute to the overall safety of an organizational system.

We propose that a systems-based approach is needed to address current limitations in safety climate and culture literatures. Systems approaches provide a dynamic representation of the way safety develops and breaks down in complex operations (Hollnagel, Paries, Woods, & Wreathall, 2011; Leveson, 2011). Although these approaches incorporate concepts of safety culture at a broad level, there are few specific links between concepts of safety culture and safety systems (Reiman & Rollenhagen, 2014). While safety culture has received some attention from systems theorists (Goh, Love, Stagbouer, & Annesley, 2012; Marais, Saleh, & Leveson, 2006; Pidgeon & O'Leary, 2000), safety climate has largely been ignored. This lack of attention is unfortunate because safety climate lends itself more readily to integration within systems-based models given its transient, multi-level, and multi-dimensional properties (Zohar, 2010).

Adopting a systems approach enables the dynamic nature of safety to be integrated with concepts of safety culture, climate, and capability. From a systems perspective, safety can be conceptualized as a control dilemma, meaning that threats and disturbances that may destabilize the system are identified, monitored, and controlled (Griffin, Cordery, & Soo, 2015). We propose that this control dilemma is best resolved by developing safety capabilities across two key domains: stability/flexibility and promotion/prevention. We position safety climate and culture within a framework of enabling capitals such that climate and culture represent the mechanisms through which this safety capability can be operationalized allows distubances can be managed.

In the following sections, we first review the development of safety climate concepts and provide some practical distinctions between safety climate and culture. In the second part of the paper, we review key systems perspectives of safety and accident causation. In the final part of the paper we present an integrative systems model incorporating safety culture and climate concepts.

1. Safety Climate, Culture, and Capability

Safety Climate

State of Current Knowledge

There is now a large body of research examining the relationships among safety climate, safety behavior, and accidents. Accidents are workplace events that result in physical harm to people, property, or the environment, while safety behavior is any form of workplace behavior that affects the likelihood of physical harm to people, property or environment (Beus, Dhanani, & McCord, 2015). The two forms of safe work behavior that have most commonly been examined are safety compliance and safety participation. Safety compliance refers to the core activities that individuals need to carry out to meet mandated safety requirements, which are typically specified in the form of rules and procedures (Griffin & Neal, 2000; Neal, Griffin, & Hart, 2000). Safety participation involves behaviors that do not directly contribute to an individual's personal safety, but which help to develop an environment that supports safety. These include helping co-workers and demonstrating initiative (Griffin & Neal, 2000; Neal et al., 2000). A closely related construct is safety citizenship, which is defined as the degree to which employees are willing to enlarge their role beyond normal job requirements by engaging in behaviors such as whistleblowing (Hofmann, Morgeson, & Gerras, 2003). Both safety participation and safety citizenship are important concepts as they represent the extent to which individuals engage in positive safety behaviors over and above what is simply expected of them.

There have been a number of meta-analyses (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006, 2010; Nahrgang et al., 2011) and systematic reviews (Beus, McCord, & Zohar, 2016) of this literature in the past decade. Meta-analyses have confirmed that safety climate is positively associated with both safety compliance (Nahrgang et al., 2011) and safety participation (Clarke, 2006), and suggest that the relationship between safety climate and safety participation may be stronger than that between safety climate and safety compliance (Christian, Bradley, Wallace, & Burke, 2009; Clarke, 2006). This is consistent with the theory that a positive safety climate is more likely to encourage safety behaviors over and above basic procedural adherence due to the norm of reciprocity established when individuals and teams perceive management as placing an adequate emphasis on workplace safety (Clarke, 2006).

Meta-analyses have also confirmed that safety behavior is associated with accidents. Clarke (2006) and Christian, Bradley, Wallace, and Burke (2009) found that both compliance and participation were negatively associated with accidents. Furthermore, Christian, Bradley, Wallace, and Burke (2009) found that a broad composite of safety behavior was more strongly associated with accidents than specific safety behaviors, and that safety behavior mediated the relationships between safety climate and accidents. Nahrgang et al. (2011), in contrast, found that compliance was negatively associated with accidents, but participation was not, although participation was associated with adverse events, such as near misses. Nahrgang et al. (2011) argued that the differences between the results of these two meta-analyses might be due to the inclusion of driving-related studies in their meta-analysis, as the factors that predict accidents in the transport industry appear to be different to those in other industries. Furthermore, we would not necessarily expect participation to be strongly related to accidents at the individual level, because the effects of participation are indirect, reducing the risk of harm to other people, rather than to the self (Griffin, Neal, & Parker, 2007).

Further research has investigated variables mediating the relationship between safety climate and safety behaviors. Most of this work has examined the role of safety knowledge and motivation. Safety knowledge refers to an individual's understanding of safety practices and procedures and safety motivation refers to an individual's willingness to work safely (Griffin & Neal, 2000). Two types of safety motivation have been identified: valence, which is the perceived value, or importance, of safety to the individual (Neal & Griffin, 2006); and instrumentality, which is the extent to which the person believes that working safely will be recognized and rewarded (Scott, Fleming, & Kelloway, 2014; Zohar, 2011). From the perspective of self-determination theory (SDT), valence can be seen as a type of autonomous motivation in which individuals are motivated by the intrinsic value of safety, while instrumentality can be seen a type of controlled motivation in which individuals are motivated by external contingencies (Gagné & Deci, 2005). Meta-analyses have confirmed that safety knowledge and safety motivation mediate the relationship between safety climate and safety behavior (Christian, Bradley, Wallace, & Burke, 2009), although there is not yet sufficient research to draw conclusions regarding the relative contribution of different forms of safety motivation.

A separate body of research informed by the job demands resource (JDR) model (Bakker & Demerouti, 2007) has examined how job demands and resources influence safety behavior (Nahrgang et al., 2011). Job demands are physical, psychological, social, or organizational aspects of the job that require sustained physical and/or psychological effort (Schaufeli & Bakker, 2004). Job resources, on the other hand, are physical, psychological, social or organizational aspects of the job which reduce job demands, or in some other way aid in the achievement of work goals or stimulate personal development (Demerouti, Bakker, Nachreiner, & Schaufeli, 2001). Safety climate is seen as a job resource from the perspective of the JDR model.

The JDR model suggests that job demands exhaust an individual's mental and physical resources, leading to burnout, which is a state of exhaustion, cynicism and lack of efficacy (Maslach & Leiter, 2008). Job resources, such as safety climate, on the other hand, are thought to protect against burnout by replenishing resources. People are thought to be more likely to work unsafely, and have accidents, when their energy levels are depleted due to burnout (Nahrgang et al., 2011). Meta-analytic results confirm that job demands are positively, and job resources are negatively, associated with indicators of burnout (anxiety, stress and depression) in the predicted direction (Nahrgang et al., 2011). Indicators of burnout, in turn are positively associated with accidents, but not unsafe behavior, although relatively few studies have examined these relationships.

Meta-analyses have also examined the relative strength of effects at the individual and group levels of analysis, and the direction of the relationship between safety climate and accidents. Christian, Bradley, Wallace, Burke, and Spears (2009) found that the relationships between safety climate on the one hand, and safety behavior and accidents on the other, were stronger at the group level than at the individual level, which is consistent with the argument that climate is an emergent group-level construct. Beus, Payne, Bergman, and Arthur (2010) found that safety climate was both a leading and lagging indicator of safety, although the correlation between prior accidents and safety climate was marginally stronger than the correlation between safety climate and future accidents. Focusing on the subdimensions of safety climate, Beus, Payne, Bergman, and Arthur (2010) found that management commitment to safety, which is the core element of safety climate, is more predictive of future accidents than prior accidents. More recently, Bergman, Payne, Taylor, and Beus (2014) examined the relationship between safety climate and accident rates across 42 worksites at multinational chemical manufacturing company over a four year period. They found that safety climate was both a leading and lagging indicator of accidents, but that the effect differed, depending on the type of incident and the time lag. The relationship between safety climate and reportable accidents diminished after three months, while the relationship between safety climate and low level (not reportable) accidents sustained for two years.

