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The Dread Factor: How Hazards and Safety Training Influence Learning and Performance

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On the basis of hypotheses derived from social and experiential learning theories, we meta-analytically investigated how safety training and workplace hazards impact the development of safety knowledge and safety performance. The results were consistent with an expected interaction between the level of engagement of safety training and hazardous event/exposure severity in the promotion of safety knowledge and performance. For safety knowledge and safety performance, highly engaging training was considerably more effective than less engaging training when hazardous event/exposure severity was high, whereas highly and less engaging training had comparable levels of effectiveness when hazardous event/exposure severity was low. Implications of these findings for theory testing and incorporating information on objective risk into workplace safety research and practice are discussed.

Keywords: safety training, occupational hazards, meta-analysis

In what has been described as the nation's worst mining disaster in 40 years (Cooper, 2010), 29 miners died and two more were seriously injured in an explosion at the Upper Big Branch mine in West Virginia on April 5, 2010 (Mining Safety and Health Administration [MSHA], n.d.-b). In the years leading up to this disaster, the Upper Big Branch mine was cited for a very large number of MSHA violations (MSHA, n.d.-c). The pattern of violations indicates several things. First, the Upper Big Branch mine had significant and systematic safety-related problems prior to the explosion on April 5, suggesting that the explosion was more than a chance occurrence. Second, many of the problems were training related or training relevant. Of the violations specific to training regulations, half were deemed to be significant and substantial, meaning that there was a reasonable likelihood of these violations resulting in serious injury or illness. Many more of the mine's violations, a large number of which deemed to be significant and substantial, were relevant to the content of the training required for miners. For instance, the mine was repeatedly in violation of 30 C.F.R. § 75.370 (mine ventilation plan; Mandatory Safety Standards Underground Coal Mines, 2008), 30 C.F.R. § 75.400 (accumulation of combustible materials; Mandatory Safety Standards Underground Coal Mines, 2008), 30 C.F.R. § 75.220 (roof control plan; Mandatory Safety Standards Underground Coal Mines, 2008), and 30 C.F.R. § 75.202 (protection from falls of roof, face, and ribs; Mandatory Safety Standards Underground Coal Mines, 2008), issues which were supposed to be part of the miners' safety training, as per federal regulations (MSHA, n.d.-d).

In the training plan submitted by Performance Coal Company, the operator of the Upper Big Branch mine, and approved by MSHA on March 29, 2007 (MSHA, n.d.-a), the methods employed in the training courses for new and experienced miners are described. For instance, self-rescuer and respiratory device training for new miners is conducted via lecture, demonstrations, and hands-on training:

> Training will include instruction and demonstration in the use, care and maintenance of the rescue and respiratory devices used at the mine. Hands on training in the complete donning of all rescue devices used at the mine, which includes assuming the donning position, opening the device, activating the device, inserting the mouth, putting the nose clip on and transferring between all rescue devices used at the mine. (MSHA, n.d.-a, p. 4)

In contrast, the objectives covered in new miner training on roof control and ventilation plans are conducted via lecture and visual aids. The recent work of Burke et al. (2006) indicates that safety

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training methodology has important implications for the effectiveness of training in terms of trainee knowledge and performance. Considering methodology alone, their findings suggest that the more engaging methods used in the self-rescuer and respiratory device training will have a greater effect on miner safety knowledge and performance than will the less engaging methods used in roof control and ventilation plans training. Indeed, most repeated violations were in roof control and ventilation plans, the areas in which miners were trained via less engaging methods.

Yet other factors may play a significant role in training effectiveness; notably, the particular hazard or hazardous conditions necessitating safety training are likely important. Currently, however, a gap exists in both the scientific and practice literatures as to where and how to systematically incorporate information on the severity or seriousness of injury, illness, and fatality potential (i.e., event/exposure information) into worker safety training efforts. In terms of the example above, we do not know whether information regarding exposure to harmful substances relevant to the use of self-rescuer and respiratory devices suggests the need for a training methodology (i.e., level of training engagement) different from that for roof control and ventilation (i.e., where the event/exposure may relate to rock falls or explosions). This shortcoming is notable given that the nature of a hazard itself dictates what constitutes safe work behavior, including when individuals should take precautions against a threat (Weinstein, 2000). Moreover, all theories of health-protective behavior consider the nature of the hazard as important in the creation of motivation for self-protection (see Brewer et al., 2007; Kirscht, 1988; Prentice-Dunn & Rogers, 1986; Rogers, 1983; Ronis, 1992).

The study reported here is an investigation of two variables—hazardous events/exposures and safety training method—expected to interact so as to affect knowledge acquisition and workplace safety behavior. The aim of the study was to systematically examine expectations concerning how different types of objectively determined hazardous events/exposures lead to enhanced learning and behavioral outcomes when considered in the context of safety training programs that vary in terms of social and experiential activities (i.e., training method). Drawing on dialogical theories of experiential learning and behavior and the literature on risk perception, a central premise of this study was that the perception of risk associated with different types of events/exposures is socially and experientially engendered and that it creates motivation to learn and transfer acquired knowledge to the job. While the positive effects of more socially engaging workforce training and development interventions have been documented (see Burke et al., 2006; Taylor, Russ-Eft, & Chan, 2005), the relationships among safety training activities, objective event/exposure considerations, and learning and performance outcomes have been largely unarticulated and unexplored. Obtaining greater understanding of such associations is necessary for optimally designing safety interventions to ultimately achieve desired outcomes, including reduction in severe workplace injuries, illnesses, and fatalities. In this sense, our research is consistent with recent calls to provide insights into organizational behavior more generally by examining how social processes contribute to understanding organizational safety (e.g., see Barton & Sutcliffe, 2009; Turner & Gray, 2009).

To unfold our study, we initially discuss aspects of risk. This discussion provides definitions of key terms and indicates how perceptions of risk are socially constructed. Subsequently, we discuss social and experiential theories of learning and present hypotheses concerning the relative effectiveness of different methods of safety training. Thereafter, we discuss how and why social and experiential forms of training would be expected to enhance the motivation to learn and the motivation to transfer training to the job, especially in relation to the motivation to learn about and avoid hazardous events and exposures of an ominous nature. Here, we present hypotheses concerning interactive effects of safety training engagement and objective hazardous events/exposures in the explanation of safety training effectiveness for learning and behavior.

Aspects of Risk and Evidence of the Social Construction of Risk Perceptions

Over the past several decades, the literature on risk and risk perception has burgeoned, with studies drawing on a variety of disciplinary perspectives including political science, psychology, sociology, and safety engineering (e.g., Roberts, 1997; Slovic, 1997; Weinstein, 2000). In general, these literatures consider objective risk or danger as the likelihood of harm (i.e., injury or illness), with terms such as *probability*, *susceptibility*, and *vulnerability* used interchangeably. In the psychological literature, the concern is often the likelihood of harm when no action or an inappropriate action is taken (e.g., Weinstein, 2000). This aspect of risk is typically considered to be distinct from the magnitude of the negative outcome, or seriousness of harm if no action or an inappropriate action is taken (see Slovic, 1987, 1997). Perceptions of risk almost always include some assessment of the likelihood and seriousness of harm or injury potential. Given that workers have difficulty judging and interpreting probabilities (Brewer et al., 2007), the literature has generally found that perceptions of risk are more informative than objective indicators of risk in the prediction of behavioral outcomes (e.g., Morrow & Crum, 1998). Furthermore, a number of subgroup differences in risk perceptions have been documented, including differences between males and females (e.g., Barke, Jenkins-Smith, & Slovic, 1997; Greenberg & Schneider, 1995), between supervisors and line workers (e.g., Weyman & Clarke, 2003), and among national/cultural groups of workers in the same occupation (e.g., Perez-Floriano, 2001).

The fact that numerous subgroup differences in risk perceptions exist (including documented differences within the same culture, work setting, and occupation) demonstrates that the social construction of risk beliefs are context bound. In fact, Pidgeon (1991) and others (e.g., Fleming, Flin, Mearns, & Gordon, 1998; Perez-Floriano & Gonzalez, 2007; Rundmo, 1996) have discussed notions of safety subcultures and how these subcultures influence the perception of risk and, ultimately, work behavior. More recently, investigators have begun to explore social and experiential influences to better understand why different social groups (within the same organization) appear to have different interpretations of risk (e.g., Weyman & Clarke, 2003). While several studies have enhanced the understanding of how workers' experiences relate to risk perceptions, these investigations have generally neglected the literature on dialogical theories of learning and behavior (e.g., see Burke, Scheurer, & Meredith, 2007; Holman, 2000; Holman, Pavlica, & Thorpe, 1997). It is our belief that these latter learning perspectives offer considerable theoretical insight for understanding the social construction of not only learning but also risk perceptions and the motivation to learn. In the following section, we discuss how learning is expected to occur within social contexts. We then discuss how different training methods (i.e., forms of learning) would be expected to interact with hazardous events/exposures in the development of perceptions of risks and the motivation to learn.

