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Measurement equivalence and mean comparisons of a safety climate measure across construction trades

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ABSTRACT

The use of safety climate measures for needs assessment and interventions has become increasingly popular. However, no research to date has examined whether the meaning and level of safety climate may differ across different groups of interest. This study used multi-group confirmatory factor analyses to investigate the measurement equivalence of a multidimensional safety climate measure across ten construction trade groups ($N = 4725$). In addition, observed mean differences in safety climate perceptions between trades were examined. Results revealed strong measurement equivalence of the safety climate measure across the construction trade groups. Further, significant mean differences were found between the ten trade groups on all four safety climate scales.

1. Introduction

Construction work has long been considered high-risk and extremely hazardous (Ringen and Englund, 2006). This is confirmed by the latest published data, indicating that in 2010 the U.S. construction industry recorded the highest number (751) of fatalities, which accounted for 17 percent of all fatalities (Bureau of Labor Statistics [BLS], 2011a). There were also 74,950 reported occupational injuries and illnesses, which resulted in days away from work in 2010 among construction workers in the U.S.; median number of days away per worker was 12 (BLS, 2011b). Furthermore, this latter statistic is likely to be an underestimate of the actual occurrence of injuries and illnesses because of documented wide-spread practices of under-reporting injuries in construction (Probst and Estrada, 2010). Consequently, improving the safety and health of construction workers continues to be a high priority for both industry and government (Gittleman et al., 2010; Melia et al., 2008).

In recent years, construction safety researchers and practitioners have come to recognize the critical role that organizational factors, such as safety climate, play in construction safety (Mohamed, 2002). In fact, one of the strategic goals of the National Occupational Research Agenda (NORA) Construction Sector Council (2008) was to increase the understanding of factors that lead to both positive and negative safety climates in the construction industry. Safety climate has been viewed as employees' perceptions of the values, policies, and procedures related to safety within an organization, as well as the priority that the organization places on safety versus production (Zohar, 1980; Griffin and Neal, 2000). This interest in the concept of safety climate is justified, considering the empirical support for the positive effects of safety climate on safety performance and injuries in many industries (Christian et al., 2009; Clarke, 2006, 2010; Nahrgang et al., 2011), including the construction industry (e.g., Gillen et al., 2002). Thus, positive safety climates have been considered to "have the single greatest impact on accident reduction of any process" (Occupational Safety and Health Administration [OSHA], 2009).

Consequently, a number of safety climate measures have been developed and used for research and organizational assessment purposes in the construction industry (e.g., Dedobbeleer and Beland, 1991; Jorgensen et al., 2007; Lingard et al., 2009; Pousette et al., 2008). However, most of this research has focused on either the construction industry as a whole, or only on one or two specific trades. In fact, to date, no published studies as we are aware of have examined the validity of safety climate measures and systematic differences in levels of safety climate perceptions between workers among various construction trades.

This gap in the literature is surprising considering that there are a large number of construction trades within the industry (e.g., electricians, laborers, bricklayers, carpenters, etc.), which differ in terms of nature and organization of work, work environment,

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as well as safety and health risks (BLS, 2010; The Center for Construction Research and Training, 2008; Occupational Information Network [O*NET], 2011). In fact, workers in different construction trades often work in distinct work environments and are exposed to unique hazards, although they tend to perform their job tasks together (Pollack et al., 1996; Ringen et al., 1995a,b). In addition, there are significant differences in fatal injury rates among trades, with construction laborers experiencing the highest number of fatalities and insulators experiencing the least fatalities (BLS, 2009). Considering that safety climate reflects the status of and priority given to safety at work (Zohar, 2003), differences in trade characteristics such as organizational structures, work operations and tasks, exposures, and equipment/tools may promote divergent views of safety across trades (Payne and Pugh, 1976). Therefore, it is essential to ask if the meaning and level of safety climate as perceived by construction workers differ across trades.

Answering this question has important implications for studying safety climate in the construction industry, as well as for making safety recommendations or designing organizational interventions to improve safety in construction work. If different trades hold qualitatively different views of safety climate based on inherent differences in trade characteristics and work experiences, then lumping together and/or comparing the responses to a safety climate measure of workers from different trades would be inappropriate unless it is first demonstrated that these responses are comparable. In other words, it must be established that construction workers from different trades have the same frame of reference and use the response scale in the same way when responding to a safety climate measure. This is referred to as measurement equivalence (ME), which is a prerequisite for comparing means between groups of interest and gives the researchers confidence that they are comparing apples versus apples, rather than apples versus oranges (Vandenberg and Lance, 2000). Establishing ME of a safety climate measure across trades would indicate that observed mean differences in safety climate among trades are due to true differences in safety climate and not due to assessing different things in different trades (i.e., measurement inequivalence, Horn and McArdle, 1992). Identifying true mean differences in a psychometrically equivalent safety climate measure may assist researchers and practitioners to tailor safety interventions based on the varying needs of trade groups.

The present study is the first to systematically compare safety climate perceptions of workers from different construction trades in terms of ME and mean levels. More specifically, we investigated the extent to which workers representing ten construction trades differ in how they interpret and respond to a multidimensional safety climate measure (i.e., ME) and in how they perceive the levels of safety climate at their worksite (i.e., mean differences). The next sections present a brief review of the concept and measurement of safety climate, followed by a description of the differences between construction trades in relation to safety and safety climate. Lastly, we discuss the issue of ME and how it pertains to safety climate assessment in construction safety studies.

2. Background

2.1. Dimensions of safety climate

The use of safety climate measures has offered several advantages to both researchers and practitioners, such as predicting safety behaviors and injuries, diagnosing safety issues, and being easy and cost-effective to administer (Seo et al., 2004; Johnson, 2007). Since its introduction in 1980 by Zohar, safety climate has been largely conceptualized and measured as a multidimensional construct. Safety climate measures have included various subscales, aiming to assess different dimensions of safety climate depending on the aim and scope of the study, e.g., management commitment, supervisor support, employee involvement, safety communication, risk perception, work pressure, etc. (Seo et al., 2004). According to Flin et al. (2000), management and supervisor support for safety, safety systems, and work pressure are among the most frequently assessed dimensions of safety climate.

