



The effects of error management climate and safety communication on safety: A multi-level study

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ABSTRACT

Work in the construction industry is considered inherently dangerous, despite the technological improvements regarding the safety of work conditions and equipment. To address the urgent need to identify organizational predictors of safety performance and outcomes among construction workers, the present study examined multi-level effects of two important indicators of safety climate, namely contractor error management climate and worker safety communication, on safety behavior, injury, and pain among union construction workers. Data were collected from 235 union construction workers employed by 15 contractors in Midwest and Northwest regions of the United States. Results revealed significant main effects for safety communication and error management climate on safety behaviors and pain, but not on injuries. Our findings suggest that positive safety communication and error management climate are important contributors to improving workplace safety. Specific implications of these results for organizational safety research and practice are discussed.

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1. Introduction

Despite continuing efforts to reduce the number of work-related accidents, every year thousands of workers die at their workplaces and millions suffer occupational injuries and illnesses (U.S. Bureau of Labor Statistics [BLS], 2008a, 2008b). Work in the construction industry, in particular, is considered inherently dangerous due to its constantly changing nature in terms of contracts, employers, employees, and work environment, as well as multiple employers and crafts operating simultaneously at a worksite (Fang et al., 2006; Ringen et al., 1995a, 1995b; Ringen and Stafford, 1996; Scharf et al., 2001).

In fact, there were 1178 fatal work injuries in the United States (U.S.) construction industry sector in 2007 (BLS, 2008c). While the construction industry comprised 6.5% of the U.S. workforce (U.S. Census Bureau, 2006), it accounted for more than 20% of the fatal occupational injuries across all industries from 2003 to 2006. The above statistics rank construction among the top four killer industries, along with agriculture, mining, and transportation (BLS, 2008c). Despite the increased efforts to reduce workplace accidents, fatalities in construction increased between 2003 and 2006 (BLS, 2008c). Furthermore, the costs associated with injuries in the

U.S. construction industry have been estimated to exceed 10 billion dollars per year (Waehrer et al., 2007).

Over the past few years, researchers and practitioners have gradually recognized the importance of organizational factors, such as safety climate, for safety performance in the construction industry (Mohamed, 2002). The National Occupational Research Agenda (NORA) construction section council (2008) even set a strategic goal in the next decade to increase the understanding of factors that comprise both positive and negative construction safety climate. This is understandable, considering that safety climate has been regarded as an important antecedent of safety in the workplace and has been studied in various industrial settings and with various samples (Zohar, 1980, 2003). In fact, there has been an increasing interest in studying safety climate in the construction industry (e.g., Goldenhar et al., 2003; Gillen et al., 2002; Gillen et al., 1997; Fang et al., 2006; Mohamed, 2002; Siu et al., 2004). Flin et al. (2000) review of existing safety climate measures revealed that the most frequently measured dimension was management commitment to safety, followed by supervisor competence, priority of safety over production, and time pressure. Considerably less is known about other constructs that have also been incorporated in the broader conceptualization and assessment of safety climate.

In the present study, we focus on two such constructs, which are particularly relevant to safety in construction – safety communication (Hofmann and Morgeson, 1999; Mearns et al., 2003) and error management climate (EMC: Hofmann and Mark, 2006; van Dyck et al., 2005). Safety communication concerns if workers would feel

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free to raise and openly discuss safety issues (Hofmann and Stetzer, 1998), and has been a major concern in the construction industry while dealing with daily pre-task planning, addressing safety hazards, working with crews and trades of different subcontractors. A number of researchers have included safety communication in their conceptualizations and assessments of safety climate in other industries (e.g., Lin et al., 2008; Mearns et al., 2003; Silva et al., 2004; Wills et al., 2006).

On the other hand, EMC refers to employees' perceptions of "organizational practices related to communicating about errors, to sharing error knowledge, to helping in error situations, and to quickly detecting and handling errors" (van Dyck et al., 2005, p. 1229). EMC has traditionally been studied independently from safety climate (Edmondson, 1996; van Dyck et al., 2005) until recently Hofmann and Mark (2006) integrated this construct into a broader definition of safety climate. They found empirical support for their argument that employee perceptions of organizational practices, which promote effective learning from and responding to errors should be considered an integral part of safety climate. This is consistent with other researchers, who have included error management components in their assessments of safety climate (e.g., Gibbons et al., 2006; Silva et al., 2004).

While previous research has provided initial evidence for the positive associations of safety communication (e.g., Bentley and Haslam, 2001; Griffin and Neal, 2000; Hofmann and Morgeson, 1999; Mearns et al., 2003) and error management climate (e.g., Edmondson, 1996; Hofmann and Mark, 2006) with various indicators of safety performance, these associations have not been well investigated in the construction work context. In fact, an extensive literature review revealed only four studies reporting mixed results regarding the association of safety communication with safety performance in construction (see Glendon and Litherland, 2001; Mohamed, 2002; Sawacha et al., 1999; Siu et al., 2004), and virtually no studies of EMC in construction safety. Moreover, safety communication and EMC have not been examined together as predictors of occupational safety. To address this deficit, the present study took a multi-level approach to investigate the roles of safety communication with immediate foremen and contractor's error management climate in predicting safety behavior, injury, and pain among union construction workers.

