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Original Article

Knowledge Management and Safety Compliance in a High-Risk Distributed Organizational System

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ABSTRACT

Background: In a safety perspective, efficient knowledge management is important for learning purposes and thus to prevent errors from occurring repeatedly. The relationship between knowledge exchange among employees and safety behavior may be of particular importance in distributed organizational systems where similar high-risk activities take place at several locations. This study develops and tests hypotheses concerning the relationship between knowledge exchange systems usage, knowledge exchange in the organizational system, and safety compliance.

Methods: The operational context of the study is petroleum drilling and well operations involving distributed high-risk activities. The hypotheses are tested by use of survey data collected from a large petroleum operator company and eight of its main contractors.

Results: The results show that safety compliance is influenced by use of knowledge exchange systems and degree of knowledge exchange in the organizational system, both within and between units. System usage is the most important predictor, and safety compliance seems to be more strongly related to knowledge exchange within units than knowledge exchange between units.

Conclusion: Overall, the study shows that knowledge management is central for safety behavior.

1. Introduction

It is widely recognized that human behavior is important for the safety level within complex work systems [1–6]. In this respect, Neal et al [7] emphasize the role of safety compliance, which involves employees "adhering to safety procedures and carrying out work in a safe manner" (p. 101). The significance of safety compliance has been confirmed by numerous accident and incident investigations in several high-risk industries identifying a lack of compliance with regulations, rules, and governing procedures as a central contributing factor [8]. Much research has for this reason been occupied with investigating the impact of individual, organizational, and environmental factors on the level of safety compliance in diverse work contexts and industries (e.g., [9–18]).

Collection of experiences about incidents and nonconformances, and distribution of this knowledge throughout the organizational system are important in order to exchange lessons learned and prevent errors from occurring repeatedly [19,20]—that is, keeping the employees up-to-date on potential challenging situations and facilitating the application of previous experiences in order to improve work processes are central for safety and health at work. Such knowledge exchange can take place through a number of different mechanisms, and use of information and communication technologies represents, in this regard, one means for collection of experiences and dissemination of knowledge. Use of knowledge exchange systems or electronic knowledge repositories to improve the processes of transfer and reuse of existing knowledge has become commonplace in many organizations [21,22]. Research has shown that such systems have the potential to facilitate knowledge exchange by making it easy and relevant for employees to store, transfer, and use knowledge [21,23–26].

Knowledge management by use of knowledge exchange systems may therefore be essential in a safety perspective, particularly in the context of high-risk distributed organizational systems where similar work operations take place at different locations, and where exchange of experiences may be difficult to achieve by use of relational/personal channels. In spite of this, the role of knowledge exchange systems in distributed organizational systems has received

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little attention in safety research. This paper aims at making a contribution to close this research gap, and investigates the relationships between safety compliance, knowledge exchange in the organizational system, and use of knowledge exchange systems.

1.1. Theory and hypotheses

1.1.1. Knowledge exchange and safety compliance

Safety compliance is considered to be a central component of safety behavior at work [27], and refers to the core activities that employees should carry out to maintain workplace safety, including adherence to standard work procedures and regulations [7,28]. Violations of such regulations and procedures describing safe or approved methods of performing a particular task or job may occur intentionally or unintentionally [29]. Violations of the former type are deliberate actions that take place when employees know of the rules/regulations but choose not to adhere to them, whereas violations of the latter type occur because of a lack of knowledge or awareness of the rules/regulations [30].

This understanding of safety compliance is based on the broader concept of task performance proposed by Borman and Motowidlo [31] and Campbell et al [32], which represents one of two components (the other is contextual performance) describing the work performance of individuals [33]. In addition to the performance components, this conceptualization further distinguishes between performance determinants and performance antecedents [34]. Regarding performance determinants, Campbell et al [32] argue that there are three significant factors at play: knowledge, skill, and motivation. This understanding thus implies that safety behavior (and thus safety compliance) is determined by individuals' motivation to perform their work in a safe manner in addition to their knowledge and skills necessary for doing so. The performance antecedents are distal causes of performance variability, and they influence task performance through the performance determinants.