The current study focused on four commonly studied dimensions of safety climate including management commitment to safety, safety practices, supervisor support for safety, and work pressure (Neal and Griffin, 2004), which have been used as a theoretical framework in a recent meta-analytic research (Christian et al., 2009).

Management commitment to safety is defined as the extent to which the general contractor management and safety personnel are perceived to place a high priority on safety, and communicate and act on safety issues effectively (Neal and Griffin, 2004). Management commitment to safety has been identified as a core indicator of safety climate, which has been linked to increased safety behaviors and decreased injury severity in the construction industry (Dedobbeleer and Beland, 1991; Mohamed, 2002; Gillen et al., 2002; Pousette et al., 2008).

Perceptions of *safety practices* reflect the extent to which safety-related training, toolbox talks, and site-specific safety information, as well as personal protective equipment (PPE) are perceived to be adequate and available. These practices have been found to be important predictors of worker safety performance (Glendon and Litherland, 2001; Griffin and Neal, 2000; Williamson et al., 1997).

Supervisor support for safety is the extent to which foremen are perceived to place high priority on safety, respond effectively to safety concerns, and encourage workers to comply with safety rules and procedures. Research has consistently shown supervisor support for safety to be significantly related with increased safety behaviors and decreased accidents and injuries (Christian et al., 2009; Huang et al., 2004).

Work pressure is the extent to which workload exceeds workers' capacity to perform their tasks safely (Neal and Griffin, 2004). Work pressure has been found to be another important dimension of safety climate (Flin et al., 2000; Gillen et al., 2002; Guldenmund, 2000), predicting safety behaviors and outcomes, such as accidents and injuries (Christian et al., 2009). This is not surprising, considering that the productivity-safety battle (Zohar, 2003) inevitably appears in many industries, including construction (Mohamed, 2002).

2.2. Trade differences in occupational safety

The construction industry encompasses many trades, which differ in terms of work activities and requirements, as well as risk exposures (BLS, 2010). For example, job analysis data (O*NET, 2011) indicate that, in general, work is most physically demanding for iron workers, elevator constructors, electricians, pipefitters, sheet metal workers, and drywall/tapers. Also, some trades, such as insulators, iron workers, elevator constructors, and painters, have to wear specialized personal protective equipment (e.g., respirators, fall harnesses, safety glasses, or protective suit) more often than workers in other trades. Further, the monitoring of work processes and environment to detect or assess risks/problems is one of the most important job tasks identified for carpenters, electricians, and operating engineers. Elevator constructors also have the greatest exposure to hazardous conditions and equipment, while insulators have the highest exposure to hazardous materials. In addition, the consequences of making an error at work are most serious for elevator constructors and iron workers, compared to other trades. In contrast, plumbers, pipefitters, and insulators have greater exposure to asbestos (Järvholm, 2006), and cement masons have reported higher exposure to silica (Carlsten et al., 2007).

In addition, exposure to extremely bright or inadequate light is typical for the work of cement masons, operating engineers, and electricians, while time pressure, although an important job component for all trades, is less characteristic of the work of carpenters. Noise levels are highest and most distracting for insulators, operating engineers, and sheet metal workers. Work characteristics, which have been identified as being most problematic for masons and laborers include "bending or twisting back in awkward way," "working in pain," and "working in the same position for a long period of time" (Goldsheyder et al., 2002).

Research also suggests that the risk for developing musculoskeletal disorders (MSD), which have been regarded as a leading cause of days away from work for all construction workers, varies significantly across trades (Spielholz et al., 2006). It has been noted that the type of work being done in combination with the tools being used greatly impact body posture and force, which are two main risk factors for MSDs (Sobeih et al., 2009). For example, body vibration, a leading cause of MSD, is most characteristic of the work of cement masons and operating engineers. Thus, it is not a coincidence that masons have been shown to be at significant risk for MSD, as their job tasks are physically demanding and approximately 90% of the tasks involve manual handling of construction materials, equipment, tools, or work objects (Goldsheyder et al., 2002).

In sum, there is some evidence suggesting that workers in different trades may differ in the levels of safety climate they perceive as a function of unique trade characteristics and work experiences. For example, trades with higher risk exposures (e.g., electricians and laborers) may focus greater attention on organizational safety policies and practices (i.e., safety climate) compared to trades with fewer risk factors (e.g., painters and bricklayers). Also, considering that perceived injury risk is negatively related to safety climate perceptions (Huang et al., 2007) and there are differential risk exposures among trades, mean differences in safety climate would be expected among trades. Specifically, we hypothesized that construction workers in different trades will perceive different levels of safety climate.

Hypothesis. There will be significant mean differences in safety climate scores between different construction trades.

2.3. Why is measurement equivalence of safety climate measures critical?

Considering the differential exposures, illnesses, and injuries described above, it is possible that construction workers in different trades (a) conceive of safety differently and thus likely interpret and respond differently to a safety climate measure and (b) experience different levels of safety climate. The first point concerns the issue of measurement equivalence (ME) of safety climate measures (or the lack of such), whereas the second point suggests that even if construction workers from different trades share a similar conceptualization of safety and safety climate, they may still differ in the level of safety climate they perceive at work, due to the unique features of their trades.

However, past research has failed to demonstrate the ME of safety climate measures while comparing levels of safety climate across different construction trades (Gillen et al., 2002; Glendon and Litherland, 2001; Jorgensen et al., 2007; Lingard et al., 2009). Establishing ME prior to any group comparison is a necessary condition to ensure that the researcher is comparing "apples to apples" rather than "sandwiches to sand wedges" (Vandenberg and Lance, 2000, p. 40). A comparison of safety climate mean scores across trades would not be appropriate without first establishing that the safety climate measure is interpreted and conceptualized in the same manner by workers in different trades (Campbell et al., 2008; Cheung, 2008).

Specifically, assessing the ME of a safety climate measure across different construction trades will allow us to answer several important questions: (1) do safety climate items elicit the same frame of reference from respondents in different trades, i.e., same number and pattern of factors (*configural equivalence*); (2) do respondents use the same or similar metrics to respond to safety climate items, i.e., same factor loadings (*metric equivalence*); (3) do respondents exhibit the same tendency to agree/disagree with items, i.e., same indicator intercepts (*scalar equivalence*); and (4) are the safety climate items similarly reliable across trades, i.e., same error variances (*invariant uniqueness*) (Vandenberg and Lance, 2000). If the answers to the above questions are "yes," then it can be concluded that the responses to the safety climate measure used in this study exhibit strong ME (Meredith, 1993), which justifies the comparison of safety climate mean scores between different trades at the latent and observed levels (Raju et al., 2002). Such findings would have important practical implications for assessing safety climate and interpreting observed safety climate scores in organizations, which are common practices (Flin et al., 2000). Thus, we will first examine if a multidimensional measure of safety climate demonstrates measurement equivalence across different construction trades before comparing safety climate mean scores among trades.