Expectations From Dialogical Theories of Experiential Learning and Behavior

Closely aligned with action theories and social learning theory are the dialogical approaches to experiential learning. The dialogical approaches highlight the social and contextual nature of learning and view thought, in large part, as a structured product (in the sense of schemas and accounts) of the internalization of interpersonal action where language use plays an important role in this process (Cunliffe, 2002; Holman, 2000). Although dialogical theorists recognize the role of individual differences and external stimuli in shaping learning, their focus is on how learning about objects and entities is achieved through a temporal flow of contingent communication (Lave & Wenger, 1991; Schon, 1983; Weil & McGill, 1989), how individuals develop and sustain ways of verbally relating themselves to others, and how these communicative interactions enable them to make sense of their surroundings (Shotter, 1995; Wildemeersch, 1989). This point is particularly relevant to occupational safety where occupations or industry groups often develop their own jargon and symbols that convey what is important to members (Hansen, 1995). For instance, hazardous waste operations and emergency response trainees and trainers have a rather elaborate manner of communicating hazard information between each other (see Labor Institute, n.d.; Midwest Consortium for Hazardous Waste Worker Training, 1992) that involves numbers (e.g., 1 = explosives, 2 = gases), colors (e.g., yellow = reactivity hazard, white = special hazard), symbols (e.g., circle with flame = oxidizing hazard, propeller = radioactive hazard), and acronyms (e.g., IDLH = immediately dangerous to life and health, PEL = permissible exposure limit). These numbers, colors, symbols, and acronyms form an efficient means for both verbal and nonverbal communications among hazardous waste workers and emergency responders where the information communicated is frequently of high importance in relation to personal and public well-being.

The implication of a dialogical approach for the acquisition of safety-related work skills is that learning methods that are more engaging (in the sense of incorporating elements of action, dialogue, and reflection) will enhance knowledge acquisition relative to less engaging (passive, more programmed) means of knowledge development. In addition, more engaging methods of learning would also be expected to force trainees to infer causal and conditional relations between events and actions; in this way, such methods can alter trainees' ways of thinking and acting, particularly in novel situations. Active approaches to learning, where trainees are encouraged to learn from errors made, have been shown to be positively related to the learning and adaptive transfer of knowledge (e.g., see Bell & Kozlowski, 2008; Hacker, 2003; Keith & Frese, 2008). In effect, more engaging forms of learning are expected to not only improve knowledge acquisition in training contexts but also promote the transfer of knowledge to the job, especially in regard to the development of anticipatory thinking for avoiding accidents in both routine and nonroutine types of work.

Burke et al. (2006) reported a meta-analysis that examined the relative effectiveness of safety and health training methods according to the extent to which trainees participated in the learning process. Their meta-analytic findings were consistent with the theoretical argument that as the method of safety and health training becomes more engaging (going from passive, less engaging methods, such as lecture, to experiential-based, highly engaging methods, such as hands-on training that incorporates dialogue), the training becomes more effective, resulting in greater knowledge acquisition, a higher level of safety performance, and a greater reduction in accidents and injuries.

Recently, the conclusions reached in Burke et al. (2006) were brought into question by Robson et al. (2010), a team of researchers associated with Canada's Institute for Work & Health and the United States's National Institute for Occupational Safety and Health. On the basis of a highly selective qualitative review of 16 experimental studies, Robson et al. concluded that their review team found insufficient evidence of high engagement training having a greater impact on occupational health and safety-related behaviors compared to low/medium engagement training. The Robson et al. white paper is highly significant in terms of workplace safety and public health as it conveys, from a governmental perspective, what is believed to be the best scientific evidence on worker safety training effectiveness relative to training engagement.

Given the above theoretical arguments and empirical findings in the literature concerning the effect of highly engaging forms of training on learning and performance, the publication of 38 additional training studies since 2003, when Burke et al.'s (2006) data-collection efforts concluded, and the recent government study and policy statement by Robson et al. (2010) that questions the relative effectiveness of highly engaging safety training in comparison to low/moderate engagement safety training, we constructively replicated the investigation of Burke et al. in regard to the training outcomes that are most relevant to this investigation (i.e., changes in knowledge and safety performance associated with training). More specifically, we tested the following hypotheses:

> *Hypothesis 1:* In comparison to less engaging safety training, highly engaging safety training will be associated with greater knowledge acquisition.

> *Hypothesis 2:* In comparison to less engaging safety training, highly engaging safety training will be associated with higher safety performance.

The Social Construction of Dread

Arguments within dialogical theories of experiential learning also provide a theoretical basis for understanding how safety-relevant motivations (i.e., the motivation to learn and the motivation to transfer acquired knowledge) emerge within safety training contexts. A key argument within dialogical theories of learning is that through communication processes and social interaction, one understands properties of objects and entities, including the risks associated with different types of hazardous events and exposures. Furthermore, communication and social interaction in highly engaging forms of safety training (e.g., hands-on and experiential based) typically provide rich, detailed information about hazardous events and exposures and frequently demonstrate the health consequences of exposures. In contrast, less engaging forms of training, such as lecture and programmed learning, present limited opportunities for social interaction or action, dialogue, and reflection in relation to hazard exposures.

When hazardous events and exposures are of an ominous nature (e.g., fires and explosions; exposure to toxic chemicals, radiation, or HIV; see Mullet, Cuitad, & Riviere-Shafighi, 2004), the action, dialogue, and considerable reflection that take place in the highly engaging forms of training would be expected to engender dread, a realization of the dangers in the work context and associated negative affect. This realization of injury/illness vulnerability and the experienced feelings or affect should play a primary role in motivating individuals to learn about how to avoid exposure to such hazards. The arguments that cognitions and affect play direct and primary roles in motivating learning and behavior are not new (e.g., see Tennyson & Jorczak, 2008, for a discussion of the interactive cognitive complexity learning model). In particular, scholars across disciplines have theorized and found empirical support for the idea that unpleasant feelings can motivate people to act in ways that they think will minimize such feelings or avoid the negative consequences associated with inaction (e.g., see Baumeister, Vohs, DeWall, & Zhang, 2007; Beer, Heerey, Keltner, Scabini, & Knight, 2003; Schwartz & Clore, 1988; Slovic & Peters, 2006; Sweeny & Shepperd, 2007; Warren & Smith-Crowe, 2008). However, while we would expect the unpleasant feelings and thoughts in relation to ominous hazards to be especially at the forefront of workers' subjective experiences in highly engaging training, we do not expect such thoughts and reactions to necessarily divert attentional resources away from knowledge acquisition. The active approach to learning within highly engaging forms of training should assist with the regulation of negative emotions by focusing attention on the means to cope with or avoid the danger. Unlike heightened levels of anxiety that have been shown to negatively relate to the motivation to learn in general training contexts (see Colquitt, LePine, & Noe, 2000), the dread factor would be expected to enhance the motivation to learn within highly engaging forms of safety training and with respect to hazards of an ominous nature. Thus, we would expect an increase in training engagement to have a substantial effect on training outcomes when hazardous event/exposure does have severe injury or illness potential.

In contrast, when hazardous events and exposures do not have severe injury potential (e.g., contact with objects and equipment, excessive physical effort, or repetitive bodily motion), we would not expect the dread factor to be produced in highly engaging forms of training. Elevated levels of affect would not necessarily be expected to occur in relation to actively learning about these types of hazards. Similarly, while less engaging forms of safety training would be expected to inform trainees of the nature of particular hazards, these types of training would also not be expected to engender affective reactions in relation to possible exposure to hazards of any nature. That is, the usual limited opportunities for social interaction within less engaging training would be expected to lessen the social construction of motivation to learn about the hazardous events and exposures irrespective of the potential severity of the event/exposure and, consequently, lessen the motivation to transfer this knowledge to the work setting. Thus, we would expect only modestly improved training outcomes in highly engaging as compared to less engaging safety training when hazardous event/exposure does not have severe injury or illness potential.

Together, the above conceptual arguments undergird the following hypotheses:

> *Hypothesis 3:* Hazardous event/exposure severity moderates the relationship between training engagement and knowledge acquisition, such that the relationship is stronger for events/exposures that are more likely to produce or inflict severe injury, illness, or death in comparison to events/exposures that are less likely to produce or inflict severe injury, illness, or death.