Intentional and unintentional violations may have different determinants. According to Lawton and Parker [35], deliberate noncompliance with procedures and regulations is associated with attitudes of the employees. Numerous studies have, for example, demonstrated that individuals differ in their willingness to take risks (e.g., [36,37]), and Brown et al [11] found that such attitudes were negatively associated with safe behavior. Unintentional violations, by contrast, can be attributed to deficiencies in skill and information processing [29,35]. With reference to the determinants of performance, this means that knowledge and skills are more strongly associated with unintentional violations, whereas motivation is a relevant factor for intentional violations.

As knowledge and skills represent important determinants of safety behavior, exchange of knowledge among employees is relevant. Knowledge exchange includes both knowledge sharing (i.e., employees providing knowledge to others), and knowledge seeking and application (i.e., employees use knowledge of others in task accomplishment) [38]. For this to occur, knowledge possessed by individuals has to be explicated, meaning that it has to be converted into a form that can be understood, absorbed, and applied by other individuals [39]. Knowledge exchange is further understood as the contribution or receipt of task information, work methods, know-how and advice, or feedback on products and procedures [40,41], and can take place by use of different channels, both formal and informal [39]. In general, research has shown that exchange of such knowledge within and across units increases the abilities of employees to benefit from the experiences accumulated by others and thereby enhance their own knowledge and skills [42]. Knowledge exchange may thus improve safety compliance by reduction of unintentional violations. Furthermore, in addition to enhancing the knowledge and skills of employees, gaining knowledge of the experiences of colleagues, such as challenges and complications that have occurred during operations, may increase the emphasis on safe work conduct. According to Catino and Patriotta [43], cognitive appraisal of risky situations trigger emotions that promote internalization of lessons learned when rationalized in retrospect. On this basis, it can be argued that knowledge of previous incidents and challenges may reduce the willingness to take risks, and thus increase compliance with procedures by reducing intentional violations. In sum, knowledge exchange may influence all performance determinants (knowledge, skills, and motivation), and lead to higher safety compliance by reducing both intentional and unintentional violations. The following hypotheses are therefore stated:

H1a: Knowledge exchange within units is positively related to safety compliance.

H1b: Knowledge exchange between units is positively related to safety compliance.

1.1.2. Knowledge exchange systems

Knowledge exchange systems are typically structured databases or electronic knowledge repositories that support the digital capture, storage, retrieval, and distribution of codified knowledge for later reuse [22,44–46]. In order for such systems to be successful, employees have to provide input to the systems and use available content [47–50]. System usage thus involves the engagement of employees in discussions of best practices, providing input on work procedures, governing documentation, and how to improve work processes in general. As research has shown that perception of safety priorities and engagement in organizations positively affects safety motivation and attitudes [51,52], this engagement may lead to an enhanced focus/emphasis on safety behavior. That is, in addition to the knowledge that employees gain when using knowledge exchange systems (which is hypothesized to increase safety compliance), providing input to knowledge exchange systems may have an additional effect on the motivational determinant of work performance, and thus reduce intentional violations. It is therefore hypothesized that:

H2: Use of knowledge exchange systems is positively related to safety compliance over and above the effects of knowledge exchange within (H1a) and between (H1b) units.

As the purpose of knowledge exchange systems is to support the exchange of knowledge between employees [21,22], system usage (i.e., providing input to electronic repositories/databases and application of available content) is also expected to enhance knowledge exchange both within and between units.

H3a: Use of knowledge exchange systems is positively related to knowledge exchange within units.

H3b: Use of knowledge exchange systems is positively related to knowledge exchange between units.

Thus, knowledge exchange systems usage is hypothesized to influence safety compliance both directly and through increased knowledge exchange between colleagues. The hypotheses are summarized in Fig. 1.