3. Method

3.1. Study context

The current study was part of a large-scale worksite safety assessment in the fall of 2008, which aimed to evaluate the state of safety programs, policies, and practices, and identify areas for improvement at a massive commercial construction project (Gittleman et al., 2010). This construction project involved two simultaneous jobsites, 24 separate buildings, over 7000 workers, and close to 13 billion dollars of private funds. Unfortunately, this project also involved eight fatalities in its first 18 months, as well as numerous injuries and near misses, which were brought to the public's attention by a one-day strike of workers in June 2008 and the incisive reports of Las Vegas Sun's journalist, Alexandra Berzon (Berzon, 2008). Consequently, the general contractor and construction unions requested the assistance of the research team to conduct a safety needs assessment that could identify safety issues and provide recommendations for improving the safety and health of workers employed at this project. More details about the background and outcomes of this project are described in Gittleman et al. (2010).

3.2. Participants and procedure

Anonymous safety needs assessment surveys were administered to four groups of construction project employees working for the general contractor, as well as numerous subcontractors: executives, superintendents, foremen, and workers. For the purposes of this study, only data from the construction workers will be analyzed. A total of 5268 construction workers agreed to participate in the study representing a response rate of 87%. Out of the total sample, 452 workers failed to provide trade information, and were excluded from subsequent analyses. The remaining sample was grouped into 13 trade categories based on taxonomies established by the BLS (2010), which included 1131 (21.5%) carpenters, 840 (15.9%) electricians, 825 (15.7%) plumbers/pipefitters, 559 (10.6%) sheet metal workers, 388 (7.4%) laborers, 314 (6.0%) bricklayers, 202 (3.8%) insulators, 180 (3.7%) painters, 152 (2.9%)

operating engineers, 134 (2.5%) cement masons, 50 (.9%) iron workers, 22 (.4%) roofers, and 19 (.4%) elevator constructors. The latter three trades, iron workers, roofers, and elevator constructors, were subsequently excluded from the analyses due to small sample sizes.

The final sample consisted of 4725 construction workers, representing 10 trade categories, with an average age of 38.68 years (*SD* = 11.00). Participants had worked in the construction industry for an average of 15.5 years (*SD* = 10.63), and had worked on the current jobsite for an average of 5.24 months (*SD* = 5.68). Of the 4725 workers, 3649 (77%) identified themselves as journeymen and 868 (18.4%) identified themselves as apprentices. In terms of race, the sample consisted of 2185 (46.2%) Caucasians, 1636 (34.6%) Hispanics, 335 (7.1%) African-Americans, 150 (3.2%) Native Americans, 61 (1.3%) Asians, and 170 (3.6%) individuals, who marked the "Other" category.

The surveys were distributed during 10-hour OSHA Hazard Awareness classes and were administered based on the following protocol. First, a trainer/coordinator explained the purpose of the survey and that completion of the survey was voluntary. No individual information was collected and participants who chose to participate were asked to complete the survey in 10 minutes. When respondents completed the surveys, the trainer/coordinator collected their surveys, placed them in sealed self-addressed envelopes, and mailed them directly to the research team.

3.3. Measures

Safety climate was assessed using a 19-item multidimensional measure, which was developed for project purposes, reflecting Neal and Griffin's (2004) safety climate framework. The measure attempts to assess four factors: management commitment to safety (α = .91, 7 items), safety practices (α = .76, 4 items), supervisory support for safety (α = .91, 6 items), and work pressure (α = .70, 2 items). Sample items included: "Management thinks that safety is more important than productivity" (*management commitment to safety*), "There is always enough personal protective equipment available to allow work to be done safely" (*safety practices*), "My foreman makes sure we follow site safety rules and procedures very closely" (*supervisory support for safety*), and "Sometimes I ignore a safety rule or policy in order to carry out an assignment to meet the schedule" (*work pressure*). Descriptive statistics and Cronbach's alphas of the safety climate scales for each trade sample are reported in Table 1. All responses were provided on a 6-point Likert-type scale, ranging from 1 (strongly disagree) to 6 (strongly agree).

3.4. Analyses

Two types of analyses were conducted in this study. First, measurement equivalence (ME) of the safety climate measure was assessed in two steps using EQS for Windows, version 6.1 (Bentler, 2004): (1) within-group tests of fit of measurement model, using a series of confirmatory factor analyses (CFA); and (2) between-group tests of ME, using a series of multi-group confirmatory factor analyses (MGCFA). Second, mean differences of trade safety climate scores were examined by a multivariate analysis of covariance (MANCOVA). Below is a more detailed description of these analyses.

3.4.1. Within-group tests of fit of measurement model

Prior to assessing the ME of the safety climate measure across the ten trades, a baseline measurement model was identified for each sample (Byrne, 2006). In addition, the fit of a four-factor model was compared to the fit of two alternative models: a one-factor and two-factor models of safety climate. The one-factor model suggested a higher order factor of safety climate, which reflected employees' global assessments of their safety and of their management commitment to their safety (Christian et al., 2009; Griffin and Neal, 2000; Zohar and Luria, 2005). The two-factor model, modified from Neal and Griffin's (2004) framework, proposed two broad safety climate dimensions: (a) organizational policies and procedures, and (b) local work conditions and practices. More specifically, Neal and Griffin suggested that management commitment, human resource management practices, and safety systems represented organizational level policies and procedures, whereas supervisor support, internal group processes, boundary management, risk and work pressure would be indicative of local work conditions and practices. These two factors would, in turn, represent a single, higher-order factor of global perceptions of safety and well-being.