> *Hypothesis 4:* Hazardous event/exposure severity moderates the relationship between training engagement and safety performance, such that the relationship is stronger for events/exposures that are more likely to produce or inflict severe injury, illness, or death in comparison to events/exposures that are less likely to produce or inflict severe injury, illness, or death.

Method

Search and Inclusion Criteria

Initially, potentially relevant articles published between 1971 (immediately following the passage of the 1970 U.S. Occupational Safety and Health Act) and December 2008 were identified via searches of electronic databases (including PubMed, PsycINFO, and Google Scholar) using the following key words: *health and safety training, health training intervention, safety training intervention, safety training, health training, error management and intervention, error prevention and intervention, safety intervention, health intervention, occupational health and safety, needlestick, NIOSH and intervention,* and *OSHA and intervention.* We also manually searched each of the following journals: *Accident Analysis & Prevention, American Journal of Industrial Medicine, American Journal of Infection Control, American Journal of Public Health, Ergonomics, Journal of Applied Psychology, Journal of Occupational and Environmental Hygiene, Journal of Occupational and Environmental Medicine, Journal of Safety Research, Infection Control in Hospital Epidemiology, Personnel Psychology, Safety Science, Scandinavian Journal of Work,* and *Environment and Health.* Furthermore, the reference lists of each qualitative and quantitative review found were searched to identify any relevant articles cited in these documents. Through this process, we identified over 800 potentially relevant articles reporting safety training research in primarily the health care, agriculture, manufacturing, and construction industries.

Studies were included in the analysis if they met certain criteria. First, studies had to be quasi-experimental or experimental studies, meaning that they had to involve an experimental intervention and observation of its effects. Second, participants in the studies could be of any age but had to be from a working population (the sample included mostly adults and some youth workers). Third, the following elements needed to be clearly identified: the method of training (i.e., high, moderate, or low levels of engagement), the nature of the workplace hazard (e.g., falls, contact with objects, or exposure to dangerous substances), and the dependent variables (safety knowledge and safety performance). Fourth, studies had to be conducted at the individual level of analysis such that the intervention focused on improving individual workers' safety knowledge and performance.

Coding of Studies

Having identified the studies to be included, we coded the studies to address our main research questions. Our primary interests in this investigation were (a) to examine the previously noted effect of training method (i.e., level of engagement) on workers' safety-related knowledge and performance (see Burke et al., 2006) and (b) to determine whether the severity of the hazardous event/exposure in workers' environments moderates the relationships between level of training engagement and learning and performance outcomes. Each study was coded for training method, safety-related knowledge, and performance by two independent coders; discrepancies were resolved by a third consensus coder. Each study was coded for hazardous event/exposure by two different independent coders; discrepancies were resolved by the same third consensus coder. In this way, four coders independently coded each study, and the hazard data were coded independently from the rest of the data.

To address the first question of interest, we recorded several pieces of information from our primary studies. First, we recorded the method of training used in each primary study. Specifically, following Burke et al.'s (2006) categorization, the method of training was initially divided into three groups: least engaging (e.g., lectures, films, reading materials, and video-based training), moderately engaging (e.g., programmed or computer-interface instruction with feedback), and most engaging (e.g., behavioral modeling, simulation, and hands-on training). If studies reported using more than one method of training, the most engaging level of training received by all participants was recorded. Because tests of hypotheses in this investigation focused on distinctions between the highly engaging forms of training and less engaging training, the latter of which does not include opportunities for action, dialogue, and considerable reflection (i.e., Burke et al.'s, 2006, least and moderately engaging methods of safety training), we collapsed the least engaging and moderately engaging categories into what we refer to as the less engaging methods.

Second, changes in participants' safety-related outcomes, our dependent variables, were coded. The dependent variables were safety-related knowledge acquisition (i.e., differences in test performance or self-reports between the target group and either a control group or a baseline measure) and behavioral safety performance (i.e., differences in observed or self-reported behaviors between the target group and either a control group or a baseline measure). In the cases where primary studies reported effects on both dependent variables, we coded both effects separately and included the effects in separate meta-analyses; no sample was represented more than once within a given meta-analysis. Also, when available, the reliability of the dependent variables was recorded (internal consistency reliability estimates for knowledge measures and, typically, interrater reliability estimates for performance measures).

Third, to address our second research question, we coded hazards in the workplace. We began by using the U.S. Bureau of Labor Statistics' Occupational Injury and Illness Classification System (OIICS) to sort hazards into seven categories that describe the manner in which an injury or illness is produced or inflicted by the source of the injury or illness (Biddle, 1998). An eighth category is reserved for other hazards that do not fit within the system. Within the OIICS, the seven categories are hierarchically arranged to reflect the increasing potential for severe illness, injury, or death due to the hazardous event or exposure: contact with objects (Category 1), falls (Category 2), bodily reaction and exertion (Category 3), exposure to harmful substances and environments (Category 4), transportation accidents (Category 5), fires and explosions (Category 6), and assaults and violent acts (Category 7). This hierarchical ordering of events/exposures roughly corresponds to the ordering of occupations and industries in terms of the number of nonfatal and fatal injuries within the Bureau of Labor Statistics annual workforce injury and illness reports. In this sense, this hazard scoring system does reflect, to a degree, the objective likelihood of injury or illness in terms of nonfatal and fatal injuries per thousand workers when an event/exposure occurs. When studies reported multiple hazards, we recorded the highest ranked event/exposure. In studies that did not explicitly state the type of hazard, we inferred the nature of the hazard based upon the content of the training intervention.

Furthermore, the Bureau of Labor Statistics' OIICS considers events involving transportation accidents, fires and explosions, and assaults and violent acts (i.e., Categories 5, 6, and 7) as taking precedence in terms of severity over all other categories. As discussed above, these types of events/exposures would be expected to, in combination with highly engaging training, induce dread and motivation to learn. In addition, Category 4, which concerns exposures to harmful substances (e.g., toxic chemicals, radiation) and environments (e.g., depletion of oxygen in enclosed, restricted, or confined spaces), would also be considered to be more ominous in nature. The remaining categories, consistent with the OIICS classification as hierarchically lower in terms of the seriousness (and likelihood) of event/exposure, would not necessarily be considered ominous in nature. Therefore, for the purposes of our analyses, we scored hazards within Categories 4, 5, 6, and 7 as one (high hazards) and hazards within Categories 1, 2, and 3 as zero (low hazards). In effect, this dichotomy allowed us to highlight the point at which the consequences of hazards go from typically being less severe (e.g., slips, overexertion, and repetitive motion within the third most severe hazard category: bodily reaction and exertion) to being more severe (e.g., the contraction of hepatitis or HIV resulting from needle sticks within the fourth most severe hazard category: exposure to harmful substances and environments). Notably, this scoring of hazardous event/exposure in terms of low and high severity roughly corresponds to splitting the Bureau of Labor's ranking system at the midpoint of the OCIIS hierarchy. While we adopted this system for the scoring of workplace hazards, we recognize that fatalities can and do occur in relation to hazards classified as low hazards. Our scoring system and that of the OCIIS reflect the typical level of severity and likelihood associated with a hazardous exposure or event (e.g., most slips and falls are nonfatal).

For level of engagement in safety training, we scored safety training as one (highly engaging training) or zero (less engaging training) for tests of all hypotheses This scoring was dictated by our theoretical arguments in relation to the dread factor being engendered only within the highly engaging methods of training that encourage action, dialogue, and reflection (i.e., behavioral modeling, hands-on, and simulation-based training) and with respect to hazards of an ominous nature (i.e., those within the top four OCIIS categories).

Intercoder agreement was very high (at least 90%) for the coding of both training intervention and hazardous event/exposure, and any disagreements were resolved by a third coder. In this manner, a consensus code was obtained for both the level of engagement of safety training and the nature of the hazardous event/exposure.

Statistical Analyses

To compute the effect of safety training for knowledge or safety performance, *d* statistics were computed using equations from Shadish, Robinson, and Lu (1999) and Lipsey and Wilson (2001). Using information provided in the primary studies, the majority of studies provided enough information to perform straightforward *d*-statistic calculations. Several studies, however, reported results in proportions or percentages or with respect to analysis of variance designs. For instance, in the case of proportions, we estimated *d* statistics via arcsine transformations (see Lipsey & Wilson, 2001). Importantly, for both single-group and independent-groups designs, we computed effect sizes to ensure that all effects were in the same raw-score effect-size metric (see Morris, 2008; Morris & DeShon, 2002). Given minimal differences in mean effects between single-group and independent-groups designs within the domain of workplace safety training (see Burke et al., 2006, for a detailed comparison of meta-analytic results for within- vs. between-subjects designs), we did not distinguish between study design features for the purposes of testing the present hypotheses. We note that in some cases, we computed effects different from the original study design due to insufficient reporting of data or data that would produce out-of-bound effect-size estimates. For instance, while Peterson, McGlothlin, and Blue's (2004) study was based on pre–post design with a control group, the authors did not report findings for the control group, which necessitated treating this study as a within-subjects design.