Limitations of Current Understanding

Substantial progress has been made in understanding the relationship between safety climate and safety behavior. However, our understanding of the underlying process is limited in a number of important ways including the methodological challenges associated with the assessment of safety climate and safety behavior. The field is still dominated by cross-sectional studies examining relationships at the individual level of analysis, although more studies are examining relationships at the group or organizational levels (e.g., Brondino, Silva, & Pasini, 2012; Lee & Dalal, 2016).

From a theoretical perspective one issue is the need to develop a better understanding of safe and unsafe work behavior at different levels within an organization, and the mechanisms through which they have an impact on safety outcomes. There is a need to incorporate a broader range of factors into models of safety behavior, so that we can account for the different ways in which people act to reduce, or increase, the risk of harm to themselves or others. For example, key behaviors that are now being included in models of safety include adaptivity, proactivity and teamwork (Griffin et al., 2007). These types of behavior are important when the risks and hazards associated with a particular work system are unpredictable, and the system is highly interdependent, meaning that the actions of one person have an impact on others.

A second general issue is the need to better understand the mechanisms by which safety climate influences safe and unsafe work behavior. In part, this can be achieved by more systematically considering factors that shape behavior such as competence, motivation, energy, and opportunity. Competence includes factors that determine what a person can do, such as knowledge, skill and expertise. To date, the safety climate literature has focused on explicit knowledge of rules and procedures, and has ignored the tacit knowledge and skill that people develop as they acquire expertise in a domain. The skill and expertise of staff is arguably more important than their knowledge of rules and procedures (Hollnagel, 2009). For example, the human factors literature focuses on situation awareness as a key factor that influences safety in a dynamic and uncertain environment (Durso & Sethumadhavan, 2008), yet situation awareness is largely ignored within the safety climate literature, possibly because it is a dynamic variable and difficult to measure using employee surveys.

Motivation determines what a person is prepared to do, and the reasons why they are prepared to do it. The safety climate literature has not yet considered the consequences of different forms of safety motivation, such as extrinsic and intrinsic safety motivation. Zohar, Huang, Lee, and Robertson (2015) recently argued that safety climate induces extrinsic safety motivation, and undermines intrinsic safety motivation. They found that the relationship between safety climate and compliance was stronger for people who reported lower levels of work engagement, suggesting that extrinsic safety motivation may compensate for a lack of intrinsic safety motivation. However, to the best of our knowledge, studies have not yet measured extrinsic and intrinsic safety motivation directly, or examined whether extrinsic safety motivation can undermine intrinsic safety motivation. Furthermore, we would expect that the effects of extrinsic and intrinsic safety motivation would depend on the type of safety behavior being examined. Specifically, intrinsic safety motivation is likely to be particularly important for discretionary behaviors, such as participation, citizenship, adaptivity and proactivity, which are important for the safety of the system as a whole.

Energy provides the drive for behavior, while situational factors provide the opportunities and constraints that limit the behaviors that are possible. While Nahrgang et al. (2011) identified engagement and burnout as energetic states that have the potential to influence safety behavior. However, these constructs were not directly assessed in their meta-analysis. Variables such as anxiety and depression were used as indicators of burnout, while participation, communication and information sharing were used as indicators of engagement. The most direct way to assess the effects of low levels of energy is to measure fatigue, yet fatigue is largely overlooked within the safety climate literature, which is surprising given that it is known to be one of the major causes of industrial accidents (e.g., Hockey, 2013). On the positive end of the scale, activated positive affect, such as feelings of energy and enthusiasm, is an important determinant of proactive and prosocial behaviors (Parker, Bindl, & Strauss, 2010). Again, these factors are largely overlooked within the safety literature. In addition, the choices that people make are limited by the opportunities that are available to them, and the constraints that they are acting under. Relatively little attention has been given to the role that opportunities and constraints play in shaping safety behavior. One exception is a recent study by Lee and Dalal (2016), who found that a strong safety climate, indexed by high levels of within-group agreement, constrained the expression of individual differences.

Finally, to better understand the mechanisms through which safety climate influences safety behavior, we need to take a more dynamic approach. Theories of self-regulation can be used to understand the process by which people adapt to task demands, and explain the choices that they make in relation to the goals that they are pursuing (Neal, Ballard, & Vancouver, in press). This is a dynamic process, and as such, needs to be studied at the within person level, using repeated measures designs, together with sophisticated statistical models, such as latent change models (Liu, Mo, Song, & Wang, 2016) that are capable of directly testing a theory of change. The safety climate literature currently paints a picture of safety that is fairly static, rather than dynamic.

Culture and Capability

The concept of safety climate overlaps with the concepts of safety culture and safety capability. In this section, we examine how these concepts can be better understood in relation to each other.

Safety culture

Safety culture represents an organization's core values about the importance of safety and the underlying beliefs and assumptions that guide behavior and decision making (Reason, 1998). Safety culture not only shapes the externally visible elements of an organization, but also the things that are "not said" or reflected only in symbolic actions. For these reasons, safety culture is often described in terms of "deep" meaning whereas safety climate is described as the "surface features" (Denison, 1996). Guldenmund (2000) identified three layers of safety culture. The core layer of culture is described as the basic and fundamental assumptions about safety and the middle layer consists of espoused values and attitudes. The outer-most layer is described as artefacts, which represent behavioral manifestations of the underlying safety culture and physical symbols such as safety posters and signage.

Safety climate can be understood as perceptions of the middle and outer layers of safety culture at a given point in time. From this perspective, safety climate is an indicator of the underlying shared assumptions that comprise an organization's safety culture. Safety climate then provides an assessment of how effectively various safety practices at different levels of an organization have been implemented, resulting in a shared sense of the overall value, priority, and importance placed on safety (Zohar, 1980, 2010).

When it is systematically invoked for practice or research, this layered metaphor of culture highlights useful distinctions between culture and climate. For example, culture is likely to be harder to change than climate, because it reflects deeper and more pervasive assumptions. Climate, on the other hand, is more amenable to change through deliberate organizational actions such as safety training, strategic planning, and participative decision-making (Beus, Payne, Bergman, & Arthur Jr, 2010).

Despite its advantages, the layer metaphor is limited in the degree it captures interactions within and between layers, obscuring important links among implicit beliefs, organizational practices, human decision-making, and actions. In particular, it provides a limited view of the types of capabilities that an organization needs to operate safely. This limitation is particularly important when trying to understand safety from a systems perspective, as safety culture is only one component within a broader socio-technical system (Reiman & Rollenhagen, 2014).

Safety capabilities

Safety capability can be defined as the capacity of an organization to maintain safe operations in dynamic and uncertain operating environments, and is generated via human, social, and organizational processes termed “enabling capitals” (Griffin et al., 2014). Enabling capitals are foundational building blocks that include technologies, structures, processes, and importantly, social aspects including safety culture and climate. Organizational capital is thought to include both human resource management, such as high performance work systems, and safety management practices such as risk management procedures. Social capital refers to capacities embedded in social relationships, such as culture and teamwork. Human capital refers to individual competences such as the knowledge, skills, abilities, experiences of employees within the organization.

Unlike safety capability, enabling capitals are hypothesized to be directly observable and hence, measurable and amenable to change (Griffin et al., 2014). Enabling capitals can be considered as the system components that shape safety processes at different levels within an organization. Figure 1 provides an overview of these three capitals and how they might relate to both the underlying safety culture and to the more observable safety climate. Each enabling capital can be mapped across the layers of Schein's culture model (Schein, 2004). Moving from the centre of the figure, core inner layers are considered less tangible and distal in terms of their influence over behavior than successive outer layers. The middle layer represents the core assumptions regarding safety and effectiveness that are held by members of the organization. These assumptions underpin all three types of capital.