To evaluate goodness of model fit, the two most commonly used fit indices were examined based on recommendations from the literature (Byrne, 2006; Meade et al., 2008; Vandenberg and Lance, 2000): the comparative fit index (CFI) and the root mean square error of approximation (RMSEA). The CFI assesses model fit by comparing the hypothesized model with the independence model while adjusting for sample size (Bentler, 1990). Values range from 0 to 1, with values between .90 and .94 signifying a reasonable fit, while values of .95 or greater indicating very good fit (Hu and Bentler, 1999). The RMSEA estimates lack of model fit, comparing the hypothesized model to an ideal model and involves tests of residuals. RMSEA values also range from 0 to 1, however smaller values represent a better-fitting model. RMSEA values of .08 and .07 indicate a reasonable model fit, while values of .06 or less suggest a very good fit (Hu and Bentler, 1999).

Consistent with common practices, traditional chi-square statistics are reported. However, due to the large samples in this study and the sensitivity of the chi-square likelihood ratio test to sample size, chi-square test results were not used in interpreting model fit (Bollen, 1990; Cheung and Rensvold, 2002).

Table 1
Background characteristics of the ten construction trade samples.

Trade category	*N*	Age		Years in construction		Months on jobsite		Work status		Ethnicity
		M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	% Journeyman	% Apprentice	% Majority
Bricklayer	314	37.3	(10.26)	13.5	(10.14	6.8	(7.24)	83.1%	13.4%	64.1% (Hispanic)
Carpenter	1131	37.7	(9.69)	15.4	(9.23)	5.9	(6.15)	88.2%	9.0%	55.2% (Hispanic)
Cement mason	134	39.5	(9.64)	17.3	(9.21)	6.8	(6.23)	86.6%	9.7%	52.3% (Hispanic)
Electrician	840	41.7	(10.8)	17.9	(10.95	3.3	(4.18)	78.7%	18.0%	63.3% (Caucasian)
Insulator	202	38.5	(12.45)	14.6	(12.83)	2.5	(3.42)	49.0%	41.6%	53.1% (Caucasian)
Laborer	388	37.2	(10.17)	11.9	(8.49)	7.4	(6.58)	84.0%	7.5%	53.5% (Hispanic)
Operating engineer	152	41.7	(11.59)	18.8	(11.94)	9.9	(7.73)	86.2%	11.2%	74.3% (Caucasian)
Painter	180	37	(10.71)	14.2	(10.17)	4.8	(4.87)	72.2%	20.6%	72.6% (Hispanic)
Plumber/pipefitter	825	38.4	(12.27)	15.5	(11.64)	5.1	(4.88)	67.3%	27.9%	63.1% (Caucasian)
Sheet metal worker	559	37.9	(11.52)	14.8	(10.63)	4.1	(4.22)	66.5%	29.2%	61.6% (Caucasian)
Total	4725	38.7	(11)	15.5	(10.63)	5.24	(5.68)	77%	18.4%	46.2% (Caucasian)

3.4.2. Between-group tests of measurement equivalence

Once an adequate fit was found for a four-factor measurement model in each of the ten samples, the measurement models were tested simultaneously across the ten samples in a sequence of four increasingly restrictive tests of ME (Vandenberg and Lance, 2000). In these analyses, a set of measurement parameters were sequentially constrained and examined for equality across the samples.

The first step in assessing ME, which is referred to as *configural equivalence*, involved testing for equality of factor structure (i.e., same number of factors and factor loading pattern) of the baseline measurement models across the groups. Establishing *configural equivalence* would mean that workers in the ten trades used a similar frame of reference when completing the safety climate measure. The next step entailed assessing *metric equivalence*, which aimed to show that the factor loadings are of equal magnitude across groups. Establishing *metric equivalence* would indicate that respondents from all the trades used the same metric to respond to the items, i.e., the conceptual frame of reference of workers from different trades influenced their item responses similarly. Non-equivalence of factor loadings, on the other hand, would suggest that there were substantial differences across trades in the extent to which observed variable scores changed as a result of a unit change in the latent variable (Vandenberg, 2002). *Scalar equivalence* refers to the equality of item intercepts across the groups, which would suggest that there were no systematic differences in response bias (positive or negative) across the different trades. Establishment of *scalar equivalence*, along with configural and metric equivalence, is a prerequisite for comparing means at the latent factor level (Meredith, 1993). Finally, demonstration of *invariant uniqueness* would indicate that the error variances were equal in all groups, meaning that the safety climate measure was equally reliable across the samples and testing mean differences in safety climate between trades would be meaningful at the observed score level.[1]

Traditionally, the chi-square difference test has been used to assess improvement or deterioration of fit of a multi-group model after adding constraints. Since its appropriateness has recently been questioned because of its sensitivity to sample size and limitations in identifying lack of ME, change in the comparative fit index (CFI) was used (i.e., ΔCFI) to gauge changes in model fit, as recommended in the literature (Cheung and Rensvold, 2002; Kelloway, 1995; Vandenberg and Lance, 2000). According to Cheung and Rensvold's (2002) guidelines, ME is supported when ΔCFI is .01 or less, while ΔCFI values of .02 or greater indicate substantial deterioration of fit when applying specific constraints. For example, if after constraining the factor loadings to be equal across the ten samples (i.e., testing for metric equivalence) the model fit decreases considerably compared to the measurement model (i.e., $\Delta\text{CFI} \geq .02$), then we would conclude that full metric equivalence is not supported.

3.4.3. Tests of observed mean differences

When ME was established based on the above criteria, we proceeded with assessing between-trade mean differences in observed scores on the safety climate measure. More specifically, a MANCOVA was conducted to evaluate if there were any overall differences among trades on each of the four dependent variables (i.e., management commitment to safety, safety practices, supervisor support for safety, and work pressure), after controlling for age, ethnicity, work status, number of months worked on the jobsite and number of years worked in construction (explained in the next section). Follow-up analyses were conducted for each of the four dependent variables by means of ANCOVAs, accompanied with post hoc analyses to identify the significant mean differences between trade samples.

3.4.4. Handling of missing data

For the CFA and MGCFA analyses, missing data were handled with the direct maximum likelihood (ML) approach with Yuan-Bentler corrections (Bentler, 2004; Schafer and Graham, 2002). Implementing the ML procedure in EQS resulted in a final combined sample of 4580 workers with 145 cases (3.2%) being excluded due missing data for all relevant variables.