1.1. Safety communication

It has long been recognized that open communication and frequent interactions between employees and supervisors are important organizational characteristics, which differentiate companies with low accident rates from those with high accident rates (e.g., Cohen et al., 1975, cited in Zohar, 1980; Smith et al., 1978). More recently, Barling and Zacharatos (1999) proposed information sharing and communication as one of 10 work practices, which have positive impact on occupational safety.

At present, a significant body of research exists in support of the relationship of safety communication with various indicators of safety performance. For example, Bentley and Haslam (2001) identified safety communication between managers and employees as one of five desirable management safety practices, which differentiated between low and high accident rate postal delivery offices. Other researchers have confirmed the negative relationship between safety communication and occupational accidents, injuries or near-misses (e.g., Hofmann and Morgeson, 1999; Mearns et al., 2003; Mearns et al., 1998; Probst, 2004; Sawacha et al., 1999; Siu et al., 2004).

Research has also indicated that safety communication was significantly associated with safety behavior such as compliance (Cheyne et al., 1998; Griffin and Neal, 2000; Parker et al., 2001), safety knowledge (Probst, 2004, Griffin and Neal, 2000), safety par-

ticipation (Griffin and Neal, 2000), and success of safety programs (Harper et al., 1997). In three intervention studies, Zohar and Luria (2003) demonstrated that as supervisors' interactions with workers about safety issues increased, so did workers' safety behaviors and their safety climate perceptions. Consistent with this, other studies have shown that the most effective supervisors displayed a more supportive style of leadership, initiated discussions about safety, and provided constructive feedback to workers about safety behavior (Mattila et al., 1994; Niskanen, 1994; Simard and Marchand, 1994).

In light of the research presented above, it is argued here that construction workers who feel more comfortable to raise and discuss safety issues with their supervisors, should be more likely to initiate and engage in such communication, and thus become more competent on safety procedures and policies, as well as more aware of the consequences of unsafe behaviors and of potential workplace hazards (Hofmann and Morgeson, 1999; Parker et al., 2001). As Parker et al. (2001) state, "one way in which good-quality communications allow employees to behave safely is to provide them with the information they need to work safely, for example, when to wear protective equipment or follow specific procedures" (p. 214). This educational function of safety-related communication is particularly relevant to construction workers, who face, on a daily basis, poorly defined situational hazards and constantly changing work and work environment (Mitropoulos et al., 2005; Ringen et al., 1995a). Construction crews, whose members feel more comfortable to talk about safety issues, would be more likely to share information and discuss minor incidents, near-misses, or errors when they occur, thus allowing for learning to take place at the individual and group level (see Edmondson, 1996). The increased knowledge and learning, due to open communication, should enable workers to detect and handle hazardous situations and errors more effectively. This, in turn, should reduce the potential negative consequences such as work-related injuries and pain. As a result, it is expected that construction workers who feel free and comfortable to raise and discuss safety issues with their supervisors, would be more likely to engage in safety behaviors and experience less injuries and pain due to work. Therefore:

Hypothesis 1a. Workers' safety communication with foremen is expected to be positively related to their safety behavior.

Hypothesis 1b. Workers' safety communication with foremen is expected to be negatively related to their experience of work-related injuries.

Hypothesis 1c. Workers' safety communication with foremen is expected to be negatively related to their experience of work-related pain.

1.2. Errors, error management, and error management climate

Imagine a co-worker exclaiming, "I made an error. That's great!" This would sound counterintuitive to many of us, and certainly is not the norm accepted in the construction industry. Errors at work, and generally in life, have a bad reputation. The main reason is that errors, defined here as any "unintended deviations from plans, goals, or adequate feedback processing as well as an incorrect action that results from lack of knowledge" and skills (van Dyck et al., 2005, p. 1229), can (but not necessarily will) result in negative consequences, such as injuries, stress, and feelings of embarrassment and incompetence (Brodbeck et al., 1993; Cannon and Edmondson, 2001; van Dyck et al., 2005).¹ Furthermore, high-

¹ Defining "error" in the context of construction work is a complex issue since most of the construction literature does not distinguish human errors from inten-

risk industries, such as the construction industry, are particularly sensitive to human errors, because of their potential to create hazardous situations and cause accidents and injuries (Huang and Hinze, 2003; Mitropoulos et al., 2005). In addition, Aronson (1999) acknowledges that our society is “contemptuous of failure and punishes mistakes of all kinds” (p. 12). As a consequence, people tend to avoid admitting errors or are reluctant to sharing errors with others when they happen (Cannon and Edmondson, 2001; van Dyck et al., 2005).