The middle layer represents the foundations upon which each capital is built. For human capital, this includes the abilities, dispositions, beliefs, attitudes, values and motives of people. For social capital, these foundations include the pattern of network ties and configurations, the shared understanding across members of the network, and the norms and trust that enable exchange relationships to work effectively. For organizational capital, the foundations include structure, technology and resources.

The outer layer in Figure 1 represents the factors that directly influence safety. For human capital, this includes the expertise, motivation and energy of people; for social capital, factors such as leadership and teamwork; for organizational capital, factors such as safety information systems, policies, procedures and practices.

Insert Figure 1 about here

To elaborate an example, consider a maintenance engineer who is injured by a release of high-pressure steam after failing to isolate a critical process because s/he believed the process had no impact on task safety. This erroneous belief can be viewed from a number of perspectives within the framework of enabling capitals. In terms of human capital, the erroneous belief might reflect a limitation in the knowledge of maintainers about safety procedures and the connection between work processes. Regarding organizational capital, the belief might be influenced by practices which affect the task or the knowledge maintainers have about the task. For example, the training system might not have conveyed adequate information, or the design might reflect a failure to isolate processes effectively. In relation to social capital, and at the most tangible level, a failure by supervisors to communicate risk or promote the value of training might limit the opportunity of maintainers to acquire a more accurate belief. At the deepest level, a shared cultural belief about the nature of the process hazard risk and its controllability may have been implicated as a distal influence over cognitions and/or behavior.

The individual, social, and organizational aspects of the failure described above can be assessed using a range of different measurement methods ranging from personal assessments through to safety climate and culture surveys, and system audit tools. These tools provide a window into the nature of the constraints that control and shape individual and team safety behavior when faced with system disruptions. For example, individuals might hold beliefs about the role of safety in successful performance, norms around leadership style might shape the way supervisors communicate safety goals, and embedded industry practices might constrain the role of training. At the deepest level, implicit assumptions form the essence of the organizational safety culture and hence the most basic mechanisms for system control.

Our capability framework clarifies some distinction between the observable features of safety climate and the more implicit elements of safety culture. The framework places safety climate within the domain of social enabling capital, differentiating it from the organizational and human capitals. Safety climate is therefore conceptualized as perceptions of behavioral norms and espoused values around safety, aggregated at different levels of the organization (e.g., team, department, company). In the following section, we integrate safety capability and these enabling capitals with systems theory to explore how safety culture and climate can act as forms of control.

2. Integrating Systems Approaches with Climate and Culture

Socio-technical systems approaches treat safety as an emergent property of the organizational system and adopt a control orientation to disturbances in the system (Leveson, 2011). Decision makers at each level of the organization pursue goals, which may be set or influenced by other actors at different levels (Rasmussen, 1997). Performance and the achievement (or not) of goals can be affected by disturbances that affect the availability or quality of inputs, or disrupt the process by which inputs are transformed into outputs, which in turn reduces system control. For example, external market forces can influence a firm's investment in safety measures, operational schedules can be disrupted by congestion or weather, and front-line operations can be disrupted by problems with equipment or supplies. An accident can only occur if there the level of control over a work system reduces to the point of failure. There are three ways that loss of control can occur: external disturbances might not be handled effectively; components within the system may fail; or components of the system may interact in unexpected ways (Leveson, 2011).

The Control Problem

One of the critical challenges that organizations face is maintaining effective control in a dynamic and uncertain environment (Griffin et al., 2015). Control is particularly difficult to achieve when the system is subject to unexpected disturbances, there are complex interdependences among the components of the system, and there are lags or delays in the response of the system, or in the provision of feedback to the people making the decisions. To maintain effective control, an organization needs the capability to: a) monitor the output of the system and act to correct any discrepancy between the output and the goal (feedback control); and b) learn from experience, and anticipate or predict the future state of the system to prevent discrepancies from occurring (feed-forward control). A control system that is unable to learn from, adapt to, and anticipate, change, is unable to operate effectively (Hollnagel, Woods, & Leveson, 2007).

Controls act to constrain the system so that it remains within the limits of acceptable performance. According to Rasmussen (1997), the boundaries for safety and economic viability define the feasible operating space for an organization. The operating point location is determined by forces that push the system towards or away from each of these boundaries. In most situations there is uncertainty regarding the exact location of the boundary for unacceptable safety, and an organization will only know that it has crossed the boundary when an accident occurs. For this reason, the organization struggles to keep away from the safety boundary. Rasmussen (1997) argues that, over time, this produces a marginal safety boundary that marks the limit of acceptable safety.

One of the key insights of socio-technical systems theory is that organizations in high risk industries tend to operate close to the marginal safety boundary (Mitropoulos & Cupido, 2009). Management pressure to improve efficiency, and worker pressure to manage the effort necessary for goal achievement push operations closer to the unsafe zone (Hollnagel, 2009; Rasmussen, 1997). The organization's safety management system exerts a counter-pressure, resisting movement towards the boundary. When an organization operates close to the marginal safety boundary, temporary control failures will cause it to cross into the buffer zone. Over time, deviations into the buffer zone become normalized, and the marginal boundary is shifted, reducing the safety margin.

Culture and Climate as System Controls

We propose that safety culture and climate enable organizations to solve the safety control problem through constraints that shape performance in ways that optimize both productivity and safety goals. Safety culture is a distal control mechanism because it is deeply embedded in the organizational functions, it is implicit rather than explicit in actions, and is slow to change (Antonsen, 2009). Core assumptions at the heart of safety culture facilitate control by supporting a shared way of interpreting situations and identifying appropriate responses or ways of acting (Choudhry, Fang, & Mohamed, 2007). For example, assumptions regarding the nature of human activity determine the extent to which people should take initiative or await instruction (Guldenmund, 2000). A belief that people should take initiative is likely to foster more effective responses to emergency scenarios when system control is lost. Conversely, a belief that people should always await instructions before acting may result in catastrophe. This distinction in belief content is apparent in the concept of safety culture maturity (Parker, Lawrie, & Hudson, 2006) whereby organizations are seen to possess varying types of beliefs that are more or less conducive to safety. At one extreme, the shared beliefs held by an organization may be described as ‘pathological’ insofar as they detract from the goal of system safety, and at the other extreme, ‘generative’ in the sense that safety beliefs generalize to all aspects of system operation. From this perspective, implicit safety beliefs (the essence of safety culture) therefore influence system safety through establishing a shared understanding of how to act and think in an organization (Antonsen, 2009; Guldenmund, 2010).

Conversely, safety climate is a proximal control mechanism because the shared perceptions of safety priority and practices at a given point in time can be modified through specific organizational, supervisor, and co-worker practices, and is more closely related to safety behavior (Neal et al., 2000). Organizations can invest resources to build a more positive and coherent safety climate, thus reducing the risk of future accidents. Dimensions of safety climate represent control strategies that elicit specific operating behaviors by enhancing the competence of employees, motivating them effectively, energizing them, and removing constraints. For example, management safety commitment is commonly identified as a key dimension of safety climate (Flin, Mearns, O'Connor, & Bryden, 2000). By establishing managerial practices (e.g., genuine safety walkarounds) and safety interactions, social exchanges activate the norm of reciprocity, obligating employees to behave in ways that are aligned with formal safety procedures and policies.

Control Dilemmas

Turner and Pidgeon (1997) explored the complex role of safety culture in disasters and elaborated ways that culture could simultaneously direct attention toward some hazards yet deflect from others. We explore this duality for both culture and climate in relation to two core control dilemmas for organizational systems. The first dimension represents the relative emphasis that the organization places on reliability as opposed to flexibility. The second dimension represents the way that the organization frames the goals that people are expected to pursue.