Listwise deletion of missing data was used for the mean comparison analyses. A substantial number of respondents did not provide complete information on covariates (26.0%) and dependent variables (18.1%), resulting in a much smaller MANCOVA sample ($N = 2642$). A multivariate analyses of variance excluding covariates, which was conducted on a sample of 3872 workers, revealed consistent results with the MANCOVA. Thus, MANCOVA results are reported below.

4. Results

4.1. Preliminary findings

First, the comparability of the ten trade samples was assessed in terms of demographic and background characteristics (see descriptive statistics in Table 1). Results indicated that there were significant mean differences among the trade samples on age ($F(9, 4597) = 11.60$, $p < .001$), years worked in construction ($F(9, 4346) = 12.74$, $p < .001$), and months worked on the jobsite ($F(9, 4382) = 41.87$, $p < .001$). Also, the composition of the samples in relation to work status (journeyman vs. apprentice) and race (Caucasian vs. Hispanic) was significantly different across trades, $\chi^2(9) = 296.65$, $p < .001$, and $\chi^2(9) = 742.80$, $p < .001$, respectively. Consequently, age, years worked in construction, months worked on the jobsite, work status, and ethnicity were included in the MANCOVA and ANCOVAs as control variables.

Scale score means, standard deviations, and coefficients alpha of the four safety climate scales for each trade are also presented in Table 2. The average alpha coefficients of the four safety climate scales across the ten samples were as follows: management commitment to safety ($\alpha = .91$), safety practices ($\alpha = .76$), supervisor support for safety ($\alpha = .91$), and work pressure ($\alpha = .70$). Examination of the individual alpha coefficients revealed relatively low internal consistency of the safety practices scale for electricians ($\alpha = .66$) and the work pressure scale for operating engineers ($\alpha = .58$), electricians ($\alpha = .64$), and laborers ($\alpha = .66$).

A principal components analysis using varimax rotation was performed on the 19 items comprising the four scales of the safety climate measure based on the full sample. As expected, four components were extracted, explaining 67% of the variance (see

[1] While the ME literature suggests three additional analytical steps (i.e., equal factor variances, co-variances, and means), which focus on the distribution and relationships of the variables at the latent or construct level (i.e., "structural" equivalence, Cheung and Rensvold, 2002; Vandenberg and Lance, 2000), these were tangential to the goals of the current study and were excluded. The main focus of this study was on the measurement properties of the safety climate instrument across different trade groups (i.e., establishing measurement equivalence) and its implications for practice given the popularized assessments of safety climate in organizations and industries (Huang et al., 2010), which are exclusively based on observed mean scores. Hence, we targeted configural, metric, and scalar equivalence, as well as variant uniqueness, because they were directly related to the measurement model. Referred to as "measurement" or "factorial" equivalence/invariance (Cheung and Rensvold, 2002; Lance and Vandenber, 2000; Meredith, 1993; Mullen, 1995), these steps specify the relationships between observed indicators and their corresponding latent variables. While establishing scalar equivalence is considered evidence for strong ME (Cheung and Rensvold, 2002), establishing invariant uniqueness is often considered an overly strict test of ME (Byrne, 2006). However, considering the applied orientation of this study, we decided to extend our ME analyses to include invariant uniqueness as a fourth step, since it is a prerequisite for observed mean score comparisons, which are common in practice (unlike latent mean comparisons).

Table 2
Descriptive statistics and Cronbach's alphas of the safety climate scales for ten construction trade samples.

Trade category	Management commitment			Supervisor support			Safety practice			Work pressure		
	M	(*SD*)	α	*M*	(*SD*)	α	*M*	(*SD*)	α	*M*	(*SD*)	α
Bricklayer	33.17	(5.95)	.87	29.29	(5.28)	.88	19.48	(3.59)	.77	4.98	(2.54)	.72
Carpenter	32.06	(6.90)	.91	29.58	(5.66)	.91	19.43	(3.75)	.80	5.24	(2.79)	.72
Cement mason	31.39	(7.76)	.91	28.67	(6.69)	.93	19.32	(4.15)	.85	4.94	(2.83)	.77
Electrician	27.52	(7.61)	.93	28.80	(5.31)	.92	19.29	(2.92)	.66	4.40	(2.19)	.64
Insulator	31.74	(6.81)	.90	30.78	(5.26)	.94	19.99	(3.58)	.84	4.08	(2.38)	.75
Laborer	31.24	(6.96)	.88	27.99	(6.91)	.91	18.50	(4.57)	.82	4.98	(2.65)	.66
Operating engineer	30.36	(6.82)	.90	28.87	(5.58)	.91	18.29	(3.94)	.76	4.53	(2.14)	.58
Painter	34.15	(6.17)	.89	29.83	(5.16)	.89	19.49	(3.44)	.70	5.30	(2.80)	.70
Plumber/pipefitter	28.81	(7.23)	.90	29.11	(5.74)	.92	19.41	(3.33)	.72	4.84	(2.49)	.69
Sheet metal worker	29.45	(7.01)	.90	29.87	(5.24)	.92	19.96	(3.06)	.73	4.97	(2.51)	.72
Total	30.54	(7.32)	.91	29.25	(5.75)	.91	19.37	(3.60)	.76	4.91	(2.59)	.70

Table 3). The four-component solution displayed a simple structure, with all items having their highest loadings (>.50) on their corresponding components and much lower loadings on the remaining components.

4.2. Results for measurement equivalence

Confirmatory factor analyses were first performed separately in each trade group to test the hypothesized four-factor model of safety climate and establish baseline measurement models. Due to significant multivariate non-normality of the data (i.e., Mardia's coefficient values >5), the Yuan-Bentler correction was applied to all analyses in order to provide more efficient and less biased estimates (Byrne, 2006). As seen in Table 4, the four-factor model provided a good fit to the data for all ten trade samples with CFI values ranging between .920 and .980, and RMSEA values ranging between .020 and .060. In addition, the goodness-of-fit indices for the four-factor model were superior to those for the one and

Table 3
Means, standard deviations, and factor loadings of the safety climate items based on the full sample.