The reality is that, despite efforts by individuals and organizations to avoid errors, errors still happen and will continue to happen (Frese, 1995) because of limitations and imperfections in human abilities and organizational systems (Edmondson, 1996; Frese and Zapf, 1994; Reason, 1997; van Dyck et al., 2005). This is especially true for complex and dynamic situations, which are often present in the construction work (Mitropoulos et al., 2005; Scharf et al., 2001). Therefore, in light of the fact that human errors are inevitable, it seems important and helpful for organizations to rely not only on error prevention but also encourage individuals and organizations to discuss and share error experience, and in turn learn from errors, which is considered essential for organizational success (Cannon and Edmondson, 2001; Sitkin, 1992; Starkey, 1998; van Dyck et al., 2005). In fact, the ability of people to learn from errors has been well established by research on error management training (see Frese et al., 1991; Heimbeck et al., 2003; Ivancic and Hesketh, 2000; Keith and Frese, 2005; Nordstrom et al., 1998).

To overcome the limitations of a strictly error prevention approach, Frese and co-workers (Frese and Zapf, 1994; van Dyck et al., 2005) have suggested that error prevention should be complemented with error management, which aims “to contain the negative and to promote the positive consequences of errors” (van Dyck et al., 2005, p. 1228). The main goals of error management are to deal effectively with errors and their consequences after the occurrence of an error and to prevent future errors (Frese, 1995). This is achieved by (1) promptly detecting, extensively analyzing, and openly communicating about errors, (2) effectively dealing with and reducing the negative error consequences, and (3) learning from errors, which are viewed as valuable learning opportunities (Frese).

Because of the ubiquity of human error in construction work and its consequential nature (Huang and Hinze, 2003), the construction industry can considerably benefit from error management. As Mitropoulos et al. (2005) voiced, the principles of error management remain largely ignored and under-utilized in the construction industry. They further argued that error management is crucial in this industry to increase workers' ability to handle hazardous situations.

The importance for workers to deal with and learn from errors (Edmondson, 2004; Rybowski et al., 1999) has prompted recent research to apply this concept to the group and organizational level (see Hofmann and Mark, 2006, van Dyck et al., 2005, respectively). According to van Dyck et al. (2005) a positive error management climate (EMC) promotes “communicating about errors, sharing error knowledge, helping in error situations as well as quick error detection and analysis, effective error recovery, and coordinated error handling efforts” (p. 1237). Their findings from two independent studies revealed that organizations differed in their approaches to

errors and organizations with more positive and constructive EMCs demonstrated better financial performance. In a manufacturing setting, Cannon and Edmondson (2001) showed that work groups with constructive responses to errors and problems and more open communication about them had better group performance in terms of customer satisfaction.

Initial research findings also support the relevance of EMC to safety (Edmondson, 1996; Hofmann and Mark, 2006). In fact, Hofmann and Mark conceived of error management as one of the important factors of safety climate. Consequently, they included error management components (e.g., error communication) in their measurement of overall safety climate along with more traditional safety climate components (e.g., management's attitude toward safety). In their study of nurses in acute care hospitals, Hofmann and Mark found that a positive safety climate at the nursing unit level, which included error management indicators, was significantly associated with fewer back injuries and medication errors, and increased patient satisfaction, perceptions of nurse responsiveness, and higher levels of nurse job satisfaction. Their results extended earlier findings by Edmondson (1996), which indicated that different nursing units differ in their shared perceptions about the consequences of making errors, which, in turn, create climates of openness or fear within nursing units and influence the willingness of nurses to report and discuss errors and problems.

Considering the above, construction workers employed by contractors, whose practices reflect a positive EMC, would be expected to be more effective in handling and reducing the negative error consequences when errors occur, learning not only from own errors but also from co-workers' errors, preventing future errors, and/or improving work procedures (van Dyck et al., 2005). Consequently, they would be able to work more safely and avoid work-related injuries and pain. Hence, it is expected that construction workers who work for contractors, which nurture a positive EMC, would be more likely to engage in safety behaviors and experience less injuries and pain at work. Thus, the following hypotheses are posited:

Hypothesis 2a. Contractors' EMC is expected to be positively related to workers' safety behaviors.

Hypothesis 2b. Contractors' EMC is expected to be negatively related to workers' work-related injuries.

Hypothesis 2c. Contractors' EMC is expected to be negatively related to workers' work-related pain.

1.3. Error management climate as a moderator

Researchers have suggested that organizational climate can serve as an enhancing environmental factor pertaining to workplace safety (DeJoy, 1996), providing a context in which individuals assess safety at work (Mearns and Flin, 1996). For example, Mark et al. (2007) found that safety climate, which was measured with both traditional safety climate items and error management climate items, moderated the effects of work conditions and work engagement on work-related injuries among nurses. Similarly, Probst (2004) found that positive safety climate attenuated the adverse effects of job insecurity on safety knowledge, safety compliance, accidents, near-miss incidents, and workplace injuries.