The meta-analysis procedure used was Raju, Burke, Normand, and Langlois's ([RBNL] 1991) method. The RBNL method was chosen because of its ability to appropriately correct for unreliability in the measure of the dependent variable whenever a primary study reliability estimate was available and in whatever proportion reliabilities were available within a meta-analytic distribution of effects. Moreover, the RBNL meta-analytic procedure was chosen for its unique ability to estimate standard errors for individually corrected correlations with and without sample-based dependent variable reliabilities. To correct observed training effects when a primary study did not report a reliability estimate, we relied on the overall, sample-size weighted average reliability estimates for knowledge and performance measures of .73 and .88, respectively. In addition, the RBNL procedures permit the estimation of confidence intervals around mean corrected effects based on a random effects estimate of the standard error of the mean corrected effect. Due to statistical advantages of working with correlations (i.e., asymptotic estimates of standard errors for individually corrected effects can be made for correlation coefficients and appropriately defined standard errors can be computed for mean corrected correlations; see Burke & Landis, 2003; Raju & Brand, 2003), we converted observed *d* statistics to correlation coefficients before conducting the meta-analyses. For the purposes of this article, we report results in correlation form and, where appropriate in the Discussion section, we discuss these effects in terms of standardized differences (i.e., *d* statistics).

Given the variances in the effect sizes in each of the eight Hazard Level $\times$ Training Method distributions and noting the potential for outliers to have a large effect on these variances, we also conducted outlier analyses. Specifically, we used the sample-adjusted meta-analytic deviancy (SAMD; Huffcutt & Arthur, 1995) statistic to check for outliers in these distributions. Given potential bias in results based on the sole use of the SAMD statistic (see Beal, Corey, & Dunlap, 2002), we also examined how close the SAMD values were in determining whether an effect was a true outlier. In total, five studies were identified as outliers, and each outlier was from a different combination of training engagement and hazard level (i.e., one outlier was identified in each of five of the eight combinations of training engagement, hazard level, and safety-related outcome). On the basis of the inclusion criteria and the outlier analyses, we included a total of 113 primary studies that had 147 independent samples and 166 safety training effects, with a total sample size of 24,694 from 16 countries. Notably, the number of studies included in this investigation for tests of Hypotheses 1 and 2 represents a 45% increase over the number of studies with safety knowledge and safety performance as dependent measures included in Burke et al. (2006).

For tests of Hypotheses 1 and 2, we compared estimated mean effects for less and highly engaging methods of safety training for knowledge and performance, respectively. We performed these tests to evaluate the consistency of our findings with the earlier reported meta-analysis by Burke et al. (2006). For tests of Hypotheses 3 and 4, we tested for the expected interaction within a meta-analytic context using the common subgrouping technique (see Hunter & Schmidt, 2004). This moderator detection technique is useful when considering dichotomous moderators and when independent variables are uncorrelated (see Steel & Kammeyer-Mueller, 2002). In this regard, we note that the phi coefficient between training engagement and hazardous event/exposure was $-.13$ and statistically nonsignificant. When subgrouping studies, we first classified training effects into low and high hazardous event/exposure separately for knowledge and performance effects. Then, we computed the mean training effect (i.e., mean corrected correlation) for less engaging training and for highly engaging training within each hazard condition. When comparing mean effects for less and highly engaging training within a hazard condition, we examined whether the respective 95% confidence intervals (based on the random effects estimate of the standard error for the mean corrected correlation; see Burke & Landis, 2003) around the estimated mean effects overlapped. Importantly, we note that the standard error for the mean corrected effect included information on the standard errors for individually corrected effects within a distribution of effects, as well as information on the between-study variance in effects within that distribution.

Results

Table 1 lists the studies we included and coded in this meta-analysis along with some descriptive information.

Table 2 presents a summary of the meta-analytic results examining the effects of safety training method on knowledge acquisition and safety performance. Among the results presented are the estimated mean correlations corrected for dependent variable unreliability (M_ρ), the 95% confidence interval around the estimated mean (95% CI M_ρ), and the estimated variance of the effects (V_ρ). We also present parallel results based on uncorrected correlations in Table 2. As both sets of results are analogous and consistent with each other, we refer to the corrected (disattenuated) results in testing the hypotheses.

According to Hypothesis 1, highly engaging training will be associated with greater safety knowledge acquisition, compared to less engaging training. As shown in Table 2, the mean training effect size, M_ρ, is greater when training method is highly engaging than when training method is less engaging (M_ρ = .61 for the highly engaging methods compared to M_ρ = .36 for the less engaging methods). The nonoverlapping 95% confidence intervals around M_ρ suggest that highly engaging methods are much more effective than the less engaging methods in increasing safety knowledge acquisition. Thus, Hypothesis 1 is supported.

In addition, the results also provide support for Hypothesis 2. Highly engaging safety training is associated with a higher level of safety performance compared to less engaging training. With reference to Table 2, the average training effect size is greater when training method is highly engaging than when training method is less engaging (M_ρ = .42 for the highly engaging methods compared to M_ρ = .22 for the less engaging methods). As with safety knowledge, the nonoverlapping 95% confidence intervals around M_ρ suggest that highly engaging methods are much more effective than the less engaging methods in improving safety performance.

Table 3 presents a summary of the meta-analytic results examining the interaction between training method and hazardous event/exposure. These results are consistent with Hypotheses 3 and 4. Hypothesis 3 predicts that the level of hazardous event/exposure in the work context will moderate the relationship between training engagement and knowledge acquisition, such that the relationships between level of engagement and training effectiveness will be stronger under high hazard conditions (i.e., when events/exposures have a greater potential of producing severe injury, illness, or death) than under low hazard conditions (i.e., when events and exposures in the occupational context are less likely to result in serious injury, illness, or death). In other words, in terms of safety knowledge acquisition, Hypothesis 3 predicts that the effectiveness of highly engaging training methods relative to the less engaging training methods will be amplified under high hazard conditions, as opposed to the low hazard conditions.

For Hypothesis 3, the mean training effect size for the less engaging methods (M_ρ = .53) is slightly greater than the mean effect for highly engaging methods (M_ρ = .47) under the low hazard condition. Notably, the mean effect associated with the highly engaging methods (.47) is part of the 95% confidence interval around the mean effect associated with the less engaging methods, that is, [.37, .70]. Similarly, the mean effect of the less engaging methods (.53) falls within the 95% confidence interval around the mean effect associated with the highly engaging methods, [.33, .61]. Thus, although the mean effect of the less engaging methods is numerically greater than that of the more engaging methods under the low hazard condition, there is an insufficient statistical basis to conclude that the mean effect of .47 is significantly different from the mean effect of .53. Whereas we expected to see a modest increase in training effectiveness across levels of engagement within the low hazard condition, we did not see such an increase.

On the other hand, under the high hazard condition, the mean training effect for highly engaging methods (M_ρ = .65) is significantly higher than the mean training effect for less engaging methods (M_ρ = .36), as evidenced by the nonoverlapping 95% confidence intervals ([.31, .41] for the less engaging methods and [.58, .71] for the highly engaging methods). Collectively, these pieces of evidence suggest that in terms of increasing safety knowledge, the effectiveness of highly engaging training methods relative to the less engaging training methods is more pronounced under conditions of high hazards than under conditions of low hazards. Thus, the meta-analytic data are consistent with Hypothesis 3.

Analogously, Hypothesis 4 predicts that in terms of safety performance, the effectiveness of highly engaging training methods relative to the less engaging training methods will be amplified under high hazard conditions as opposed to the low hazard conditions. With reference to the safety performance meta-analytic results in Table 3, the mean training effect size for the less engaging methods (M_ρ = .31) is essentially the same as the mean effect for highly engaging methods (M_ρ = .32) under the low hazard condition. The mean effect associated with the less engaging methods falls within the 95% confidence interval, [.23, .41], around the mean effect for the highly engaging methods. Likewise, the mean effect associated with the highly engaging methods falls within the 95% confidence interval for the less engaging methods, [.24, .37]. These confidence intervals suggest that the two mean effects, .31 and .32, are not significantly different from each other. Here, too, we expected to see a modest increase in training effectiveness across levels of engagement within the low hazard condition; instead, we found no significant increase.