Item description	Factor pattern						
	M	(*SD*)	MC	SS	SP	WP	h^2
Safety is visible on this job – for example, I have seen safety personnel or site supervisors or site management doing daily safety checks.	4.62	(1.19)	**.618**	.209	.228	.024	.48
The General Contractor thinks that job site safety is more important than job schedules and deadlines.	4.24	(1.38)	**.837**	.117	.096	−.046	.73
The General Contractor's safety personnel step in to stop unsafe operations.	4.50	(1.24)	**.803**	.145	.114	−.027	.68
The General Contractor thinks that safety is more important than productivity.	4.23	(1.32)	**.835**	.159	.096	−.066	.74
The General Contractor's safety staff follows up when there is a problem – it gets fixed right away and stays that way.	4.22	(1.26)	**.786**	.162	.099	−.030	.66
The General Contractor likes to get safety reports/feedback from workers like me.	4.04	(1.42)	**.769**	.154	.063	−.006	.62
The General Contractor cares for my safety on this job.	4.62	(1.22)	**.792**	.199	.146	−.022	.69
There is always enough personal protective equipment available to allow work to be done safely.	4.95	(1.11)	.224	**.802**	.236	−.006	.75
I have received enough training to do my work safely.	4.99	(1.09)	.228	**.824**	.236	−.052	.79
I always get enough site-specific information about a job to do it safely.	5.12	(1.02)	.207	**.810**	.240	−.058	.77
Toolbox talks about safety are given regularly.	4.76	(1.20)	.185	**.762**	.205	−.078	.66
My foreman has the safety knowledge needed for the hazards we face on this job.	4.75	(1.22)	.145	**.784**	.177	−.145	.69
My foreman makes sure we follow site safety rules and procedures very closely.	4.76	(1.23)	.179	**.713**	.203	−.158	.61
My foreman wants us to inform him/her of any safety problems so they can get them fixed or reported to others.	4.65	(1.31)	.201	.234	**.671**	−.115	.56
If my foreman is unsure of a safety question, he or she always calls in a safety specialist.	5.04	(1.03)	.106	.213	**.804**	−.047	.70
My foreman thinks that safety is more important than productivity.	4.72	(1.15)	.272	.295	**.744**	−.054	.72
My foreman stops work if working conditions are unsafe, even if we have a deadline.	4.99	(1.19)	.046	.370	**.523**	−.034	.43
Sometimes I don't report a hazard because there isn't time to stop work or the work task is of too short a duration, so I work around the hazard	2.36	(1.41)	−.016	−.143	−.086	**.852**	.76
Sometimes I ignore a safety rule or policy in order to carry out an assignment to meet the schedule.	2.52	(1.50)	−.052	−.116	−.077	**.861**	.77
% of variance (rotated solution)			24.33	22.32	12.36	8.21	
Alpha coefficient			.91	.91	.76	.70	

Note: *N* = 3716 after listwise deletion of missing data. The actual name of the management company was replaced with "The General Contractor" in items 2, 3, 4, 6, 7, and 10. MC, management commitment to safety; SS, safety support for safety; SP, safety practice; WP, work pressure; boldface values indicate highest loadings on the factor.

Table 4
Tests of within-group measurement model fit of the safety climate scales across ten construction trades.

Model	Bricklayer	Carpenter	Cement mason	Electrician	Insulator	Laborer	Operating engineer	Painter	Plumber/ pipefitter	Sheet metal worker
1-Factor model										
χ^2	524.42	2028.136	350.563	2283.301	530.386	718.273	444.022	311.291	2458.653	1521.42
df	152	152	152	152	152	152	152	152	152	152
CFI	.728	.650	.739	.617	.605	.737	.721	.822	.545	.520
RMSEA	.083	.101	.087	.117	.104	.093	.107	.067	.131	.122
90% CI	.075–.092	.097–.105	.072–.101	.112–.121	.093–.114	.085–.100	.094–.119	.054–.080	.126–.136	.116–.128
2-Factor model										
χ^2	391.638	1373.274	290.399	814.751	394.581	470.431	341.834	247.784	1024.386	735.696
df	151	151	151	151	151	151	151	151	151	151
CFI	.830	.780	.829	.878	.759	.858	.827	.909	.826	.797
RMSEA	.066	.080	.071	.066	.082	.068	.084	.048	.081	.080
90% CI	.056–.074	.076–.084	.054–.086	.061–.071	.070–.093	.061–.076	.071–.097	.032–.063	.076–.086	.074–.086
4-Factor model										
χ^2	227.35	492.734	194.314	411.915	234.645	243.843	233.628	184.687	428.147	307.368
df	146	146	146	146	146	146	146	146	146	146
CFI	.950	.938	.966	.956	.922	.960	.927	.980	.946	.946
RMSEA	.036	.043	.032	.040	.047	.037	.056	.023	.046	.042
90% CI	.023–.047	.039–.048	.000–.054	.035–.046	.031–.061	.027–.047	.039–.071	.000–.044	.041–.051	.035–.049
N	303	1103	127	793	193	378	151	173	807	552

Note: Statistics are based on Yuan-Bentler correction with robust standard errors. CFI, comparative fit index; RMSEA, root mean square error of approximation; CI, confidence interval. All χ^2 values are significant at the $p < .05$ level.

two factor models in all samples. Finally, the four-factor model showed a significantly better fit to the data compared to the one-factor and two-factor models based on nested chi-square difference test results. Consequently, the four-factor measurement model was chosen for the subsequent analyses of measurement equivalence (ME).

Results for the sequence of increasingly restrictive tests of ME are reported in Table 5. *Configural equivalence* was tested by comparing the number of factors and pattern of factor loadings across the ten samples, i.e., equivalence of the baseline measurement models. Results indicated a good model fit, CFI = .950 and RMSEA = .040, 90% CI [.037, .043]. *Metric equivalence* was assessed by constraining the factor loadings in all ten samples and testing fit of the constrained multi-group model. There was no substantial deterioration in fit as suggested by a CFI value of .949 (ΔCFI = −.001) and a RMSEA value of .039, 90% CI [.037, .042]. Next, indicator intercepts were constrained to be equal across the groups in addition to the factor loadings to test *scalar equivalence*. The results again met the criteria for a good model fit, CFI = .947 (ΔCFI = −.002); RMSEA = .042, 90% CI [.040, .045], with a negligible reduction in fit from the previously tested model. Finally, *invariant uniqueness* was supported by a non-substantial reduction in model fit after constraining the error variances across the groups in addition to the previous two constraints, CFI = .936 (ΔCFI = −.013), RMSEA = .044, 90% CI [.042, .046]. The above results allow for subsequent comparisons of safety climate mean scores at the observed level.