By focusing on the positive consequences of errors (e.g., learning), encouraging workers to share error knowledge, and constructively responding to and dealing with errors, a positive EMC is likely to promote free discussion of safety-related issues to support safety communication, as well as encourage workers to learn from errors (Edmondson, 1996, 2004). Considering this enhancing role of EMC, it is logical to expect that the relationship between safety communication and safety outcomes would be strong when posi-

tional violations of safety standards (e.g., Huang and Hinze, 2003). Furthermore, it is important to differentiate human errors from error consequences. For example, a misfire of a nail gun or improperly securing a ladder due to lack of knowledge and skills are considered errors, which may or may not lead to injury or citation for the construction worker (i.e., error consequences). However, deliberate misuse of a nail gun or intentional failure to secure a ladder as a shortcut are not considered errors, according to the definition used in this study, but rather intentional violations.

tive EMC exists. In contrast, the above relationship is expected to be attenuated when sharing errors or near-misses are not endorsed in the job sites. Thus, it is hypothesized that:

Hypothesis 3a. Contractors' EMC will moderate the relationship between workers' safety communication and safety behaviors, such that a stronger positive relationship will appear under high EMC.

Hypothesis 3b. Contractors' EMC will moderate the relationship between workers' safety communication and work-related injuries, such that a stronger negative relationship will appear under high EMC.

Hypothesis 3c. Contractor EMC will moderate the relationship between workers' safety communication and work-related pain, such that a stronger negative relationship will appear under high EMC.

2. Method

2.1. Participants and procedures

This study surveyed union pipefitters from two union locals in the Midwest and Northwest regions of the United States. The variables of interest in this study were measured as part of a larger survey. All surveys were paper-based, anonymous, and mailed to the participants in May of 2005. Usable data from 235 total participants was gathered in two samples. The participants represented 15 different contractors,

2.1.1. Sample 1

Five hundred seventy-seven members of a union local in the Northwest region of the United States were mailed the survey. One hundred eighty-three surveys were returned for a response rate of 32%. Due to incomplete data, 18 surveys were excluded to reduce the final sample to 165. Those reporting gender indicated a highly male sample (98%), which is representative of this industry. Average age of this sample was 45.4 years, and the majority of respondents were Caucasian (97%). Of those responding, 82% reported working in solely construction, with 10% in solely service positions, and the remaining 9% working in both construction and service.

2.1.2. Sample 2

Three hundred sixty construction workers from a union local in the Mid-Western United States were mailed the survey. Seventy three surveys were received representing a 29% response rate. Three surveys were further excluded due to incomplete data, resulting in a final sample of 70. Similar to the first sample, the participants in this sample were mainly male (98%) and Caucasian (92%). Their average age was 47.7. Most participants worked in construction (94%) while the remaining 6% worked both in construction and service.

2.2. Measures²

All measures used in this study are provided in the Appendix. Scale scores were computed by summing up individual item scores.

2.2.1. Safety communication

A 5-item safety communication scale was modified from the original 7-item scale developed by Hofmann and Morgeson (1999). After examining reliability data provided by Hofmann and Morgeson, the original 7-item scale was reduced to five items. Sample

items include, "I feel comfortable discussing safety issues with my immediate foreman," and "I feel that my immediate foreman openly accepts ideas for improving safety." Responses were on a 6-point Likert-type scale, with 1 meaning "Strongly Disagree" and 6 signifying "Strongly Agree." Coefficient alpha for this scale was estimated at 0.89. A higher scale score indicates a more positive safety communication with immediate foremen.

2.2.2. Error management climate

Sixteen items from van Dyck et al. (2005) were used in the current study to measure four dimensions of error management climate (EMC): learning from errors (4 items; e.g., "When mastering a task, people can learn a lot from their mistakes"), thinking about errors (5 items; e.g., "After making a mistake, people try to analyze what caused it"), error competence (3 items; e.g., "When an error is made, it is corrected right away"), and error communication (4 items; e.g., "When someone makes an error, he shares it with others so they don't make the same mistake"). Consistent with our theoretical model and following recommendations regarding multi-level research (Klein et al., 1994; Morgeson and Hofmann, 1999), participants were asked to respond to the EMC items with reference to their contractor. Responses were on a 6-point Likert-type scale, ranging from 1 ("Strongly Disagree") to 6 ("Strongly Agree").

The theoretical model in the current study focused on overall EMC. In addition, preliminary analyses revealed similar results when using EMC overall scores or subscale scores. Thus, the four subscales were combined into an overall measure, which is consistent with previous research (see van Dyck et al., 2005; Mark et al., 2007).³ Coefficient alpha for the full scale was 0.90. Higher scale scores reflect a more positive EMC.

2.2.3. Injuries

Work-related injury data were gathered using a reduced version of Krauss (2004) scale. Based on workers' compensation records provided by an insurance company, injury items were included if they had at least a 20% base rate of occurrence, resulting in a 9-item scale. Dichotomous 0 (*no*) or 1 (*yes*) responses were given in response to the question, "Since January 1, 2005, have you experienced any of the following injuries at work?" Sample items include "cut/laceration" and "dislocation." A total injury score was computed by summing the "yes" responses.