In contrast, under the high hazard conditions, the mean training effect for highly engaging methods (M_ρ = .46) is significantly higher than the mean training effect for less engaging methods (M_ρ = .20), as evidenced by the nonoverlapping 95% confidence intervals ([.16, .25] for the less engaging methods and [.39, .53] for the highly engaging methods). Notably, the confidence interval around the mean effect of .46 for highly engaging training is outside (i.e., above) the confidence intervals for all other mean effects concerning safety performance. Taken together, these pieces of evidence suggest that in terms of enhancing safety performance, the effectiveness of highly engaging training methods relative to the less engaging training methods is more pronounced under conditions of high hazards than under conditions of low hazards. Hence, the meta-analytic evidence is consistent with Hypothesis 4.

Discussion

Our hypotheses for this investigation concern two issues: (a) the extent to which the level of training engagement in safety training influences knowledge acquisition and safety performance, and (b)

Table 1
Studies Included in the Meta-Analysis

Study	N	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
Alavosius & Sulzer-Azaroff (1986)	6	USA	Pre–post, w/o control group	Direct care staff workers (for physically handicapped clients)	Written and verbal feedback	Bodily reaction and exertion	.89	Performance
Albers et al. (1997)	34	USA	Posttest only, comparison	Carpenter apprentices	Lecture, discussion, feedback, hands-on practice	Bodily reaction and exertion		Knowledge
Al-Hemoud & Al-Asfoor (2006)	21	Kuwait	Pre–post, w/control group	Industrial engineers	Feedback	Bodily reaction and exertion	.89	Performance
Anger et al. (2006)	51	USA	Pre–post, w/o control group	Agricultural workforce (orchard workers)	Computer-based programmed instruction	Falls	.90	Knowledge & performance
Arcury, Quandt, Austin, Preisser, & Cabrera (1999)	270	USA	Posttest only, comparison	Farm workers	Lecture, video	Exposure to harmful substances or environments		Knowledge & performance
Askari & Mehring (1992)	100	USA	Pre–post, w/o control group	Health care workers	Feedback	Exposure to harmful substances or environments		Knowledge
Azizi et al. (2000)	72	Israel	Pre–post, w/control group	Outdoor water resources workers	Lecture, slide presentation, brochures	Exposure to harmful substances or environments		Performance
Baker (1998)	6	USA	Pre–post, w/o control group	Direct care staff workers for clients with physical or mental disabilities	Videotaped segments and vignettes, discussion, hands-on/simulation training, feedback	Exposure to harmful substances or environments	1.00	Performance
Barnett et al. (1984)	110	USA	Pre–post, w/o control group	Farm workers	Slideshow presentation, brochure	Exposure to harmful substances or environments		Knowledge
Bosco & Wagner (1988)	209	USA	Posttest only, comparison	Auto manufacturing workers	Lecture, videotape, computer-based training	Exposure to harmful substances or environments	.66	Knowledge
Brnich, Derick, Mallett, & Vaught (2002)	178	USA	Pre–post, w/o control group	Miners	Lecture, discussion, video presentation	Fires and explosions		Knowledge
Calabro, Weltge, Parnell, Kouzekanani, & Ramirez (1998)	172	USA	Pre–post, w/o control group	Medical students	Lecture, discussion, behavioral modeling (role-play), case studies	Exposure to harmful substances or environments		Knowledge
Caparaz, Rice, Graumlich, Radike, & Morawetz (1990)	9	USA	Pre–post, w/o control group	Foundry/maintenance workers	Lecture, small group discussion, workbook exercises	Exposure to harmful substances or environments		Knowledge
Carlton (1987)	30	USA	Posttest only, comparison	Food service employees	Behavioral modeling, feedback	Bodily reaction and exertion	.96	Knowledge
	30	USA	Posttest only, comparison	Food service employees	Behavioral modeling, feedback	Bodily reaction and exertion	.96	Performance
Carrabba, Field, Tormoehlen, & Talbert (2000)	212	USA	Posttest only, comparison	4-H tractor program members	Exercise, feedback	Transportation accidents		Performance
Chaffin, Gallay, Wooley, & Kuciemba (1986)	26	USA	Pre–post, w/o control group	Warehouse employees	Lecture, discussion, video	Bodily reaction and exertion		Performance

(*table continues*)

Table 1 (*continued*)

Study	*N*	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
Chhokar & Wallin (1984)	58	USA	Pre–post, w/o control group	Heat exchanger manufacturing and repairing plant workers	Slideshow, feedback, goal-setting	Exposure to harmful substances or environments	.93	Performance
Cohen & Jensen (1984)	24	USA	Pre–post, w/control group	Lift truck operators (Warehouse 1)	Behavioral modeling	Transportation accidents	.90	Performance
	48	USA	Pre–post, w/control group	Lift truck operators (Warehouse 2)	Behavioral modeling	Transportation accidents		Performance
Cole et al. (1988)	36	USA	Pre–post, w/control group	Coal miners	Task demonstration, hands-on training	Fires and explosions		Performance
Coutts, Graham, Braun, & Wells (2000)	33	Canada	Pre–post, w/o control group	Bar staff	Lecture, discussion, video, case study, exercises, role playing	Assaults and violent acts		Knowledge
Curwick, Reeb-Whitaker, & Connon (2003)	30	USA	Pre–post, w/o control group	Various manufacturing-related occupations	Hands-on (with simulation training)	Bodily reaction and exertion		Knowledge
Daltroy et al. (1993)	178	USA	Posttest only, comparison	Postal workers	Lecture, discussion, slides, hands-on training, feedback on the job	Bodily reaction and exertion		Knowledge
DeVries, Burnette, & Redmon (1991)	4	USA	Pre–post, w/o control group	Nursing	Feedback	Exposure to harmful substances or environments	.98	Performance
Dortch & Trombly (1990)	12	USA	Pre–post, w/control group	Electronic assembly workers	Lecture, discussion, handout	Bodily reaction and exertion	.83	Performance
	11	USA	Pre–post, w/control group	Electronic assembly workers	Lecture, discussion, handout, simulation	Bodily reaction and exertion	.83	Performance
Eckerman et al. (2002)	60	USA	Posttest only, comparison	Various occupations	Computer-based programmed instruction	Exposure to harmful substance or environments		Knowledge
Eckerman et al. (2004)	73	USA	Pre–post, w/o control group	Food service workers at a hospital	Behavioral modeling	Exposure to harmful substances or environments		Knowledge & performance
Engels, Van der Gulden, Senden, Kolk, & Binkhorst (1998)	18	Netherlands	Pre–post, w/control group	Nursing	Feedback	Bodily reaction and exertion		Performance
Ewigman, Kivlahan, Hosokawa, & Horman (1990)	94	USA	Pre–post, w/o control group	Firefighters	Lecture, discussion, handouts, posters, video	Exposure to harmful substances or environments		Knowledge & performance
Finch & Daniel (2005)	276	USA	Pre–post, w/o control group	Emergency food relief organization workers	Lecture/discussion	Exposure to harmful substances or environments		Knowledge
Forst et al. (2004)	239	USA	Pre–post, w/control group	Community health workers	Hands-on (with simulation training)	Exposure to harmful substances or environments		Performance

Table 1 (*continued*)

Study	*N*	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
Fox & Sulzer-Azaroff (1987)	12	USA	Pre–post, w/o control group	Paper mill foremen	Feedback	Bodily reaction and exertion	.97	Performance
Froom, Kristal-Boneh, Melamed, Shalom, & Ribak (1998)	167	Israel	Pre–post, w/control group	Medical students	Lecture	Exposure to harmful substances or environments		Performance
Gagnon (2003)	10	Canada	Pre–post, w/o control group	Physical education students doing manual handling	Hands-on (with simulation training)	Bodily reaction and exertion	.80	Performance
Gerbert et al. (1988)	99	USA	Pre–post, w/control group	Dentists	Bulletins, discussion, feedback	Exposure to harmful substances or environments		Knowledge & performance
Girgis, Sanson, & Watson (1994)	142	Australia	Pre–post, w/control group	Electrical company outdoor workers	Lecture, discussion, pamphlets	Exposure to harmful substances or environments		Knowledge & performance
Goldrick (1989)	78	USA	Pre–post, w/o control group	Nurses	Computer-based programmed instruction	Exposure to harmful substances or environments	.60	Knowledge
	66	USA	Pre–post, w/o control group	Nurses	Lecture	Exposure to harmful substances or environments	.60	Knowledge
Greene, DeJoy, & Olejnik (2005)	82	USA	Pre–post, w/control group	University employees (computer users)	Feedback	Bodily reaction and exertion		Performance
Harrington & Walker (2002)	20	USA	Pre–post, w/o control group	Administrative staff at life-care community facility	Instructor-led lecture and discussion (fire behavior module)	Fires and explosions	.79	Knowledge
	42	USA	Pre–post, w/control group	Administrative staff at life-care community facility	Computer-based programmed instruction (fire hazard module)	Fires and explosions	.72	Knowledge
Harrington & Walker (2003)	37	USA	Pre–post, w/o control group	Nursing facility staff	Computer-based programmed instruction (need for fire safety module)	Fires and explosions		Knowledge
	31	USA	Pre–post, w/o control group	Nursing facility staff	Instructor-led lecture and discussion (need for fire safety module)	Fires and explosions		Knowledge
	44	USA	Pre–post, w/o control group	Nursing facility staff	Computer-based programmed instruction (human factors in fire module)	Fires and explosions		Knowledge
	38	USA	Pre–post, w/o control group	Nursing facility staff	Instructor-led lecture and discussion (human factors in fire module)	Fires and explosions		Knowledge
	40	USA	Pre–post, w/o control group	Nursing facility staff	Computer-based programmed instruction (fire emergency planning module)	Fires and explosions		Knowledge
	36	USA	Pre–post, w/o control group	Nursing facility staff	Instructor-led lecture and discussion (fire emergency planning module)	Fires and explosions		Knowledge
	31	USA	Pre–post, w/o control group	Nursing facility staff	Computer-based programmed instruction (fire safety devices module)	Fires and explosions		Knowledge