4.3. *Results for observed mean differences*

MANCOVA results for observed trade mean differences in the four safety climate dimensions (i.e., management commitment to safety, safety practices, supervisor support for safety, and work pressure) after controlling for age, years worked in construction, months worked on the jobsite, work status, and ethnicity are shown in Table 6. The Wilks' Lambda multivariate test of overall differences among trades was statistically significant, $F(36, 9835) = 8.53$, $p < .001$, Wilks' Lambda = .89, $\eta^2 = .03$. Univariate between-subject tests indicated significant mean differences for management commitment to safety ($F(14, 2627) = 24.45$, $p < .001$, $\eta^2 = .12$), safety practices ($F(14, 2627) = 2.26$, $p < .001$, $\eta^2 = .01$), supervisor support for safety ($F(14, 2627) = 2.19$, $p < .001$, $\eta^2 = .01$), and work pressure ($F(14, 2627) = 3.44$, $p < .001$, $\eta^2 = .02$). The examination of Scheffe post hoc test results based on estimated marginal means (which take into account model covariates) revealed that, for management commitment to safety, electricians ($M = 27.05$, $SD = 7.55$) reported significantly lower mean scores than all other trades, followed by plumbers/pipefitters ($M = 28.61$, $SD = 7.22$) and sheet metal workers ($M = 29.37$, $SD = 7.01$). In addition, painters ($M = 34.39$, $SD = 5.45$) reported significantly higher perceptions of management commitment to safety than the remaining trades. On the other hand, operating engineers ($M = 18.24$, $SD = 3.97$) and laborers ($M = 18.55$, $SD = 4.49$) reported on average significantly lower perceptions of safety practices than any other trade. In regards to perceptions of supervisor support for safety, laborers ($M = 28.22$, $SD = 6.77$) reported the lowest supervisor support for safety, which were significantly lower than that of carpenters, insulators, and sheet metal workers. Finally, painters ($M = 5.29$, $SD = 2.80$) and carpenters ($M = 5.19$, $SD = 2.74$) reported the highest work pressure; significantly higher than electricians, insulators, and operating engineers. Insulators ($M = 4.08$, $SD = 2.34$) reported on average the lowest perceptions of work pressure, which were significantly lower compared to six of the other nine trades.

Table 5
Measurement equivalence for the four-factor model across ten construction trades.

Model	χ^2	*df*	CFI	ΔCFI	RMSEA	90% CI for RMSEA
Configural equivalence	2932.491	1460	.950		.040	.037–.043
Metric equivalence	3117.163	1580	.949	−.001	.039	.037–.042
Scalar equivalence	3841.410	1732	.947	−.002	.042	.040–.045
Invariant uniqueness	4196.202	1884	.936	−.013	.044	.042–.046

Note: $N = 4580$. Statistics are based on Yuan-Bentler correction with robust standard errors. All χ^2 values are significant at the $p < .001$ level.

Table 6
Multivariate analysis of covariance of the safety climate scales across the ten construction trades.

Source	*df*	MC		SS		SP		WP	
		MS	*F*	*MS*	*F*	*MS*	*F*	*MS*	*F*
Covariates									
Age	1	196.632	4.219*	1.002	.032	.625	.053	1.726	.275
Years worked	1	21.968	.471	15.334	.491	10.966	.922	17.788	2.833
Months worked	1	1849.078	39.676*	64.759	2.073	33.235	2.795	39.262*	6.253
Ethnicity	1	1674.367	35.927*	44.111	1.412	18.223	1.532	.852	.136
Work status	1	133.436	2.863	23.315	.746	1.758	.148	15.569	2.494
Trade	9	1139.266	24.445*	68.258	2.185*	26.814	2.255*	21.596	3.439*
Residual	2627	46.605	–	31.239	–	11.893	–	6.279	–
Total	2642	2,568,828.944	–	2,358,985.880	–	1,037,200.778	–	77,654.000	–

Note: Years worked, years of work experience in construction; months worked, months of work experience on the current jobsite; ethnicity was coded as 1 for Caucasian Non-Hispanic and 2 for Non-Caucasian; work status was coded as 1 for journeyman and 2 for apprentice.
* $p < .05$

5. Discussion

Although safety climate has received significant attention in construction research (Fang et al., 2006; Gillen et al., 2002; Mohamed, 2002), little is known about the psychometric properties of safety climate measures and mean levels of safety climate perceptions across different trades. This study is the first to assess the measurement equivalence (ME) of a multidimensional safety climate measure across different trades in the construction industry and examine trade mean differences in safety climate perceptions. Overall, the findings of this study provided strong support for the ME of the safety climate measure under study and indicated significant mean differences among the ten trades on all four safety climate dimensions: management commitment to safety, safety practices, supervisor support for safety, and work pressure. Specifically, the findings suggest that construction workers in the represented trades (1) used a similar frame-of-reference when responding to the safety climate items (evidenced by configural equivalence), (2) viewed the 1–6 Likert response scale and its' intervals in a similar fashion (revealed by metric equivalence), (3) responded to the items without methodical bias (demonstrated by scalar equivalence), and (4) provided responses, which were similarly reliable (substantiated by invariant uniqueness[2]). These results suggest that in spite of inherent trade differences in work organization, environment, and risks, workers in different trades share the same fundamental view of safety climate as assessed by the current instrument. Specifically, construction workers in different trades share the same larger, over-arching work factors such as safety, production pressure, dynamic work environment, and common federal regulations such as OSHA (Ringen et al., 1995a,b). This is consistent with construction research, revealing similar underlying safety climate themes, derived both theoretically and empirically, and using samples from different construction populations (see Dedobbeleer and Beland, 1991; Fang et al., 2006; Gillen et al., 2002; Mohamed, 2002).

A second aim of this study was to examine observed mean differences in safety climate perceptions across the ten construction trades, given measurement equivalence. Overall, results supported the hypothesis showing significant trade mean differences in management commitment to safety, safety practices, supervisor support for safety, and work pressure. These findings are not surprising given the varying nature and intensity of job tasks, risks, and work demands for different trades (BLS, 2010; O*NET, 2011), as well as research indicating trade differences in work fatigue, pain, and elevated heart rate (Chang et al., 2009).