2.2.4. Pain

Participants were asked to provide yes/no responses to 8 items starting with the question: "Since January 1, 2005, have you experienced pain in any of the following body areas every day for at least one week (seven days)?" Sample items include "Neck" and "Hand/wrist/fingers." The sum of the 8 items provided a total score.

2.2.5. Safety behaviors

Safety behaviors were measured with a 10-item scale, which included four task safety behavior items (e.g., "Appropriately report incidents, accidents, or illnesses") modified from Burke et al. (2002) General Safety Performance Scale, as well as six contextual safety behavior items (e.g., "Attend non-mandatory safety meeting") adopted from Hofmann and Morgeson (1999) 27-item scale of citizenship safety performance. Respondents were asked to indicate how often they engaged in the behaviors on a 6-point scale, ranging

³ Principal component analysis, conducted on the 16 error management climate items, revealed three components instead of the expected four-component solution. The components were learning from errors, thinking about errors, and a combined error competence and communication component.

² Item-level data are available from Konstantin P. Cigularov.

Table 1
Descriptives, individual level correlations, and internal consistency coefficients.

Variable	<i>n</i>	<i>M</i>	<i>SD</i>	Skew	PR	OR	1	2	3	4	5
1. Safety communication	235	26.11	3.58	−1.16	5–30	11–30	(0.89)				
2. Error management climate	235	76.42	8.71	0.10	16–96	50–96	0.47*	(0.90)			
3. Injury ^a	235	1.75	1.63	0.57	0–9	0–6	−0.11	−0.16*	–		
4. Pain ^b	235	1.73	1.98	1.27	0–8	0–8	−0.24*	−0.16	0.46*	–	
5. Safety behavior	165	46.57	9.43	−0.43	10–60	20–60	0.31*	0.48*	−0.32*	−0.25*	(0.89)

Note. Internal consistency coefficients are displayed in parentheses on the diagonal. Skew = skewness. PR = possible range. OR = observed range.

^a No injuries were reported by 31% of the respondents.

^b No pain was reported by 37% of the respondents.

* $p < 0.05$, two-tailed.

from 1 (*Never*), 2 (*Once in a While*), 3 (*Sometimes*), 4 (*Quite Often*), 5 (*Frequently, if Not Always*), and 6 (*Always*).

Because the focus of this study was on overall safety behaviors, the 10 items were combined into an overall measure, which is consistent with other research (e.g., Hofmann and Stetzer, 1996).⁴ Furthermore, analyses using the two separate subscales (i.e., task and contextual safety behavior) revealed similar results. Thus, for the purposes of this study, all hypotheses were tested using the overall safety behavior measure. Coefficient alpha for the full scale was 0.89. Higher scale scores indicated more safety behavior engaged. It should be noted that, the safety behaviors were assessed only in Sample 1.

2.3. Levels of analysis

According to Klein et al. (1994), researchers should describe the levels of analysis at which the predictor variables are assumed to operate and investigate the validity of these assumptions. In the present study, the target level of safety communication was the foreman. It was expected that the foreman, as the immediate supervisor, would have the most influence on construction workers' willingness to speak up about safety issues. In addition, the constant change of foremen in construction is likely to hinder the formation of shared perceptions. Even if shared perceptions exist, they will be very difficult to measure due to the high turnover (Ringen et al., 1995a). Therefore, safety communication was hypothesized to operate and was measured at the individual level, which is in line with most of the previous research (see Griffin and Neal, 2000; Mearns et al., 2003; Mohamed, 2002; Probst, 2004). EMC, on the other hand, was theorized and measured at the contractor level. This is consistent with traditions in the safety climate literature (see Zohar, 2000, 2002, 2003), and the notion that shared perceptions form as people in organizations and groups exchange information (Salancic and Pfeffer, 1978).

To empirically justify aggregation of individuals' responses to the EMC items, we examined within-group homogeneity (i.e., participants employed by the same contractor share similar perceptions), and between-group variance (i.e., participants employed by different contractors share different perceptions) (see Zohar, 2000). Within-group homogeneity was assessed using $r_{wg(j)}$ (James et al., 1993). The results showed a median $r_{wg(j)}$ of 0.98 with a range from 0.97 to 0.99, indicating sufficiently high homogeneity for all 15 contractors. Between-group variance was tested with a one way analysis of variance, using contractor affiliation as the independent variable and individual EMC scores as the dependent variable. The results were not significant, $F(14, 220) = 0.967$, $p > 0.05$, suggesting that contractors did not differ significantly in their levels of EMC. However, contractor was chosen as the appropriate level of analy-

sis for EMC, based on the high within-group homogeneity and the above-mentioned theoretical considerations.