Reliability vs Flexibility

One of the key dilemmas that any organization faces is balancing the need for reliability with flexibility (Quinn & Rohrbaugh, 1983). On the one hand, an organization needs to be able to operate reliably under routine operational conditions. When uncertainty is low, as is often the case under routine conditions, it is possible to specify what needs to be done, and how it should be done, using instructions and procedures (Griffin et al., 2007). This is a top-down style of control that is directive and prescriptive. Many organizations try to achieve control over safety using this approach (Rasmussen, 1997) and in fact is the approach taken by most safety management systems (McDonald, Corrigan, Daly, & Cromie, 2000). On the other hand, organizations need flexibility to respond to unanticipated in adaptive ways. This type of response often requires decentralized decision making using local expertise and knowledge (Pidgeon, 1998).

The goal of the top-down approach is to ensure that known risks and hazards are eliminated or controlled. It assumes that work can be decomposed into a set of independent steps, the risks identified for each step, and appropriate controls put in place, typically in the form of procedures. Compliance with safe work procedures is monitored and enforced. This style of control can be effective when the task, corresponding hazards, risk control mechanisms, and the external environment are well-known and isolated from unplanned disruption (Hale & Borys, 2013; Hollnagel, 2011). A top-down control approach is reflected in many safety climate and culture measures, for example, assessing whether people are adequately trained in the use of and comply with safety procedures (Zohar, 1980; Zohar & Luria, 2005).

However, top-down control is problematic in a dynamic and uncertain work environment because it is not possible to write a set of rules to cover every potential circumstance. As a result, the top-down approach is largely reactive, requires large investments of resources to maintain, limits learning, and is more likely to fail under non-routine conditions (Mitropoulos, Abdelhamid, & Howell, 2005). Top-down control also emphasizes uncertainty reduction, whereby prescriptive rules and standardization aim to minimize uncertainty and achieve reliable performance (Grote, 2007). It is particularly problematic when the top-down control mechanisms interact in unforeseen ways, creating conflicting goals and increasing uncertainty (Grote, 2007, 2015). The locations of safety performance boundaries may become obfuscated or shift, especially when efficiency pressures regularly drive performance closer to the boundary of acceptable performance and these deviations become accepted ways of doing work (Dekker & Pruchnicki, 2014). Top-down control strategies may also impair the quality of feedback loops about control implementation and effectiveness from lower to higher levels (Leveson, 2015).

An alternative approach is to emphasize flexibility, using bottom-up control, in which people are given autonomy to make decisions within their area of competence. When uncertainty is high, people need the autonomy to decide what needs to be done, and how to do it (Griffin et al., 2007). Within socio-technical systems theory, this bottom up process is captured by the principle that variance should be controlled as near to the point of origin as possible (Cherns, 1976) . Autonomy has been shown to enhance performance when uncertainty is high, because it: a) allows problems to be detected and solved more quickly and effectively; b) enables decision makers to learn from experience and acquire higher levels of expertise; c) enhances intrinsic work motivation; and d) makes people more proactive and innovative (Parker et al., 2010). In addition to formal changes in how work is done and organized, organizations may also invest in informal and "soft" (Grote, 2007) control mechanisms such as leadership and culture that not only motivate proactive work behaviors, but also elicit normative pressures and constraints on behavior during uncertain system states that require flexibility. Such constraints also aim to manage risk through increasing uncertainty – cultural standards for behavior such as speaking up is an example of how uncertainty can be increased yet risk managed effectively through flexibility(Grote, 2015).

High reliability organizations are a type of work system that can balance the competing demands for reliability and flexibility. These organizations are thought to operate at consistently safe levels close to the acceptable performance boundary using a combination of top-down and bottom-up control (Cook & Rasmussen, 2005). Top-down control is achieved by setting goals or objectives for people to achieve, rather than directing people what to do and how to do it. Procedures are used to standardize operations under routine conditions to ensure consistency and facilitate coordination amongst different actors in the system. However, local operators are given the autonomy to manage disturbances. For example, they are allowed to improvise where necessary, and do what is needed to stabilize the system and respond to threats/disruptions effectively (Weick, 1987; Weick & Sutcliffe, 2001). Achieving optimal levels of both flexibility- and reliability-inducing control strategies should be a goal of high-risk organizations (Grote, 2015).

Promotion vs Prevention

A second control dilemma that organizations-as-systems must successfully reconcile is between promoting gains and preventing losses. Others ways of conceptualizing this control dilemma include the efficiency-thoroughness trade-off (Marais & Saleh, 2008) and the protection-production goals conflict (Wang, Ding, Love, & Edwards, 2016). Given that production--focused promotion goals exert a continual pressure on system operations, pushing closer to the boundary of acceptable performance (Rasmussen, 1997), reframing promotion goals in terms of safety and/or exerting a counter-pressure through prevention goals is critical to achieve safety goals/targets and avoid accidents. Recent research has shown that individual differences in regulatory focus influence risk-taking behavior, with alignment between control strategy and regulatory focus resulting in higher safety performance and misalignment (e.g., negatively-framed safety campaigns for promotion-focused individuals) resulting in lower safety performance (Hamstra, Bolderdijk, & Veldstra, 2011).

As noted above, goals are a key mechanism through which control is achieved in an organization. From a psychological perspective, the framing of a goal as something positive that a person strives to achieve, as opposed to something negative to avoid or prevent, has a profound impact on behavior (Arnold & Reynolds, 2009). According to Regulatory Focus Theory (Higgins, 1997), a promotion focus fulfils fundamental needs of nurturance and growth, is underpinned by strong ideals, aspirations, and desirable end states, and motivates approach behaviors that may include risk-taking and exploration. On the other hand, a prevention focus satisfies needs of security and safety, is underpinned by a sense of obligations, and motivates avoidance or risk-averse behaviors such as rule-following and risk minimization.

From an organizational perspective, it is important to achieve a balance of promotion and prevention. Prevention is essential for organizational survival. The organization needs to respond to economic, social and environmental threats in ways that reduce risk and withdraw from adverse situations to avoid system failures (Weick, Sutcliffe, & Obstfeld, 1999). A focus on duties and obligations keeps people alert to risk, and ensures compliance with minimum standards. On the other hand, an excessive focus on prevention may limit personal initiative, and emphasize compliance behaviors such as rule-following (Aryee & Hsiung, 2016). Promotion, on the other hand, is essential for prosperity. An organization needs to pursue opportunities for growth and development (Scott & Davis, 2015) and a focus on ideals and aspirations keeps people striving for continuous improvement (Wu, McMullen, Neubert, & Yi, 2008).

For example, Wallace and colleagues (Wallace & Chen, 2006; Wallace, Johnson, & Frazier, 2009) found that a prevention focus is negatively associated with injuries because workers are more likely to show vigilance and care, following rules and adopting safety responsibilities. Conversely, a promotion focus was positively associated with injuries as speed and efficiency strategies tended to be used over safe and cautious work behaviors. Others have found that employees' promotion focus was positively related to safety performance through safety initiative – proactive safety behaviors that are self-starting and focused on changing the organization's safety practices to improve them (Aryee & Hsiung, 2016; Kark, Katz-Navon, & Delegach, 2015). In the latter case, it appears that safety can be framed in terms of aspirations and ideals, meaning that promotion-focused safety goals complement prevention-focused goals through elicitation of proactive behaviors that tap into personal and shared values (Kark et al., 2015).

Framing safety as a promotion goal entails describing a future state where work tasks are completed efficiently and without hazard release. Thus, a promotion-focused safety goal means the work system is operating as close as possible to the boundary of safe operations, and is able to do so without unacceptable risk through proper coordination and management of performance variability (Cook & Rasmussen, 2005). A promotion-oriented safety goal also emphasizes ongoing adjustments to performance, resulting in successful variability, continuous improvement, and flexibility to anticipated threats (Curcuruto, Mearns, & Mariani, 2016). Importantly, simultaneous optimization of both prevention- and promotion-focused orientations at work appears to be not only possible, but desirable in terms of performance outcomes, including safety (Kark et al., 2015; Wallace & Chen, 2006).