(*table continues*)

Table 1 (*continued*)

Study	N	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
	32	USA	Pre–post, w/o control group	Nursing facility staff	Instructor-led lecture and discussion (fire safety devices module)	Fires and explosions		Knowledge
Harrington & Walker (2004)	670	USA	Pre–post, w/o control group	Staff from a life-care community/nursing community	Computer-based programmed instruction	Fires and explosions	.76	Knowledge
	624	USA	Pre–post, w/o control group	Staff from a life-care community/nursing community	Instructor-led lecture and discussion	Fires and explosions		Knowledge
Held, Mygind, Wolff, Gynterlberg, & Agner (2002)	287	Denmark	Pre–post, w/control group	Wetwork employees	Behavioral modeling	Exposure to harmful substances or environments		Performance
Hickman & Geller (2003)	15	USA	Pre–post, w/control group	Miners	Feedback	Exposure to harmful substances or environments	.97	Knowledge
Hong, Ronis, Lusk, & Kee (2006)	403	USA	Pre–post, w/control group	Engineers on construction sites	Computer-based programmed instruction	Exposure to harmful substances or environments		Performance
Hopkins (1984)	6	USA	Pre–post, w/o control group	Plastics manufacturing plant workers	Feedback	Exposure to harmful substances or environments	.99	Performance
Huang et al. (2002)	98	China	Pre–post, w/control group	Hospital nurses	Behavioral modeling	Exposure to harmful substances or environments		Knowledge & performance
Hultman, Nordin, & Ortengren (1984)	6	Sweden	Pre–post, w/o control group	Janitors	Hands-on training (simulation), feedback	Bodily reaction and exertion		Performance
Hurlebaus & Link (1997)	22	USA	Pre–post, w/o control group	Nurses	Discussion, handouts, behavioral modeling, hands-on training (supervised practice)	Assaults and violent acts		Knowledge
Inman & Blanciforti (2002)	106	USA	Pre–post, w/control group	Carpenters	Lecture, reminders, posters	Contact with objects		Performance
Jensen & Friche (2007)	208	Denmark	Pre–post, w/o control group	Floor layers	Hands-on (with simulation training)	Bodily reaction and exertion		Performance
Johnsson, Carlosson, & Lagerstrom (2002)	49	Sweden	Posttest only, comparison	Hospital and home care personnel	Feedback	Bodily reaction and exertion	.91	Performance
Kerrigan et al. (2006)	206	Dominican Republic	Pre–post, w/o control group	Sex workers (Santo Domingo)	Lecture/discussion	Exposure to harmful substances or environments		Performance
	200	Dominican Republic	Pre–post, w/o control group	Sex workers (Puerto Plata)	Lecture/discussion	Exposure to harmful substances or environments		Performance
Knobloch & Broste (1998)	691	USA	Pre–post, w/control group	Agricultural workers	Lecture, discussion, videos, behavioral prompts (e.g., direct mailings), feedback, hands-on training (supervised practice)	Exposure to harmful substances or environments		Performance

Table 1 (*continued*)

Study	*N*	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
Komaki, Barwick, & Scott (1978)	22	USA	Pre–post, w/o control group	Bakery workers (wrapping department)	Slideshow, discussion, feedback	Contact with objects	.99	Performance
	16	USA	Pre–post, w/o control group	Bakery workers (makeup department)	Slideshow, discussion, feedback	Contact with objects	.97	Performance
Komaki, Heinzmann, & Lawson (1980)	7	USA	Pre–post, w/o control group	Vehicle maintenance workers (sweeper repair section)	Slideshow, discussion, feedback	Contact with objects	.95	Performance
	37	USA	Pre–post, w/o control group	Vehicle maintenance workers (preventive maintenance section)	Slideshow, discussion, feedback	Contact with objects	.95	Performance
	7	USA	Pre–post, w/o control group	Vehicle maintenance workers (light equipment repair section)	Slideshow, discussion, feedback	Contact with objects	.95	Performance
	4	USA	Pre–post, w/o control group	Vehicle maintenance workers (heavy equipment repair section)	Slideshow, discussion, feedback	Contact with objects	.95	Performance
Kowalski-Trakofler & Barrett (2003)	82	USA	Posttest only, comparison	Mining workers	Lecture/discussion	Contact with objects		Knowledge
Leslie & Adams (1973)	50	USA	Pre–post, w/control group	Unskilled workers	Lecture, audiovisual presentation, discussion	Contact with objects		Performance
Ludwig & Geller (1991)	60	USA	Posttest only, comparison	Pizza deliverers	Discussion, store-based verbal reminders	Transportation accidents	.90	Performance
Ludwig & Geller (1997)	29	USA	Pre–post, w/control group	Pizza deliverers	Discussion, participative goal setting, feedback	Transportation accidents	.86	Performance
	20	USA	Pre–post, w/control group	Pizza deliverers	Lecture, (assigned) goal setting, feedback	Transportation accidents	.86	Performance
Lueveswanij, Nittayananta, & Robison (2000)	139	Thailand	Pre–post, w/control group	Oral health personnel	Lectures, videos, interviews with infected persons, behavioral demonstrations, role-plays	Exposure to harmful substances or environments		Knowledge
Lusk et al. (2003)	878	USA	Pre–post, w/control group	Automotive factory workers	Computer-based programmed instruction	Exposure to harmful substances or environments	.89	Performance
Luskin, Somers, Wooding, & Levenstein (1992)	20	USA	Pre–post, w/o control group	Hazardous waste site workers, emergency responders	Lecture, group discussion, hands-on, participatory exercises, simulation (mock incident)	Exposure to harmful substances or environments		Knowledge
P. Lynch et al. (1990)	717	USA	Pre–post, w/o control group	Hospital staff	Slide presentation, discussion	Exposure to harmful substances or environments	.80	Knowledge
	29	USA	Pre–post, w/o control group	Medical personnel	Slide presentation, discussion	Exposure to harmful substances or environments		Performance
	201	USA	Pre–post, w/o control group	Nursing personnel	Slide presentation, discussion	Exposure to harmful substances or environments		Performance

(*table continues*)

Table 1 (*continued*)