2. Materials and Methods

2.1. Sample and data collection

Collecting data from employees working in a distributed organizational setting, where knowledge exchange within and between units is relevant and (potentially) takes place on a regular basis,

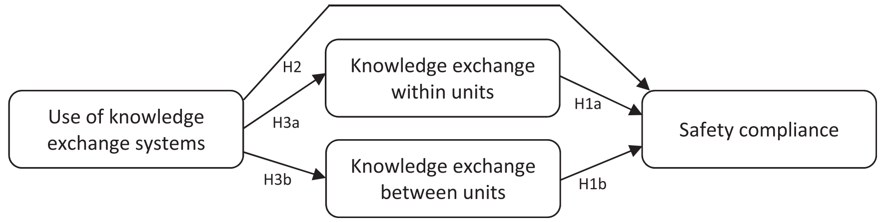

Fig. 1. Research model with hypotheses.

represented a fundamental requirement for the study. Meeting this requirement, the data applied to test the hypotheses were collected from a cross-sectional sample of 5856 employees from nine different organizations involved in petroleum drilling operations (one operator company and eight of its main contractors). In this work context, similar high-risk operations take place at different locations, making knowledge exchange relevant both for efficiency and safety reasons.

Web-based questionnaires containing 105 questions concerning various aspects of the work situation (including knowledge exchange processes and safety compliance) were developed and administered to 1398 employees of the operator company and 4458 employees of the contractors by use of e-mail. A cover letter explaining the purpose of the survey as well as details concerning ethical and practical issues of participation was also distributed to the potential respondents. As some of the questions were measuring aspects related to the relationship between the operator and the contractors, the wordings of these questions had to be adapted to the respondent group, and two sets of questionnaires (one for operator employees and one for contractor employees) were therefore developed. The questions concerning the variables in this present study (knowledge exchange systems usage, knowledge exchange within and between units, and safety compliance) were identical, making it possible to include data from all respondents in the analysis.

The response rates for the operator employees and contractor employees were 63% (880 completed questionnaires) and 40% (1773 completed questionnaires), respectively. The total number of responses was thus 2653 (response rate of 45%). However, as some of the respondents had no experience with the knowledge exchange systems, or found the questions to be irrelevant for their work situation, the total number of usable responses for hypotheses testing was 2106. Demographic details of the respondents in the study are presented in Table 1.

2.2. Measures

The questionnaire was constructed based on existing studies and input from industry representatives. Operator company personnel were involved in this process in order to assure that the questions were relevant for the specific work context, and thus achieve a high level of face validity of the measures. This input was of particular importance for the questions concerning knowledge exchange systems usage, as these questions were related to specific systems applied in daily work conduct. That is, instead of asking the respondents to assess their use of knowledge exchange systems in general, using the names of specific systems and channels for knowledge exchange in the questionnaire was preferred in order to make it easier for the respondents to relate the questions to their work situation.

2.2.1. Safety compliance

Measurement of safety compliance was based on measures applied by Dahl and Olsen [10] and Tharaldsen et al [53], and included the following items: “In my unit we always use safe job analysis (SJA) in the completion of tasks that could entail risk,” “In my unit we always comply with governing documentation,” “In my unit we handle nonconformities according to governing documentation,” and “In my unit we always use governing documentation in planning, organization, and completion of the work.” The items were rated on a 6-point scale ranging from totally disagree (1) to fully agree (6). The Cronbach alpha of the scale was 0.85.

2.2.2. Knowledge exchange

The respondents were given the following introduction to the knowledge exchange questions: “We are interested in the exchange of advice and information, participation in transfer of experience and other forms of knowledge transfer. This concerns your daily accomplishment of tasks, questions about methods, and choice of technology, etc.” Thereafter, the respondents were asked to rate the extent to which such knowledge exchange occurs “at your entity/installation” and “between entities/installations” on a 6-point scale ranging from none (1) to very much (6). Single-item questions were chosen as the respondents were likely to understand the term “knowledge” in light of their specific work situation and context. The respondents were thus allowed to consider all relevant aspects and individual preferences to provide a single rating [54–56].