3. Results

Descriptive statistics, correlations, and internal consistency estimates for all variables in the study are presented in Table 1.⁵

To test the hypotheses, we used hierarchical linear modeling (HLM; Raudenbush and Bryk, 2002) for each of the three outcome variables: safety behaviors, injuries, and pain. Specifically, we used a random coefficients model with two levels, which could be described with the following conceptual equation: $DV = \text{intercept} + EMC + SC + EMC \times SC(\text{interaction}) + \text{Errors}$.⁶ In this equation, DV represents one of three outcome variables: safety behaviors, injuries, or pain. Also, EMC and safety communication (SC) represent the predictors at Levels 2 and 1, respectively, while $EMC \times SC$ represents the cross-level interaction between EMC and SC. Safety communication was group-mean centered and EMC was grand-mean centered, following recommendations by Hofmann and Gavin (1998).

With regard to safety behaviors, as shown in Table 2, the main effects for both safety communication ($t = 3.07$, $p < 0.05$) and error management climate ($t = 2.90$, $p < 0.05$) were significant, which support Hypotheses 1a and 2a. However, no cross-level interaction was found, which failed to support Hypothesis 3a. As indicated in Table 2, the main effects on injuries for both safety communication and EMC approached the significance level. In addition, the cross-level interaction was non-significant. Overall, the data failed to support Hypotheses 1b, 2b, and 3b, although the findings were in the expected direction. The results for pain, shown in Table 2, indicate significant main effects for safety communication ($t = -3.14$, $p < 0.05$) and EMC ($t = -2.31$, $p < 0.05$). These results support Hypotheses 1c and 2c. However, Hypothesis 3c

⁵ In order to address concerns for discriminant validity and common method bias, confirmatory factor analyses were conducted on the safety communication (SC), error management climate (EMC), and safety behavior measures using Sample 1, with recognition of the small sample size. A six-factor model (SC, learning from errors, thinking about errors, error competence/communication, task safety behaviors, and contextual safety behavior) showed a superior fit (comparative fit index = .91 and root-mean-square error of approximation = .07 with a confidence interval of .06–.08) compared to a one- and three-factor models, the latter model emphasizing the overall measures (i.e., SC, EMC, and overall safety behavior). However, as explained previously, the authors tested their hypotheses using scores of the full measures, based on theoretical and practical considerations.

⁶ The full equation for the tested random coefficients model is $Y_{ij} = \gamma_{00} + \gamma_{01}W_j + \gamma_{10}X_{ij} + \gamma_{11}W_jX_{ij} + u_{1j}X_{ij} + u_{0j} + r_{ij}$, where i and j refer to the level one (participant) and level two (contractor) variables, respectively. In this case, Y_{ij} represents one of three outcome variables: safety behaviors, injuries, or pain. In addition, W_j represents the level two EMC variable, X_{ij} represents safety communication for participant i who works for contractor j , and W_jX_{ij} represents the cross-level interaction between EMC and safety communication. In addition, u and r represent the error terms in the model where r_{ij} is the individual error term, u_{0j} is the variability in EMC between contractors, and u_{1j} is the variability in the relationship between EMC and safety communication between contractors.

⁴ Principal component analysis of the 10 safety behavior items yielded two components identified as task and contextual safety performance, consistent with our expectations.

Table 2
Random coefficients models for predicting safety behaviors, injuries, and pain.

Variable	Safety behaviors ^a				Injuries ^b				Pain ^c			
	γ	$SE\gamma$	<i>T</i> -ratio	<i>p</i>	γ	$SE\gamma$	<i>T</i> -ratio	<i>p</i>	γ	$SE\gamma$	<i>T</i> -ratio	<i>p</i>
Level 1												
Intercept	47.19	0.79	59.58	0.00*	1.77	0.11	16.68	0.00*	1.89	0.17	10.92	0.00*
SC	0.92	0.30	3.07	.01*	-0.04	0.03	-1.59	0.07	-0.15	0.05	-3.14	0.00*
Level 2												
EMC	1.20	0.41	2.90	0.01*	-0.08	0.05	-1.66	0.06	-0.17	0.07	-2.31	0.02*
EMC × SC	0.00	0.15	0.01	0.99	-0.02	0.02	-1.16	0.27	-0.03	0.02	-1.09	0.30

Note. SC = safety communication. EMC = error management climate. EMC × SC = interaction between error management climate and safety communication.

^a *n* = 165.

^b *n* = 235.

^c *n* = 235.

* *p* < 0.05, one-tailed.

was not supported, although the result was in the expected direction.

We also estimated the residual variance components for the three models. When these are different from zero one can assume that some variability exists in the data that is not well explained by the model. Of all three outcome variables, only pain showed a substantial amount of unexplained variance. Table 3 indicates that the u_{1j} component for pain is significant ($\chi^2 = 23.90$, $p < 0.05$). This suggests that there was unexplained variability in the slopes of the regression lines for pain on safety communication across contractors, suggesting that incorporating other Level 2 predictors into the model may increase the model's explanatory power.