Of particular interest are the significant differences among trades in their perceptions of general contractor's management commitment to safety, given that all trades were working on the same construction project and under the same general contractor (i.e., top management). Results indicated that electricians, plumber/pipefitters, and sheet metal workers reported the lowest perceptions of top management's commitment to safety, whereas painters reported the highest. It is interesting to note that carpenters and painters perceived the highest work pressure, which may be attributed to the circumstance that carpenters and painters are likely to be the last trades working and putting the finishing touches on a jobsite (BLS, 2010). As a result, carpenters and painters may be more likely to feel the pressure of meeting deadlines.

Another noteworthy finding is that laborers reported relatively lower support from their supervisors regarding safety and received less resources (e.g., PPE, training) to work safely compared to other trades. This is not surprising considering that laborers tend to (a) perform varied and physically demanding and dangerous tasks (e.g., loading and unloading building materials, tending to various machinery, assembling scaffolding, removing hazardous waste materials) (BLS, 2010), (b) have very limited freedom in making decisions within their work context (O*NET, 2010), which may make their work more stressful (Karasek, 1979), and (c) experience the highest number of occupational injuries and illnesses among all trades – 27 percent of all recorded injuries and illnesses in U.S. construction in 2009 (BLS, 2010).

As suggested above, systematic variation in trade safety climate perceptions can be attributed to systematic differences in work tasks, environment, and risk exposures among different construction trades. This is consistent with the structuralist perspective (Payne and Pugh, 1976), which suggests that safety climate arises from employees' responses or reactions to work organization variables, such as group and organizational structures, as well as nature and characteristics of work. These variables can affect how trades receive safety information and how workers interact within their own trade and between those of other trade groups to comprehend any safety rules or policies. In support of this, Glendon and Litherland (2001) found significant differences in the levels of safety climate perceptions between construction crews and maintenance crews in the same road construction company; while construction crews scored higher on the relationships dimension, maintenance crews scored higher on the safety rules dimension. These differences were attributed to variations in work environment between the two groups, as construction crews had more

[2] As indicated by an anonymous reviewer, caution is needed to make a conclusion about the equivalence of the safety climate scale's reliability unless equivalence of factor variances is established prior to testing invariant uniqueness (see Vandenberg and Lance, 2000). This analytic step was not undertaken in the current study, because assessing scale reliability was not a primary aim of this investigation.

contact with their supervisors and fewer safety rules were applicable to the work of maintenance crews (Glendon and Litherland, 2001).

5.1. Implications for research and practice

A main contribution of this study is the demonstration of ME of a multidimensional safety climate measure across ten construction trades, which has important implications for future research and practice. In practice, organizational surveying is often used in the construction industry for assessing workplace safety, safety climate and development of interventions to remediate problems or prevent injuries and illnesses (Gittleman et al., 2010). The findings of strong ME in this study provide an important first piece of empirical evidence about the utility of using safety climate measures across various trades to gather meaningful safety climate data. Such data can further be used to study trade disparities in antecedents and consequences of safety climate, which in turn develop appropriate solutions to improve construction safety and health. Further, using measurement-equivalent measures of safety climate ensures that observed mean differences and comparisons between groups of construction workers are in fact valid (Vandenberg and Lance, 2000), which has important implications for making appropriate organizational decisions related to safety policies and practices, considering that errors related to these decisions could be costly to organizations and individuals.

In light of the well-established relationship of safety climate with safety performance and outcomes (e.g., accidents, injuries, see Christian et al., 2009; Clarke, 2006, 2010; Nahrgang et al., 2011), comparison of observed mean differences in safety climate perceptions can shed light on potential trade differences in safety performance and outcomes and lead to the development of more effective trade-specific safety interventions, policies, and procedures based on particular trade needs. For example, based on this study's findings, organizational interventions focusing on increasing supervisor support for safety (e.g., supervisor training) and management commitment to safety can prove particularly useful for improving safety climate perceptions among laborers, electricians, plumber/pipefitters, and sheet metal workers. On the other hand, better project planning, scheduling, and work organization may help carpenters and painters feel less work pressure in their efforts to finalize construction project within established deadlines. Gittleman et al. (2010) provide specific recommendations for organizational interventions aiming to improve construction workers' perceptions of safety climate, as well as safety performance.

5.2. Strengths, limitations, and directions for future research

This study has numerous strengths; however, its uniqueness rests on the rare opportunity, which was presented to the research team, to study a large sample of construction workers representing numerous trades and working on the same construction project and examine the ME and mean levels of a multidimensional safety climate measure across multiple construction trades.

As with any study, our research is not without its limitations, which should be considered when interpreting the findings. For example, all of the participants took the survey while working on the same project (two adjacent jobsites), which may limit the generalizability of our findings to other construction projects. Also, while the sample sizes for most of the trade groups in this study were adequate for the analyses performed, sample sizes varied, which could affect the observed mean differences (Murphy et al., 2009). However, this effect is unlikely because equivalence of measurement errors was demonstrated.

Because this study was conducted following eight fatal injuries, a labor strike, and mediation between general contractor and labor union (Gittleman et al., 2010), it is possible that these unusual circumstances have affected the frame-of-reference used by workers to respond to the safety climate scales.[3] Should this effect be in play, we might expect small variation within each trade and similar variations across trades for each safety climate scale. While carefully examining the coefficients of variation (a normalized index of variation) based on means and *SD*s in Table 2, we observed similar variations across trades for each dimension of safety climate. Yet, variations within each trade seemed to vary across scales. For instance, the coefficients of variation within each trade for work pressure ranged from 47% to 58%, which were quite large. Yet, variations within each trade were relatively small for management commitment, supervisor support, or safety practice, ranging from 15% to 25%. This post hoc finding provides some evidence that the situation, albeit strong, may not be the main driver of participants' responses; future safety climate research should further examine the extent to which situational effects shape the frame of reference used by respondents, and in what ways.

Consistent with an emphasis on understanding occupational safety and health disparities in construction (The Center for Construction Research and Training, 2008; Ringen et al., 1995a,b), future research should continue to validate and examine the ME of safety-related measures in different construction populations of interest. More studies should add to our research to address NORA's (2008) call for a better understanding of how safety climate is developed, measured, and influences safety in various construction industry subgroups, e.g., young/older workers, apprentices/journeymen, immigrant workers.

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[3] We thank an anonymous reviewer for pointing this out.

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