3. Practical Control Strategies

From a control systems perspective, differences in safety culture and climate configurations represent differences in the types and effectiveness of various control strategies that organizations can employ. The arguments above highlight different ways that organizations strive to solve the safety control problem. These strategies and their associated policies, procedures, and practices are amenable to influence through safety culture and climate. As explained below, the combination of these two control dimensions produce four different types of control strategy.

We expect that the need for these strategies may vary depending on the state of the system, but that over time, organizations are best served by using a balance of all strategies, and dynamically shifting their emphasis on each strategy in anticipation of or in response to changes in system state. Through modifying leadership and safety management practices, which in turn make aspects of the underlying safety culture salient and establish a particular safety climate, organizations are able to deploy appropriate control strategies that return the system to a safe and stable state.

Defend

The first strategy is termed ‘defend’. The defend strategy emphasizes reliability and has a prevention orientation, so is primarily reactive. Defend is employed during system states where a safety incident or near-miss has occurred and the organization is reacting in ways to bolster its barriers to future reoccurrences. Defend may also be used when the system’s risk levels are deemed high such as when routine violations like workarounds or other unsafe acts are occurring. In these system states, high management production pressure and workers’ desire to invest the least effort to complete tasks result in tendencies to sidestep rules to get the job done.

Accordingly, the defend strategy uses control measures that seek to protect against harm or economic loss in a stable environment. These control measures exert a counter-pressure that resists the operating state moving into the unsafe zone, and tightly constrains operating variability. This control is achieved by establishing and enforcing safety standards, monitoring compliance, and acting to correct deviations. The emphasis is on top-down supervisory control. It is a reactive strategy that is most effective when dealing with well-known risks and hazards that are encountered during routine operations. Defend is best described as an uncertainty reduction control strategy, whereby prescriptive action rules and automation are used to centralize control over work systems and achieve reliable and stable operations (Grote, 2015). These practices serve to constrain the variability of performance through prescriptive rules and exerting a counter-pressure in the form of traditional safety campaigns that emphasize rule-following behavior.

Safety climate, as the shared perceptions of safety procedures, creates a ‘strong situation’ that restricts behavior. At a deeper level, shared beliefs and assumptions about the nature of rules exert constraints by providing a referent for how rules should be thought about and acted on. Beliefs regarding the process of justice and power are additional cultural constraints that shape the performance of system operators.

In some organizations, a defend control strategy may become excessively bureaucratic, with increased formalization of safety procedures resulting in apathy and poor quality upwards feedback about system operations from lower levels (Marais et al., 2006). Another disadvantage of the defend strategy is that is sets up a tension with production/efficiency goals, meaning that operators may be inclined to implement workarounds or fail to provide accurate feedback data to higher levels of the organization. Another disadvantage of the defend strategy is the attempted elimination of uncertainty, which may impair safety-related innovation (Grote, 2015). These points suggest that reliance on defend as the primary safety control mechanism is likely to be inadequate.

Adapt

The second strategy is termed ‘adapt’. The adapt strategy emphasizes flexibility and has a prevention orientation, so is also primarily reactive in nature. Adapt is most useful when the system has crossed the boundary of acceptable performance and a hazard has been released. In this situation, the variability of system operations becomes erratic and tightly-coupled, whereby small perturbations in the work system can result in marked changes that could result in disaster (Cook & Rasmussen, 2005). The system objective is to return to a controlled and safe state as quickly as possible.

The adapt control strategy implements constraints that seek to protect against harm or economic loss during non-routine operations, such as when new hazards are encountered for the first time. Adapt exerts control through providing local operators with the flexibility they need to respond quickly and effectively to unexpected disturbances, and to do what is needed to move the system out of the unsafe or unproductive zone. They also enable local operators to learn from mistakes and errors, and to prevent the same problems from occurring again by engaging in proactive safety behaviors such as raising improvement suggestions. At higher levels within the organization, they enable procedures, practices, technology or strategy to be adjusted to suit changing circumstances, thereby obtaining better control over the location of the operating point and performance boundaries, and pulling the operating point to move back into a safe state.

Perceptions of emergency readiness and continuous improvement practices, such as error management, represent the types of constraints exerted by safety climate. Relatedly, climate perceptions around psychological safety, the perception that it is safe to take interpersonal risks, (Edmondson, 1999) are also likely to be important for successful implementation of the adapt strategy. A positive psychological safety climate is related to higher levels of speaking up behavior, such as when a safety incident is first noticed (Grote, 2015). Beliefs about the consequences for speaking up about an error or mistake, and assumptions about the causes of accidents are additional deeper constraints over thinking and behavior within the work system.

Leverage

The third strategy is termed ‘leverage’. The leverage strategy emphasizes the achievement of an optimum balance between production and safety, and so is most effective during normal operational states. Leverage is most useful when the system is operating in stable conditions, and by virtue of production pressures that seek to push the operating state closer to the boundary of acceptable performance, at risk of crossing into the unsafe zone. The location of the acceptable performance boundary may become obfuscated or shift, especially when efficiency pressures routinely drive performance closer to the boundary and these deviations become accepted or ‘normalized’ through implementation of practices and shared understandings across the organization (Dekker & Pruchnicki, 2014). In this situation, operators become complacent to hazards (Marais et al., 2006) and have ‘forgotten to be afraid’ (Reason, 1997).

Leverage uses control measures that seek to simultaneously promote both safety and productivity in a stable environment. These control measures exert a force that pushes the system toward the boundary of acceptable performance, and maintains a dynamic equilibrium over production and safety goals. Leverage achieves optimal balance through promotion-focused goals. These goals appeal to employees’ sense of nurturance and achievement, being challenging in nature and rewarded once attained. Importantly, safety is framed according to a promotion-focused orientation, such as positive targets to be achieved. Recognition of successful task behaviors that achieve promotion goals without compromising safety is a key practice underpinning the leverage control strategy. In this way, the system implements reinforcing loops to encourage future repetition of successful behaviors that optimize both production and safety goals (Goh, Brown, & Spickett, 2010). Leverage requires the removal of barriers or constraints that impede progress, typically by ensuring that activities and operations are appropriately planned and coordinated. Effective coordination of activities between levels of an organizational system is critical for safe performance (Leveson, 2011). Without effective coordination, inappropriate control actions may be issued, resulting in disaster. There must also be clear allocation of accountability for safety performance, and operators need to have the appropriate for the means for achieving accountability (Grote, 2015).

From a safety climate perspective, shared perceptions of reward/recognition, safety communication, and planning practices establish strong behavior-outcome expectancies that shape performance ‘at the pointy end’ of system operations. Culturally, shared assumptions and beliefs about the nature of human relationships and agreement around accountabilities and responsibilities are relevant constraints afforded by the leverage strategy. Culture has long been associated with methods to achieve coordination of independent organizational actors using an approach that deemphasizes effortful surveillance and verification (e.g., Weick, 1987). Using a socio-technical model of safety culture, Grote (2007) described shared practices, norms, and attitudes that achieve coordinated action in ways that are compatible with the leverage control strategy. Examples include measurement of safety indicators, resource planning focused on safety promotion, and collective safety awareness.

Energize

The final strategy is ‘energize’. The energize strategy emphasizes flexibility and has a promotion orientation, so is proactive in nature. This strategy uses control measures that seek to promote safety and/or productivity in a changing environment. These changes can arise from factors such as new technology, the availability of supplies or resources, customer demand, competitors, organizational strategy, structure, or operating conditions. Changes in production technology may put organizations at risk (Marais et al., 2006). Advances in technology may result in hidden sources of risk due to a lack of understanding around how the technology will interface with existing system structures, constraints, and operators. The risk carried by organizational change may be further exacerbated if these produce short-term production benefits, with safety decreasing in importance as a result.