4. Discussion

In the current study, we examined the relationship of two understudied safety climate factors, namely error management climate (EMC) and safety communication, with safety behaviors and outcomes among union construction workers. Our results show that EMC and safety communication are significant predictors of safety behaviors and work-related pain, substantiating the importance of these factors in construction safety. However, the relationships of EMC and safety communication with work-related injuries, as well as the hypothesized cross-level interactions were not significant, although they were in the predicted direction.

Overall, it appears that safety in the construction industry could benefit from a positive and constructive EMC and enhanced safety communication. This is consistent with conclusions drawn from previous research in other industries (e.g., Cheyne et al., 1998; Griffin and Neal, 2000; Hofmann and Mark, 2006; Hofmann and Morgeson, 1999; Mearns et al., 2003; Probst, 2004), suggesting that it is important for construction management to engage in behaviors, which (a) promote a proactive and constructive approach to errors, (b) encourage workers to talk about errors or near-misses, and (c) encourage workers to raise and discuss safety concerns. One way to achieve this is through building positive exchange relationships with workers (Hofmann and Morgeson, 1999). Contractors, who use informal contacts and communications, as well as a constructive, non-punitive approach to errors, are more likely to raise

the safety awareness of their workers, elicit more suggestions for safety improvements, and encourage the reporting of safety problems, such as errors, near-misses, unsafe conditions, or practices (Clarke, 2003; Edmondson, 1996).

Furthermore, our results are in line with previous research suggesting that an organizational climate of open communication with a focus on problem-solving and learning (i.e., a positive EMC) is vital to safety and is associated with safety communication so that employees feel comfortable to raise and express safety concerns (see Table 1). Foremen can play an important role to stimulate and develop EMC, as they are able to influence the establishment of norms for practices and procedures, and thus form and shape EMC. In fact, Zohar and Luria (2003) empirically demonstrated how supervisors' verbal exchanges about safety could be used as a leverage to improve workers' safety behaviors and safety climate. In their study, increases in supervisory safety practices (i.e., safety-related interactions with employees) as a result of an intervention were associated with decreases in unsafe behaviors and more positive safety climate perceptions. Thus, supervisory-level interventions could prove valuable in improving EMC and safety communication.

Furthermore, for a positive EMC to develop, contractors, as well as management, should go beyond the use of control strategies and mechanisms to reinforce safety compliance. Management, such as superintendents or general foremen, should avoid creating "a climate of fear," which can adversely affect the free sharing of information in the organization (Ashkanasy and Nicholson, 2003). Instead, they should acknowledge the educational value of errors, constructively respond to and deal with errors, exhibit a supportive, non-punitive, coaching management style, as well as model positive communication by sharing information with their employees (Edmondson, 2004; Parker et al., 2001). Nonetheless, van Dyck et al. (2005) point out that this may be easier said than done, because "managers have to walk a fine line between taking errors seriously and emphasizing error tolerance and between using information on errors as examples of (lack of) performance and using errors as opportunities for learning" (p. 1236). This dilemma is particularly valid for superintendents, general foremen, and foremen in high-stake industries, such as construction, where errors can cause fatal accidents and injuries. However, it is important to note that, while accidents and injuries are considered error consequences, the error management approach focuses on discussing, learning from, and analyzing errors, which have already occurred, thus serving a secondary error prevention function (van Dyck et al., 2005).

Based on error management research in aviation, Helmreich et al. (2001) provide several guidelines for organizations on how to develop an effective error management program in addition to error prevention, such as: (1) building a trusting relationship between management and employees, which encourages and rewards individuals and teams for sharing safety-related infor-

Table 3
Variance components for predicting pain.

Variable	σ^2	τ	χ^2	<i>p</i>
u_{0j}		0.17	19.66	0.10
u_{1j}		0.01	23.90	0.03*
τ_{ij}	3.35			

Note. *n* = 235.

* *p* < 0.05, one-tailed.

mation, (2) management adopting a non-punitive policy toward errors, and (3) training work crews in error avoidance and management.

5. Strengths, limitations, and directions for future research

The research reported here is unique in several ways. It is the first study to use a cross-level model to investigate the relationship of error management climate (EMC) and safety communication with work-related safety behaviors, injuries, and pain. Although EMC and safety communication have been studied independently as important factors of safety climate (Hofmann and Mark, 2006; Lin et al., 2008; Mearns et al., 2003), their role in construction safety has been largely neglected, despite their relevance. In fact, our study is first to empirically examine EMC in a construction safety context, corroborating Mitropoulos et al. (2005) assertion that error management principles are relevant to construction safety and need to be applied more extensively.

Despite these strengths, several limitations of the study need to be considered. First, this study used a single source of information, thus increasing the probability for common method bias. However, there is evidence suggesting that the prevalence of bias due to a common method may be overestimated (see Crampton and Wagner, 1994). Furthermore, Spector (1992) stated that using a common method could bias a relationship in both directions (i.e., inflate or attenuate it), depending on the constructs studied. Several null results found in the present study may suggest the limited impacts, if any, of a common method bias. Second, the study used a cross-sectional design, which precludes inferences about cause and effect. This design is most prevalent in organizational safety research and is useful in initial investigations of constructs of interest and their nomological networks (Barling et al., 2002).