2.2.3. Knowledge exchange systems usage

Four different systems that the employees of the involved companies apply to exchange work experiences, challenges, and solutions were included in the questionnaire. The systems cover different aspects of work conduct, but all involve knowledge exchange both within and between units. Two of the systems are

Table 1
Survey demographics

	Categories	%
Age	<25	4.1
	25–35	23.2
	36–45	35.1
	46–57	31.6
	>58	5.9
Education	Primary and secondary schools	4.8
	Upper secondary school	32.9
	Higher education <4 y	40
	Higher education >4 y	22.3
Experience (y) — drilling and well operations	<1	5.2
	1–3	7.4
	3–5	12.6
	5–10	15.2
	>10	59.5
Work location	Mainly onshore	45.5
	Mainly offshore	54.5
Leader responsibility	No supervisory function	59.9
	First line manager	30.4
	Line manager at higher level	9.6
Length of employment (y) — current employer	<1	5.6
	1–3	10.2
	3–5	15.8
	5–10	20.3
	>10	48

related to the exchange of knowledge concerning planning and execution of drilling operations, one system focuses on safety issues (i.e., registration and sharing of incidents), and one system focuses on knowledge exchange needs of teams in general (i.e., exchange of documents between team members located at different sites). All systems are available to both operator employees and contractor employees (i.e., both groups of employees are able to codify/store knowledge in the systems and apply available content).

The selection of systems was based on the relevancy considerations of the operator personnel involved in questionnaire development. For each of the four systems, the respondents were asked to rate the following items (on a 6-point scale from totally disagree to fully agree): "I actively use others experiences documented in [name of the system]," "I use [name of the system] to document our experiences," and "The information available in [name of the system] is useful for me." High scale reliabilities were achieved (the lowest single-scale alpha was 0.80), and alpha of the aggregate measure (including usage of all systems) was 0.87. Respondents who did not have any experience with the systems were excluded from the analyses.

Finally, as research indicates that individual level variables like ability and experience are important antecedents of task performance [33], several control variables were included in the analyses in addition to the variables depicted in the research model (Fig. 1) in order to account for individual differences. These control variables were age, education, experience with drilling and well operations, work location, leader responsibility, and length of employment. Table 1 lists the scales and demographic statistics of the control variables.

3. Results

Table 2 displays the zero-order correlations, means, and standard deviations for the study variables (including control variables). The variables show varying degrees of association with each other. The strongest correlations are between length of employment and work experience within drilling operations (0.70), and between the knowledge exchange variables (0.61). However, collinearity statistics show that the highest variance inflation factor is 2.1, which indicates that no multicollinearity problems exist [57]. Also, controlling for common method bias, Harman's single factor test revealed the presence of three factors. The largest factor did not account for a majority of the variance; thus, no general factor was apparent.

In order to test H1a–b and H2, hierarchical multiple regression analysis with safety compliance as dependent variable was conducted. The control variables, knowledge exchange within and between units, and system usage were included in steps 1, 2, and 3, respectively. The results are presented in Table 3.

Table 3 shows that all predictors (except three control variables) in the model are significantly related to safety compliance. Knowledge exchange systems usage is the most important predictor, and has a significant effect over and above the effects of knowledge exchange. This means that the results lend support for the hypothesized relationships (H1a–b and H2). We should also note that work experience and education are negatively related to safety compliance, whereas leader responsibility is positively related to this variable. The model explains 19% of the variance in the dependent variable, which is rather low but nevertheless well above the threshold of 10% for substantive explanatory power suggested by Falk and Miller [58].

The remaining hypotheses (H3a and H3b) were tested by use of hierarchical multiple regression analyses with knowledge exchange within and between units as dependent variables. The control variables were included in Step 1, and knowledge exchange systems usage was included in Step 2. The results are shown in Table 4.

Table 4 shows that system usage is positively related to both knowledge exchange within units and knowledge exchange between units, and H3a and H3b are therefore supported. Table 4 also shows that age is negatively associated with both dependent variables, and that education and work location are negatively related to knowledge exchange between units (onshore employees exchange knowledge across units to a larger extent than offshore employees). The control variables explain 1% and 2% of the variance in knowledge exchange within and between units, respectively, and explained variance increases to 10% and 8% when system usage is introduced in the models.