The energize control measures exert a force, pushing the system towards the boundary of acceptable performance. Control is maintained in this situation through constraints such as a shared vision for safety or productivity, inspiring a collective sense of purpose or commitment to these goals, and providing autonomy for people to be able to make it happen. Internalization of company values means that operators look for ways to simultaneously enhance both productivity and safety. Given this emphasis on autonomy and internalization of company goals, energize exerts control over system operators primarily through its effects on internalized forms of motivation. Energize is characterized by proactive work behaviors, such as initiating change in a future-focused manner (e.g., making suggestions to improve efficiency and/or safety of the system). Energize control strategies build employees' level of autonomous and intrinsic motivation, resulting in increased role breadth self-efficacy and role flexibility, appraisals of being in control of work tasks, and openness to change (Curcuruto et al., 2016; Parker, Williams, & Turner, 2006).

Safety climate exerts control through shared perceptions of practices such as employee consultation and involvement in organizational decision-making. Consulting with employees on safety-related changes not only increases their sense of ownership and engagement (Geller, Roberts, & Gilmore, 1996), but also provides upwards feedback information to equip controllers with additional information about how such changes may impact on boundaries and performance. Safety culture exerts control through shared assumptions about the nature of human activity, specifically, the expectation that safety-related proactivity and initiative are desirable behaviors. Also, shared organizational values related to participation and involvement mean that employees are likely to internalize company goals and strive to achieve them. These values can be embedded in systems such as safety rules, with decisional latitude built-in to how rules should be implemented (Grote, 2007).

Insert Table 1 about here

Conclusion

Recent advances in fields such as cognitive systems engineering and resilience engineering have started to integrate safety culture into models of organizational systems. Safety culture tends to be referenced more frequently than safety climate in these systems models. However, safety culture is best considered as an embedded, intangible, and distal influence over system performance, whereas safety climate is more dynamic and malleable, and applicable across multiple levels of analysis. These properties mean that safety climate is readily applied to systems-based models of safety and acts as a proximal mechanism for managing system safety.

Scholars within the resilience engineering discipline have developed novel assessment techniques that are being used to measure the nature and effectiveness of control efforts such as those using signal detection theory, (Abdelhamid, Patel, Howell, & Mitropoulos, 2003) and the resilience analysis grid (Hollnagel, 2009). However, the concept safety climate has largely been absent from these investigations. In light of this work, we recommend that future research should examine the safety climate and culture components that underpin each of the described control strategies, and relate assessment data across these to performance outcomes. Such data will provide organizations with the direction needed to develop the control capabilities required to achieve resilient and safe operations under a range of operating conditions. An additional avenue for research is examining more dynamic models of safety climate that elucidate how climate perceptions can be ‘deployed’ or strategically implemented by decision-makers at different levels of an organizational system to shape and constrain behavior. Such longitudinal research designs will help to establish the control functions afforded by different dimensions of safety climate, and help to inform practical recommendations for industry in terms of implementing safety climate as a form of social control over safety performance. Perhaps the most compelling rationale for including safety climate and culture within systems models is the notion of bottom-up control. Bottom-up control is likely to be more effective and sustainable under the types of conditions faced by high hazard organizations in the modern age, where uncertainty, interdependence, and dynamic environments are encountered routinely.

References

Abdelhamid, T., Patel, B., Howell, G., & Mitropoulos, P. (2003). *Signal detection theory: enabling work near the edge.* Paper presented at the Annual Conference on Lean Construction.

Antonsen, S. (2009). The relationship between culture and safety on offshore supply vessels. *Safety science, 47*(8), 1118-1128.

Arnold, M. J., & Reynolds, K. E. (2009). Affect and retail shopping behavior: Understanding the role of mood regulation and regulatory focus. *Journal of Retailing, 85*(3), 308-320.

Aryee, S., & Hsiung, H.-H. (2016). Regulatory focus and safety outcomes: An examination of the mediating influence of safety behavior. *Safety science, 86*, 27-35.

Bakker, A. B., & Demerouti, E. (2007). The job demands-resources model: State of the art. *Journal of managerial psychology, 22*(3), 309-328.

Bergman, M. E., Payne, S. C., Taylor, A. B., & Beus, J. M. (2014). The Shelf Life of a Safety Climate Assessment: How Long Until the Relationship with Safety–Critical Incidents Expires? *Journal of business and psychology, 29*(4), 519-540.

Beus, J. M., Dhanani, L. Y., & McCord, M. A. (2015). A meta-analysis of personality and workplace safety: Addressing unanswered questions. *Journal of Applied Psychology, 100*(2), 481-498.

Beus, J. M., McCord, M. A., & Zohar, D. (2016). Workplace safety A review and research synthesis. *Organizational psychology review*, 2041386615626243.

Beus, J. M., Payne, S. C., Bergman, M. E., & Arthur Jr, W. (2010). Safety climate and injuries: an examination of theoretical and empirical relationships. *Journal of Applied Psychology, 95*(4), 713.

Beus, J. M., Payne, S. C., Bergman, M. E., & Arthur, W. (2010). Safety climate and injuries: an examination of theoretical and empirical relationships. *The Journal of Applied Psychology, 95*(4), 713-727.

Brondino, M., Silva, S. A., & Pasini, M. (2012). Multilevel approach to organizational and group safety climate and safety performance: Co-workers as the missing link. *Safety Science, 50*(9), 1847-1856.

Cherns, A. (1976). The principles of sociotechnical design. *Human relations*.

Choudhry, R. M., Fang, D., & Mohamed, S. (2007). The nature of safety culture: A survey of the state-of-the-art. *Safety science, 45*(10), 993-1012.

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.

Christian, M. S., Bradley, J. C., Wallace, J. C., Burke, M. J., & Spears, J. (2009). Workplace safety: A meta-analysis of the roles of person and situation factors. *Journal of Applied Psychology, 94*(5), 1103-1127.

Clarke, S. (2006). The Relationship Between Safety Climate and Safety Performance: A Meta-Analytic Review. *Journal of Occupational Health Psychology, 11*(4), 315-327.

Clarke, S. (2010). An integrative model of safety climate: Linking psychological climate and work attitudes to individual safety outcomes using meta-analysis. *Journal of Occupational and Organizational psychology, 83*(3), 553-578.

Cook, R., & Rasmussen, J. (2005). “Going solid”: a model of system dynamics and consequences for patient safety. *Quality and Safety in Health Care, 14*(2), 130-134.

Cox, S., & Flin, R. (1998). Safety culture: philosopher's stone or man of straw? *Work & stress, 12*(3), 189-201.

Curcuruto, M., Mearns, K. J., & Mariani, M. G. (2016). Proactive role-orientation toward workplace safety: Psychological dimensions, nomological network and external validity. *Safety science, 87*, 144-155.

Dekker, S., & Pruchnicki, S. (2014). Drifting into failure: theorising the dynamics of disaster incubation. *Theoretical Issues in Ergonomics Science, 15*(6), 534-544.

Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. (2001). The job demands-resources model of burnout. *Journal of Applied psychology, 86*(3), 499.

Denison, D. R. (1996). What is the difference between organizational culture and organizational climate? A native's point of view on a decade of paradigm wars. *Academy of management review, 21*(3), 619-654.

Durso, F. T., & Sethumadhavan, A. (2008). Situation awareness: Understanding dynamic environments. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50*(3), 442-448.

Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative science quarterly, 44*(2), 350-383.

Flin, R., Mearns, K., O'Connor, P., & Bryden, R. (2000). Measuring safety climate: Identifying the common features. *Safety science, 34*(1), 177-192.

Gagné, M., & Deci, E. L. (2005). Self-determination theory and work motivation. *Journal of Organizational behavior*, *26*(4), 331-362.

Geller, E., Roberts, D., & Gilmore, M. R. (1996). Predicting propensity to actively care for occupational safety. *Journal of Safety Research, 27*(1), 1-8.