Study	N	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
R. M. Lynch & Freund (2000)	104	USA	Pre–post, w/control group	Nursing, patient care	35-mm slideshow, hands-on equipment training, feedback	Bodily reaction and exertion		Knowledge & performance
Ma et al. (2002)	815	China	Pre–post, w/o control group	Sex workers	Lecture/discussion	Exposure to harmful substances or environments		Knowledge & performance
Marsh & Kendrick (1998)	58	UK	Pre–post, w/o control group	Health care professionals	Feedback	Accidents/injuries		Knowledge
Martyny, Buchan, Keefe, & Blehm (1988)	19	USA	Pre–post, w/control group	Occupational health and safety officers	Lecture	Exposure to harmful substances or environments		Knowledge
Materna et al. (2002)	45	USA	Pre–post, w/o control group	Painting contractors	Lecture, audiovisual presentation, discussion, behavioral modeling, hands-on training/simulation	Exposure to harmful substance or environments		Performance
Mattila (1990)	38	Finland	Pre–post, w/o control group	Veneer refining and coating workers	Feedback based on safety inspections	Transportation accidents	.89	Performance
Mattila & Hyodynmaa (1988)	70	Finland	Pre–post, w/o control group	Construction workers (office building site)	Feedback based on safety inspections	Exposure to harmful substances or environments	.87	Performance
	17	Finland	Pre–post, w/o control group	Construction workers (apartment building site)	Feedback based on safety inspections	Falls	.87	Performance
Mayer et al. (2007)	2,501	USA	Pre–post, w/control group	Postal service letter carriers	Lecture/discussion	Exposure to harmful substances or environments		Performance
McCauley (1990)	30	USA	Pre–post, w/control group	Groundskeepers and custodians	Lecture, discussion, slideshow, simulated work situations	Bodily reaction and exertion		Performance
Michaels, Zoloth, Bernstein, Kass, & Schrier (1992)	170	USA	Pre–post, w/o control group	Carpenters	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
	367	USA	Pre–post, w/o control group	Construction laborers and pipe caulkers	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
	170	USA	Pre–post, w/o control group	Custodial assistants	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
	86	USA	Pre–post, w/o control group	Dental assistants, hygienists, and dentists	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
	177	USA	Pre–post, w/o control group	Electricians	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
	234	USA	Pre–post, w/o control group	Stationary engineers and high-pressure, plant tenders	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge

Table 1 (*continued*)

Study	*N*	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
	160	USA	Pre–post, w/o control group	Plumbers	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
	147	USA	Pre–post, w/o control group	Print shop workers	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
	109	USA	Pre–post, w/o control group	Traffic device maintainers	Lecture, group discussion, feedback	Exposure to harmful substances or environments		Knowledge
Näsänen & Saari (1987)	32	Finland	Pre–post, w/o control group	Shipyard workers	Slideshow, discussion, feedback	Falls	.88	Performance
Nieuwenhuijsen (2004)	40	USA	Posttest only, comparison	Office workers employed in an administrative office	Hands-on (with simulation training)	Bodily reaction and exertion		Performance
Parkinson et al. (1989)	297	USA & Canada	Pre–post, w/control group	Coke oven plant workers	Lecture, discussion	Exposure to harmful substances or environments		Knowledge & performance
Patros (2001)	30	USA	Pre–post, w/o control group	Health care workers	Feedback	Exposure to harmful substances or environments	.99	Performance
Perry & Layde (2003)	385	USA	Posttest only, comparison	Dairy farmers (certified pesticide applicators)	Feedback	Exposure to harmful substances or environments		Knowledge & performance
Peterson, McGlothlin, & Blue (2004)	35	USA	Pre–post, w/o control group	Nursing assistants	Lecture/discussion	Bodily reaction and exertion		Knowledge
Poosanthanasarn, Lohachit, Fungladda, Sriborapa, & Pulkae (2005)	52	Thailand	Pre–post, w/control group	Metal auto-parts factory workers	Lecture/discussion, feedback	Bodily reaction and exertion		Performance
Porru et al. (1993)	50	Italy	Pre–post, w/o control group	Manufacturing plant workers	Lecture, discussion, booklet of information	Exposure to harmful substances or environments		Knowledge
Rasmussen et al. (2003)	201	Denmark	Pre–post, w/control group	Farm workers	Lecture/discussion	Exposure to harmful substances or environments	.60	Performance
Ray, Bishop, & Wang (1997)	41	USA	Pre–post, w/control group	Automobile manufacturing workers	Visual presentation, discussion, feedback	Contact with objects		Performance
Ray, Purswell, & Schlegel (1990)	200	USA	Pre–post, w/control group	Machinists, welders, general fitting technicians	Discussion, feedback	Contact with objects	.98	Performance

(*table continues*)

Table 1 (*continued*)

Study	N	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
Reber & Wallin (1984)	105	USA	Pre–post, w/o control group	Farm machinery manufacturing workers	Lecture, slideshow, feedback, goal setting	Falls	.88	Performance
Reber, Wallin, & Chhokar (1984)	105	USA	Pre–post, w/o control group	Sugar cane machinery manufacturing plant workers	Feedback based on observed levels of safe behavior	Contact with objects	.88	Performance
Reed (2003)	26	USA	Pre–post, w/o control group	High school agricultural students	Hands-on (with simulation training)	Exposure to harmful substances or environments		Performance
Robertson et al. (2002)	31	USA	Pre–post, w/o control group	Knowledge workers	Hands-on (with simulation training)	Bodily reaction and exertion		Knowledge
Rundio (1994)	33	USA	Pre–post, w/control group	Nurses	Hands-on training, simulation	Exposure to harmful substance or environments		Knowledge
Saari (1987)	18	Finland	Pre–post, w/o control group	Margarine factory workers	Slide presentation, feedback	Falls		Performance
Saari & Näsänen (1989)	70	Finland	Pre–post, w/o control group	Shipyard workers	Feedback	Falls	.91	Performance
Sadler & Montgomery (1982)	8	USA	Pre–post, w/o control group	Military aviation maintenance personnel	Lecture (standard lecture group)	Exposure to harmful substances or environments	.90	Performance
	8	USA	Pre–post, w/o control group	Military aviation maintenance personnel	Lecture, feedback (leader-directed group)	Exposure to harmful substances or environments	.90	Performance
Seto, Ching, Chu, & Fielding (1990)	129	China (Hong Kong)	Pre–post, w/control group	Nurses	Lecture	Exposure to harmful substances or environments		Knowledge & performance
Stave, Torner, & Eklof (2007)	26	Sweden	Pre–post, w/o control group	Agriculture/farming workers	Lecture/discussion	Transportation accidents		Performance
Stephens & Ludwig (2005)	7	USA	Pre–post, w/o control group	Nurses	Feedback	Exposure to harmful substances or environments		Performance
Streff, Kalsher, & Geller (1993)	51	USA	Pre–post, w/o control group	Machinists in electronics components plant	Lecture, group discussion	Exposure to harmful substances or environments	.90	Performance
Symes, Graveling, & Campbell (1992)	139	UK	Pre–post, w/o control group	Coal miners	Lecture	Exposure to harmful substances or environments		Knowledge
Troup & Rauhala (1987)	198	Finland	Posttest only, comparison	Student nurses	Lecture, videotaped self-evaluation, diary of patient-handling activities	Bodily reaction and exertion	.94	Performance

Table 1 (*continued*)

Study	*N*	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
Uwakwe (2000)	141	Nigeria	Pre–post, w/control group	Registered (student) nurses	Lecture, discussion, multimedia presentations	Exposure to harmful substances or environments		Knowledge & performance
Vaught, Brinch, & Kellner (1988)	127	USA	Posttest only, comparison	Professional and technical employees	Hands-on training	Fires and explosions		Performance
	97	USA	Posttest only, comparison	Professional and technical employees	Computer-based training	Fires and explosions		Performance
Vela Acosta, Chapman, Bigelow, Kennedy, & Buchan (2005)	152	USA	Pre–post, w/control group	Migrant farm workers	Feedback	Exposure to harmful substances or environments		Knowledge
Videman et al. (1989)	199	Finland	Posttest only, comparison	Nurses	Lecture, feedback	Bodily reaction and exertion		Performance
Wallen & Mulloy (2005)	14	USA	Posttest only, comparison	Factory workers (younger group)	Computer-based programmed instruction	Exposure to harmful substances or environments		Knowledge
	16	USA	Posttest only, comparison	Factory workers (older group)	Computer-based programmed instruction	Exposure to harmful substances or environments		Knowledge
Wang, Fennie, He, Burgess, & Williams (2003)	91	China	Pre–post, w/control group	Student nurses	Lecture, video, behavioral modeling	Exposure to harmful substance or environments		Knowledge & performance
Wertz, Sorenson, Liebling, Kessler, & Heeren (1987)	1,247	USA	Pre–post, w/o control group	Health care workers (e.g., nurses, support staff, lab technicians)	Lecture, discussion	Exposure to harmful substances or environments		Knowledge
Whitby, Stead, & Najman (1991)	333	New Zealand	Pre–post, w/o control group	Hospital nursing staff	Feedback	Exposure to harmful substances or environments		Knowledge & performance
J. H. Williams & Geller (2000)	97	USA	Pre–post, w/o control group	Manufacturing	Lecture, discussion, feedback	Bodily reaction and exertion		Performance
T. C. Williams & Zahed (1996)	27	USA	Pre–post, w/o control group	Chemical processors	Lecture, discussion	Exposure to harmful substances or environments		Knowledge
	27	USA	Pre–post, w/o control group	Chemical processors	Computer-based training modules	Exposure to harmful substances or environments		Knowledge
Wong et al. (1991)	186	USA	Pre–post, w/o control group	Physicians	Lecture, feedback	Exposure to harmful substances or environments		Performance
Wu et al. (2002)	833	China	Pre–post, w/control group	Health professionals	Behavioral modeling	Exposure to harmful substances or environments		Knowledge
Wynn & Black (1998)	96	USA	Pre–post, w/o control group	Medical flight crew personnel (nurses, paramedics)	Lecture	Fires and explosions		Knowledge