4. Discussion

4.1. Knowledge exchange and safety compliance

Efficient knowledge management in organizations is considered to be fundamental for designing a work climate that supports failure-based learning and preventing incidents and accidents to occur repeatedly [20]. Although some attention has been given to the role of knowledge exchange in the organizational safety literature (e.g., [59–61]), most research on organizational antecedents of safety behavior has emphasized safety climate factors such as management commitment, communication for safety, safety equipment and maintenance, and safety training (e.g., [16,62,63]).

Table 2
Correlation matrix

Variable	1	2	3	4	5	6	7	8	9	10
1. Age										
2. Education	−0.06†									
3. Experience	0.59†	−0.05†								
4. Work location	−0.07†	0.29†	−0.14†							
5. Leader responsibility	0.22†	0.01	0.30†	−0.05†						
6. Length of employment	0.57†	−0.05†	−0.70†	−0.13†	0.32†					
7. System usage	0.01	−0.02	−0.06†	0.02	−0.02	−0.09†				
8. Knowledge exchange within units	−0.05*	0.01	−0.05*	0.05*	0.01	−0.05*	0.30†			
9. Knowledge exchange between units	−0.04	−0.11†	−0.04	−0.07†	−0.01	−0.04	0.25†	0.61†		
10. Safety compliance	−0.03	−0.07†	−0.08†	−0.07†	0.03	−0.08†	0.34†	0.31†	0.27†	
Mean	3.1	2.8	4.2	1.5	1.5	4	4.2	4.7	4.2	5.1
Standard deviation	1.0	0.8	1.2	0.5	0.7	1.2	0.8	0.9	1.0	0.6
Min.	1	1	1	1	1	1	1	1	1	1
Max.	5	4	5	2	3	5	6	6	6	6

*$p < 0.05$.
†$p < 0.01$.

Table 3
Results of regression analysis — test of H1a–b and H2

Predictor	Dependent variable: Safety compliance					
	Step 1		*Step 2*		*Step 3*	
	t	*β*	*t*	*β*	*t*	*β*
Age	1.5	0.04	2.3	0.05*	1.1	0.03
Education	−3.2	−0.07†	−2.4	−0.05*	−2.8	−0.05†
Experience with drilling operations	−2.8	−0.09†	−3.1	−0.09†	−2.9	−0.09†
Work location	−1.4	−0.03	−1.3	−0.03	−1.5	−0.03
Leader responsibility	3.6	0.08‡	3.7	0.08‡	3.8	0.08‡
Length of employment	−2.4	−0.08*	−2.0	−0.06*	−1.0	−0.03
Knowledge exchange within units			9.9	0.25‡	7.6	0.19‡
Knowledge exchange between units			4.6	0.12‡	3.4	0.08†
System usage					13.2	0.26‡
ΔR^2			0.12		0.05	
ΔF			263.2‡		55.4‡	
R^2	0.02		0.14		0.19	
F	8.0‡		45.4‡		49.6‡	

*$p < 0.05$.
†$p < 0.01$.
‡$p < 0.001$.

This study shows that knowledge exchange among employees in general, and use of knowledge exchange systems in particular, are significant factors for safety behavior, and on an overall level therefore underlines that organizational aspects beyond the traditional safety climate factors are relevant for safety research. Interpreting the results in light of the theoretical perspective that sees knowledge, skills, and motivation as determinants of task performance [31,32], it can be argued that exchange of work methods, experiences, and other types of knowledge influence safety compliance by increasing employees' work skills and understanding of work procedures and regulations, and also by directing attention to the importance of risk moderation and thus increasing employees motivation for safe work conduct.

The results also indicate that safety compliance is more strongly related to knowledge exchange within units than knowledge exchange between units (betas of 0.19 and 0.08, respectively; see Table 3), which implies that organizational distribution is relevant for the relationship between knowledge exchange and safety behavior. This can be explained by a potential difference in perceived relevance of knowledge, meaning that local practices/experiences may be more relevant for work conduct than experiences from employees working at other (more geographical and organizational distant) locations in the organizational system. Based on the understanding of knowledge exchange to involve modification, adaptation, and application of existing knowledge when solving specific problems [64], it is natural that a higher level of contextual distance between organizational units is accompanied with a lower level of knowledge application. The organizational context in which knowledge is embedded thereby represents a source of internal stickiness [65,66], which leads to challenges of "translation" of knowledge to other settings and tasks, hence making the knowledge appear less relevant.