Goh, Y. M., Brown, H., & Spickett, J. (2010). Applying systems thinking concepts in the analysis of major incidents and safety culture. *Safety science, 48,* 302-309.

Goh, Y. M., Love, P. E., Stagbouer, G., & Annesley, C. (2012). Dynamics of safety performance and culture: A group model building approach. *Accident Analysis & Prevention, 48*, 118-125.

Griffin, M. A., Cordery, J., & Soo, C. (2015). Dynamic safety capability How organizations proactively change core safety systems. *Organizational Psychology Review*.

Griffin, M. A., & Curcuruto, M. (2016). Safety climate in organizations. *Annual Review of Organizational Psychology and Organizational Behavior, 3*, 191-212.

Griffin, M. A., Hodkiewicz, M. R., Dunster, J., Kanse, L., Parkes, K. R., Finnerty, D., et al. (2014). A conceptual framework and practical guide for assessing fitness-to-operate in the offshore oil and gas industry. *Accident Analysis and Prevention, 68*, 156-171.

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*(3), 347-358.

Griffin, M. A., Neal, A., & Parker, S. K. (2007). A new model of work role performance: Positive behavior in uncertain and interdependent contexts. *Academy of Management Journal, 50*(2), 327-347.

Grote, G. (2007). Understanding and assessing safety culture through the lens of organizational management of uncertainty. *Safety science*, *45*(6), 637-652.

Grote, G. (2015). Promoting safety by increasing uncertainty–Implications for risk management. *Safety science, 71*, 71-79.

Guldenmund, F. W. (2000). The nature of safety culture: a review of theory and research. *Safety Science, 34*(1), 215-257.

Guldenmund, F. W. (2010). (Mis)understanding Safety Culture and Its Relationship to Safety Management. *Risk Analysis, 30*(10), 1466-1480.

Hale, A., & Borys, D. (2013). Working to rule, or working safely? Part 1: A state of the art review. *Safety science, 55*, 207-221.

Hamstra, M. R. W., Bolderdijk, J. W., & Veldstra, J. L. (2011). Everyday risk taking as a function of regulatory focus. *Journal of research in personality, 45*(1), 134-137.
Higgins, E. T. (1997). Beyond pleasure and pain. *American Psychologist, 52*(12), 1280-1300.
Hockey, G. (2013). 'The problem of fatigue: The Psychology of Fatigue: Work, Effort and Control, ed. GR Hockey (Cambridge: Cambridge University Press).
Hofmann, D. A., Morgeson, F. P., & Gerras, S. J. (2003). Climate as a moderator of the relationship between leader-member exchange and content specific citizenship: Safety climate as an exemplar. *Journal of Applied Psychology, 88*(1), 170-178.
Hollnagel, E. (2009). *Safer complex industrial environments: A human factors approach*. Boca Raton, FL: CRC Press.
Hollnagel, E. (2011). Prologue: The scope of resilience engineering. In E. Hollnagel, J. Paries, D. D. Woods & J. Wreathall (Eds.), *Resilience Engineering in Practice: A Guidebook* (pp. xxx-xxxix). Burlington: Ashgate Pub Co.
Hollnagel, E., Paries, J., Woods, D. D., & Wreathall, J. (2011). *Resilience engineering in practice: A guidebook*. Burlington, VA: Ashgate
Hollnagel, E., Woods, D. D., & Leveson, N. (2007). *Resilience engineering: Concepts and precepts*. Aldershot: Ashgate.
Kark, R., Katz-Navon, T., & Delegach, M. (2015). The dual effects of leading for safety: The mediating role of employee regulatory focus. *Journal of Applied Psychology, 100*(5), 1332.
Lee, S., & Dalal, R. S. (2016). Climate as situational strength: Safety climate strength as a cross-level moderator of the relationship between conscientiousness and safety behaviour. *European Journal of Work and Organizational Psychology, 25*(1), 120-132.
Leveson, N. (2011). *Engineering a safer world : systems thinking applied to safety*. Cambridge, MA: MIT Press.
Leveson, N. (2015). A systems approach to risk management through leading safety indicators. *Reliability Engineering & System Safety, 136*, 17-34.
Liu, Y., Mo, S., Song, Y., & Wang, M. (2016). Longitudinal Analysis in Occupational Health Psychology: A Review and Tutorial of Three Longitudinal Modeling Techniques. *Applied Psychology An International Review, 65*(2), 379-411.
Marais, K., & Saleh, J. H. (2008). Conceptualizing and communicating organizational risk dynamics in the thoroughness–efficiency space. *Reliability Engineering & System Safety, 93*(11), 1710-1719.
Marais, K., Saleh, J. H., & Leveson, N. G. (2006). Archetypes for organizational safety. *Safety science, 44*(7), 565-582.
Maslach, C., & Leiter, M. P. (2008). Early predictors of job burnout and engagement. *Journal of Applied Psychology, 93*(3), 498-512.
McDonald, N., Corrigan, S., Daly, C., & Cromie, S. (2000). Safety management systems and safety culture in aircraft maintenance organisations. *Safety Science, 34*(1), 151-176.
Mitropoulos, P., Abdelhamid, T. S., & Howell, G. A. (2005). Systems model of construction accident causation. *Journal of Construction Engineering and Management, 131*(7), 816-825.
Mitropoulos, P., & Cupido, G. (2009). Safety as an emergent property: investigation into the work practices of high-reliability framing crews. *Journal of Construction Engineering and Management, 135*(5), 407-415.
Nahrgang, J. D., Morgeson, F. P., & Hofmann, D. A. (2011). Safety at work: A meta-analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. *Journal of Applied Psychology, 96*(1), 71-94.

Neal, A., Ballard, T., & Vancouver, J. B. (in press). Dynamic self-regulation and multiple-goal pursuit. *Annual Review of Organisational Psychology and Organisational Behavior*.

Neal, A., & Griffin, M. A. (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. *Journal of Applied Psychology, 91*(4), 946-953.

Neal, A., Griffin, M. A., & Hart, P. M. (2000). The impact of organizational climate on safety climate and individual behavior. *Safety Science, 34*(1), 99-109.

Parker, D., Lawrie, M., & Hudson, P. (2006). A framework for understanding the development of organisational safety culture. *Safety Science, 44*(6), 551-562.

Parker, S. K., Bindl, U. K., & Strauss, K. (2010). Making things happen: A model of proactive motivation. *Journal of management*.

Parker, S. K., Williams, H. M., & Turner, N. (2006). Modeling the antecedents of proactive behavior at work. *Journal of Applied Psychology, 91*(3), 636-652.

Pidgeon, N. (1998). Safety culture: Key theoretical issues. *Work & Stress, 12*(3), 202-216.

Pidgeon, N., & O'Leary, M. (2000). Man-made disasters: why technology and organizations (sometimes) fail. *Safety Science, 34*(1), 15-30.

Quinn, R. E., & Rohrbaugh, J. (1983). A spatial model of effectiveness criteria: towards a competing values approach to organizational analysis. *Management Science, 29*(3), 363-377.

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. *Safety science, 27*(2), 183-213.

Reason, J. T. (1997). *Managing the risks of organizational accidents*. Aldershot: Ashgate.

Reason, J. T. (1998). Achieving a safe culture: theory and practice. *Work and Stress, 12*(3), 293-306.

Reiman, T., & Rollenhagen, C. (2014). Does the concept of safety culture help or hinder systems thinking in safety? *Accident Analysis & Prevention, 68*, 5-15.

Schaufeli, W. B., & Bakker, A. B. (2004). Job demands, job resources, and their relationship with burnout and engagement: A multi-sample study. *Journal of organizational Behavior, 25*(3), 293-315.

Schein, E. H. (2004). *Organizational Culture and Leadership*. New York: John Wiley & Sons.