A third potential limitation of this study is the low response rate, despite authors' attempts to encourage participation by keeping the survey length short, using the scantron formatting, and sending a reminder postcard. Although the low response rate suggests the possibility of nonresponse bias limiting the representativeness of the results, the effects of this bias are likely to be small as suggested by Krosnick (1999) and Schalm and Kelloway (2001).

Another limitation of the current research is the finding of non-significant between-group variance for EMC, which suggests the need to include more diverse groups (e.g., contractors who hire non-unionized workers) in future studies. Future research should also examine how "errors" are perceived and defined within the construction industry from different perspectives, including construction workers, foremen, management, safety officers and regulatory bodies (e.g., Occupational Safety and Health Administration), as well as insurance companies. This issue was beyond the scope of the current study.

While this study focused on safety communication to foremen from the workers' point of view, future research should also investigate communications about safety on the construction worksite from different perspectives (e.g., foremen). Specifically, social network analysis can be used to understand the frequency and importance of different types of safety communications among key players on the construction worksite (i.e., workers, foremen, safety officers, and management). From a practical perspective, social network analysis can also identify the "informal safety leaders," or people who are well connected within the workplace network and have influence over others at work. These would be the people who can promote productive and safety-conscious work norms, as well as provide others with exemplary safety performance and support for safety.

In conclusion, the positive findings for EMC and safety communication as significant predictors of safety in construction should

serve as an impetus for additional research to further examine the roles that individual and organizational level psychological variables play on safety performance.

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Appendix A. Measures Used in the Study

Safety Communication

Regarding your immediate foreman. . .

1. I feel comfortable discussing safety issues with my immediate foreman.
2. I try to avoid talking about safety issues with my immediate foreman. (Reverse)
3. I feel that my immediate foreman openly accepts ideas for improving safety.
4. I am reluctant to discuss safety-related problems with my immediate foreman. (Reverse)
5. I feel that my immediate foreman encourages open communication about safety.

Error Management Climate

Regarding people at your current worksite (your contractor, safety officer, foreman, co-workers, etc.). . .

1. For us, errors are very useful for improving the work process. (*learning from errors*)
2. After an error, people think through how to correct it. (*thinking about errors*)
3. Although we make mistakes, we don't let go of the final goal. (*error competence*)
4. An error provides important information for the continuation of the work. (*learning from errors*)
5. After an error has occurred, it is analyzed thoroughly. (*thinking about errors*)
6. When people are unable to correct an error by themselves, they turn to their co-workers. (*error communication*)
7. If something went wrong, people take the time to think it through. (*thinking about errors*)
8. Our errors point us at what we can improve. (*learning from errors*)
9. After making a mistake, people try to analyze what caused it. (*thinking about errors*)
10. When an error is made, it is corrected right away. (*error competence*)
11. When people make an error, they can ask others for advice on how to continue. (*error communication*)
12. When working for this contractor, people think a lot about how an error could have been avoided. (*thinking about errors*)
13. When mastering a task, people can learn a lot from their mistakes. (*learning from errors*)
14. When an error has occurred, we usually know how to rectify it. (*error competence*)
15. If people are unable to continue their work after an error, they can rely on others. (*error communication*)

16. When someone makes an error, he shares it with others so they don't make the same mistake. (*error communication*)

Safety Behaviors

How often do you. . .

1. Use the appropriate personal protective equipment as indicated by the site health and safety plan? (*task safety behavior*)
2. Apply the appropriate work practices to reduce exposures to hazards including applicable standard operating procedures relating to operations and construction? (*task safety behavior*)
3. Appropriately report incidents, accidents, or illnesses? (*task safety behavior*)
4. Take the appropriate steps if prevented from or punished for exercising your rights under OSHA policies and procedures? (*task safety behavior*)
5. Assist others to make sure they perform their work safely? (*contextual safety behavior*)
6. Attend non-mandatory safety oriented training? (*contextual safety behavior*)
7. Speak up and encourage others to get involved in safety issues? (*contextual safety behavior*)
8. Try to change the way the job is done to make it safer? (*contextual safety behavior*)
9. Explain to other workers that you will report safety violations? (*contextual safety behavior*)
10. Take action to stop safety violations in order to protect the well-being of other crew members? (*contextual safety behavior*)

Workplace Injuries

Since January 1, 2005, have you experienced any of the following injuries at work?

1. Strain/Sprain/Tore Ligament
2. Dislocation
3. Amputation
4. Cut/Laceration
5. Broken Bone/Fracture
6. Scrape/Abrasion
7. Burn/Blister/Scald/Welding Flash
8. Bruise/Contusion
9. Other

Pain

Since January 1, 2005, have you experienced pain in any of the following body areas every day for at least one week (seven days)?

1. Head/skull/face
2. Neck
3. Shoulders
4. Hand/wrist/fingers
5. Chest/ribs/sternum
6. Lower back
7. Knees
8. Feet

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