4.2. Knowledge exchange systems

As the objective of knowledge exchange systems is to facilitate knowledge flows within and between organizations, such systems represent a means for safety behavior improvements. The results showed in this regard that system usage plays a minor role for the overall level of knowledge exchange in the organizational system (although significant effects were found between system usage and knowledge exchange). This finding is in line with previous research

Table 4
Results of regression analyses — test of H3a and H3b

Predictor	Dependent variable: knowledge exchange							
	Within units				Between units			
	Step 1		*Step 2*		*Step 1*		*Step 2*	
	t	*β*	*t*	*β*	*t*	*β*	*t*	*β*
Age	−2.3	−0.06*	−3.5	−0.09‡	−1.8	−0.05	−2.8	−0.07†
Education	−1.3	0.03	−1.0	−0.02	−4.7	−0.11‡	−4.6	−0.10‡
Experience with drilling operations	1.2	0.04	1.7	0.05	0.5	0.02	0.8	0.02
Work location	2.1	0.05*	1.9	0.04	−2.2	−0.05*	−2.5	−0.05*
Leader responsibilities	0.9	0.02	0.7	0.02	−0.3	−0.01	−0.4	0.01
Length of employment	−1.5	−0.05	−0.3	−0.01	−1.0	−0.03	0.1	0.00
System usage			14.9	0.31‡			12.1	0.25‡
ΔR^2			0.09				0.06	
ΔF			222.6‡				145.6‡	
R^2	0.01		0.10		0.02		0.08	
F	2.7*		34.4‡		7.1‡		27.3‡	

*$p < 0.05$.
†$p < 0.01$.
‡$p < 0.001$.

showing that the most amount of knowledge is shared in informal settings through relational channels (e.g., [39,67–69]). However, it is notable that use of knowledge exchange systems has a positive effect on safety compliance over and above the effects of knowledge exchange. This finding indicates that the process of using such systems makes the employees think about how they carry out their work, and thus directs attention toward safe work conduct. Attitudes and motivation for safe work conduct are, in other words, expected to be explanatory factors underlying this relationship.

4.3. Implications for practice

On a practical level, the results of the study confirm that elements in the work environment are important for an individual's disposition toward safety compliance, and thus underscore that solutions to the problem of unsafe behavior at the workplace goes beyond the training approach often emphasized in safety programs [11]. Organizational climate can influence the amount and quality of knowledge in the organizational system [7], and a focus on work climate factors that improve knowledge exchange processes between employees is therefore important for safety improvement purposes. Implementation of organizational practices that promote knowledge exchange systems usage should, in this respect, be emphasized.

4.4. Limitations and directions for future research

It is important to draw attention to the study limitations and provide directions for future research. First, the cross-sectional survey methodology applied in the study prevents drawing any causal inferences, and researchers should therefore apply research designs that offer a sounder basis for inferring causality. Second, measurement of knowledge exchange systems usage was based on self-reported use of four specific systems, and other systems (potentially more relevant for certain groups of employees) were left out. This may represent one explanation of the low levels of variance in knowledge exchange within and between units that system usage was able to explain. Research focusing on knowledge exchange system usage in general is therefore necessary, as well as research applying objective measures (i.e., actual system usage). Third, the lack of measurement of important explanatory variables such as knowledge, skills, and motivation is a limitation, and future research should provide measures of these variables in order to explain more evidently the linkage between safety behavior, knowledge exchange, and knowledge exchange systems usage. Related to this, the study does not distinguish between intentional and unintentional violations, and providing a more detailed measurement of safety compliance aspects would also increase our understanding of the role of knowledge exchange and system usage for safety behavior. Finally, future research should also study additional variables related to knowledge exchange (e.g., work climate antecedents and formal/informal channels) and workplace safety (e.g., safety participation).

Conflicts of interest

All authors declare no conflicts of interest.

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