Scott, N., Fleming, M., & Kelloway, E. K. (2014). Understanding Why Employees Behave Safely from a Self-Determination Theory Perspective. In M. Gagné (Ed.), *The Oxford Handbook of Work Engagement, Motivation and Self-Determination Theory* (pp. 276-294). USA: Oxford University Press.

Scott, W. R., & Davis, G. F. (2015). *Organizations and organizing: Rational, natural and open systems perspectives*: Routledge.

Turner, B. A., & Pidgeon, N. F. (1997). *Man-made disasters* (2nd ed.). Oxford: Butterworth-Heinemann.

Wallace, C., & Chen, G. (2006). A multilevel integration of personality, climate, self-regulation, and performance. *Personnel Psychology, 59*(3), 529-557.

Wallace, J. C., Johnson, P. D., & Frazier, M. L. (2009). An examination of the factorial, construct, and predictive validity and utility of the regulatory focus at work scale. *Journal of Organizational Behavior, 30*(6), 805-831.

Wang, F., Ding, L., Love, P. E., & Edwards, D. J. (2016). Modeling tunnel construction risk dynamics: Addressing the production versus protection problem. *Safety science, 87*, 101-115.

Weick, K. E. (1987). Organizational culture as a source of high reliability. *California Management Review, 29*(2), 112-127.

Weick, K. E., & Sutcliffe, K. M. (2001). *Managing the unexpected*: Jossey-Bass San Francisco.
Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (1999). Organizing for high reliability: Processes of collective mindfulness. *Research in Organizational Behavior, 21*, 23-81.
Wu, C., McMullen, J. S., Neubert, M. J., & Yi, X. (2008). The influence of leader regulatory focus on employee creativity. *Journal of Business Venturing*, *23*(5), 587-602.
Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied implications. *Journal of Applied Psychology, 65*(1), 96-102.
Zohar, D. (2010). Thirty years of safety climate research: Reflections and future directions. *Accident Analysis & Prevention, 42*(5), 1517-1522.
Zohar, D. (2011). Safety climate: Conceptual and measurement issues. In *Handbook of occupational health psychology* (2nd ed., pp. 141-164). Washington, DC: American Psychological Association; US.
Zohar, D., Huang, Y.-h., Lee, J., & Robertson, M. M. (2015). Testing extrinsic and intrinsic motivation as explanatory variables for the safety climate–safety performance relationship among long-haul truck drivers. *Transportation Research Part F: Traffic Psychology and Behaviour, 30*, 84-96.
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*(4), 616-628.

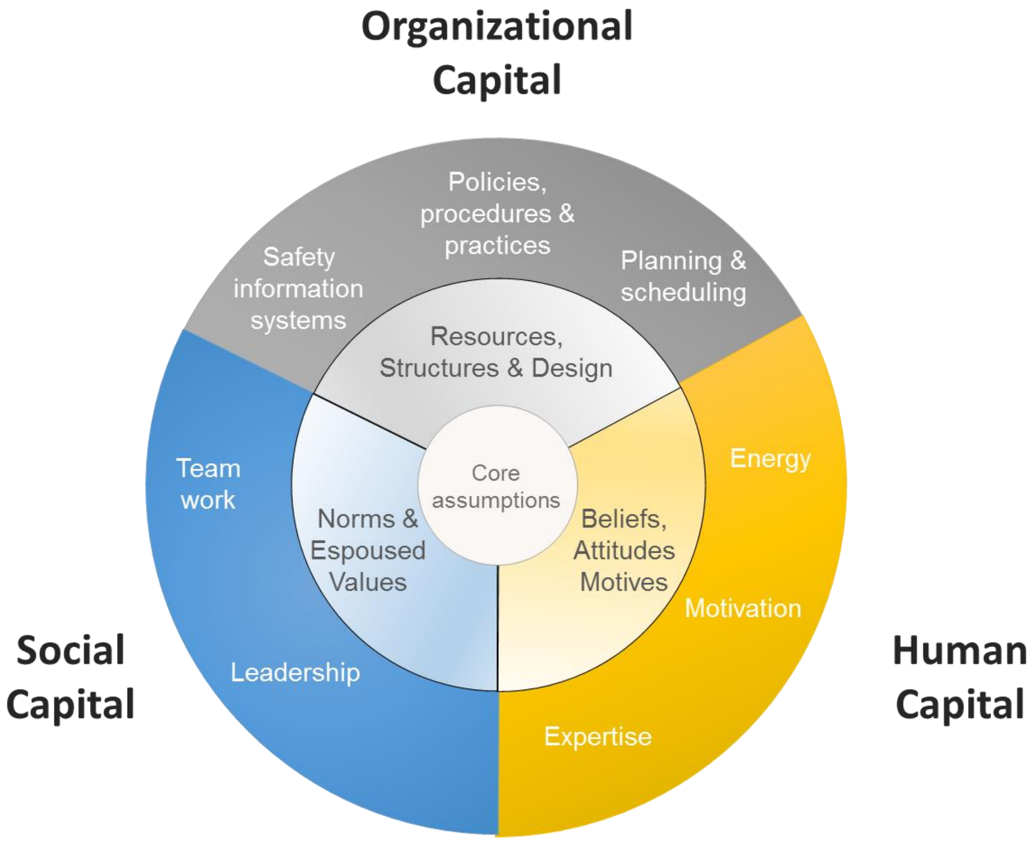

Figure 1. Organizational, social, and human enabling capitals.

Table 1. Overview of control strategies.

Energize	***Adapt***
Control measures that seek to promote safe production in a changing environment (e.g., changes in technology, the availability of supplies or resources, customer demand, competitors, organizational strategy, structure, or operating conditions). These control measures change the system boundaries to enhance efficiency and safety performance. This is done by developing a shared vision for safe production as an aspirational goal, inspiring a collective sense of purpose or commitment to these goals, providing autonomy, and involving operators in decision-making. Safety climate: Perceptions of employee consultation and involvement practices. Safety culture: Beliefs around the nature of human activity, and specifically safety initiative. The system is proactive and forward-looking with a view to exploring new opportunities and capitalizing on them to improve efficiency and/or safety.	Control measures that seek to protect against harm or economic loss in novel accident scenarios (e.g., loss of process control, hazard release). These control measures exert a counter-pressure that pulls the system operating point back into the safe zone. This is achieved by implementing well-practiced emergency routines, and adjusting procedures, practices, technology or strategy to prevent future reoccurrences. Safety climate: Perceptions of emergency readiness and error management practices. Safety culture: Beliefs about the consequences of speaking up about errors/mistakes, and the causes of accidents. The system is reactive and reflective with a view to improving future performance through exploiting current capabilities to restore safety, and ensuring the system adapts and learns from its failures.
Leverage	***Defend***
Control measures that seek to promote safe production in a stable and routine environment. These control measures push the system towards an optimal production/safety balance. Constraints are established through setting aspirational standards, monitoring progress, and rewarding success and accomplishment. It requires the removal of barriers or constraints that impede progress. Effective planning and coordination are hallmarks of this control strategy. Safety climate: Perceptions of safety recognition, communication, and planning practices. Safety culture: Beliefs about the nature of human relationships, particularly cooperation to achieve shared safety goals. The system is proactive and forward-looking with a view maintaining a dynamic equilibrium between safety and efficiency.	Control measures that seek to protect against harm or economic loss in a stable and routine environment. These control measures exert a force that pulls the operating state back into the safe zone and constraints variability to reduce risk as low as possible. Defend exerts control by setting and enforcing safety standards, monitoring compliance, and acting to correct deviations. The emphasis is on top-down control. Disciplinary practices aim to eliminate violations and performance variability. Safety climate: Perceptions of safety procedures and practices. Safety culture: Beliefs about the nature of rules, organizational justice, and distribution/use of power. The system is reactive and reflective with a view to eliminating sources of performance variability and resisting the pressures exerted by production and efficiency goals.