(*table continues*)

Table 1 (*continued*)

Study	*N*	Country	Study design[a]	Participant occupation	Method of safety training[b]	Type of hazard	Dependent variable reliability[c]	Dependent variable
Yarrall (1986)	73	New Zealand	Pre–post, w/control group	Unspecified worksite employees (Worksite B)	Lecture, audiovisual presentation, discussion	Exposure to harmful substances or environments		Knowledge & performance
	67	New Zealand	Pre–post, w/control group	Unspecified worksite employees (Worksite C)	Feedback	Exposure to harmful substances or environments		Knowledge & performance
Yassi et al. (2001)	204	Canada	Pre–post, w/control group	Health care workers	Problem-based, hands-on training/practice with equipment	Bodily reaction and exertion		Performance
Zohar, Cohen, & Azar (1980)	76	Israel	Pre–post, w/control group	Metal fabrication plant workers	Lecture, discussion, feedback	Exposure to harmful substances or environments		Performance

Note. N = sample size relevant to the respective effect size.
[a] Study design for the purpose of estimating the effect size is not necessarily the same as the actual study design. Designs were reconsidered in some cases to deal with comparison groups that did not serve as reasonable control groups, with a lack of data on pre–post change for the control group, and with substantively range restricted pretest data that would create out-of-bound effect size estimates. [b] The level of engagement of safety training was based on the most engaging training method incorporated into a study design. [c] The sample-size weighted average reliability for the respective knowledge and performance reliabilities was substituted for missing study reliabilities. These mean reliability values were .73 for knowledge and .88 for performance.

how hazardous event/exposure severity interacts with training engagement to influence these outcomes. Although we found a main effect for training in relation to knowledge acquisition and safety performance that was consistent with expectations from active approaches to learning (Bell & Kozlowski, 2008; Burke et al., 2006; Taylor et al., 2005), this finding was overshadowed by evidence of an interaction between the level of training engagement and hazardous event/exposure. More specifically, highly engaging training is considerably more effective in promoting safety knowledge and safety performance than less engaging training, particularly when the severity level of hazardous event/exposure is high. When hazardous event/exposure severity is low, less engaging training approaches appear to be as effective as those that are highly engaging. This interaction effect is consistent with theoretical arguments based on dialogical theories of experiential learning and, at the same time, suggests that low hazards constitute a boundary condition for the effectiveness of training engagement. The scientific and practical implications of these findings are discussed below.

Training Engagement

Our findings indicate that, on average, the highly engaging methods of safety training are considerably more effective than the less engaging methods of training in knowledge acquisition and safety performance. Scientifically, these findings provide further support for conceptual arguments within experiential learning theories concerning enhancements in learning that result from action, dialogue, and reflection. From a practical perspective, these findings suggest the need for safety managers to more carefully consider the relative costs and benefits of placing a trainee in a passive versus more active type of safety training for knowledge acquisition and performance enhancement. In particular, although distance learning and electronic learning (e-learning) approaches to training offer economies of scale and may appear cost effective from a short-term financial perspective, a lack of participant engagement in such training approaches has been acknowledged as a major issue (Derouin, Fritzsche, & Salas, 2005). Given the importance of knowledge and performance as outcomes of safety training, balancing training engagement with the short-term financial costs becomes critical both to keeping workers safe and to avoiding the long-term financial costs of safety-related disasters, including the aforementioned deadly explosion at the Upper Big Branch mine in West Virginia.

We note that our findings for the relative effectiveness of less versus highly engaging forms of safety training are stronger and more robust than the respective uncorrected study effects reported in Robson et al. (2010). These differences in findings are likely, in part, due to the highly selective sampling of studies (16 of which entered the final analyses compared to our analysis of 113 studies) and second-order sampling error introduced in Robson et al. Importantly, the present findings offer the most comprehensive scientific findings concerning the relative effectiveness of training engagement to date and serve to inform evidence-based policy on worker safety training with respect to highly hazardous work conditions. To underscore the importance of more informed policy and practice related to worker safety training, one need only look at recent news headlines concerning work safety training for the largest oil spill recovery effort in U.S. history. For instance, David

Table 2
Safety and Health Training Method Meta-Analysis Results in Correlation Form

Training method	N	k	Uncorrected M_r	Uncorrected 95% CI M_r	Uncorrected V_r	Disattenuated M_ρ	Disattenuated 95% CI M_ρ	Disattenuated V_ρ
Safety knowledge								
Less engaging methods	10,073	60	.31	[.27, .35]	.020	.36	[.32, .41]	.029
Highly engaging methods	1,848	15	.52	[.46, .59]	.011	.61	[.54, .68]	.014
Safety performance								
Less engaging methods	10,214	69	.20	[.17, .24]	.015	.22	[.18, .25]	.017
Highly engaging methods	2,559	22	.39	[.34, .45]	.013	.42	[.36, .48]	.015

Note. N = total number of individuals; k = number of study effects; M_r = sample-size weighted mean uncorrected correlation; 95% CI M_r = 95% confidence interval around the estimated M_r; V_r = variance of uncorrected effects; M_ρ = sample-size weighted mean correlation corrected for dependent variable unreliability (mean rho); 95% CI M_ρ = 95% confidence interval around the estimated M_ρ; V_ρ = variance of corrected effects.

Michaels, Assistant Secretary of Labor for the Occupational Safety and Health Administration, was quoted as saying, "We have reports that some [in reference to British Petroleum's oil recovery safety training programs] are offering training in significantly fewer than 40 hours, showing video presentations instead of requiring hands-on training and offering only limited instruction" (Mirza, 2010, p. 1). These workers' insufficient training was reflected in their behaviors: some of the clean-up workers were reportedly working without gloves and in their regular clothes, meaning not only that they were likely coming into direct contact with contaminants but that they were then probably bringing these contaminants into their homes on their clothes. We comment more and qualify our comments on the policy and practice implications of our results below in relation to findings for Hypotheses 3 and 4, which pertain to the interaction of training engagement and hazardous event/exposure severity on training effectiveness.

The Interaction of Training Engagement and Hazardous Event/Exposure Severity

An important finding from this study is that hazardous event/exposure severity interacted with training engagement to, on average, produce increased learning and performance when hazardous event/exposure severity was high and training was highly engaging. The primary psychological mechanism we offer as an explanation for this effect is the dread factor, the realization of the dangers associated with ominous hazards and the experienced feelings that one has about the possibility of such events/exposures. This affective reaction and realization of threat severity is, in turn, expected to promote the motivation to learn more about such hazards and how to avoid them, as well as motivation for transferring such knowledge to the work setting. Our argument is consistent with the considerable amount of research on the functional nature of affect and emotions.

Our theorizing on how the dread factor develops involves the social and experiential construction of affect and understanding of threat severity. As such, our theorizing and empirical findings uniquely contribute to research on learning in safety contexts, as well as to research on why and how workers transfer knowledge to the work setting in terms of dealing with hazards of an ominous nature. Consistent with our theorizing and findings, people become more pessimistic in their predictions about negative outcomes when they are able to reflect on or imagine the experience of such

Table 3
Hazardous Event/Exposure Severity Level by Training Method Results in Correlation Form

Hazard level/training method	N	k	Uncorrected M_r	Uncorrected 95% CI M_r	Uncorrected V_r	Disattenuated M_ρ	Disattenuated 95% CI M_ρ	Disattenuated V_ρ
Safety knowledge								
Low hazard								
Less engaging methods	250	4	.45	[.31, .60]	.011	.53	[.37, .70]	.016
Highly engaging methods	407	6	.41	[.28, .54]	.019	.47	[.33, .61]	.019
High hazard								
Less engaging methods	9,823	56	.31	[.27, .35]	.020	.36	[.31, .41]	.028
Highly engaging methods	1,441	9	.55	[.50, .61]	.004	.65	[.58, .71]	.006
Safety performance								
Low hazard								
Less engaging methods	1,462	28	.29	[.23, .35]	.011	.31	[.24, .37]	.014
Highly engaging methods	841	10	.31	[.22, .39]	.010	.32	[.23, .41]	.011
High hazard								
Less engaging methods	8,752	41	.19	[.15, .23]	.014	.20	[.16, .25]	.016
Highly engaging methods	1,718	12	.44	[.37, .50]	.009	.46	[.39, .53]	.010

Note. N = total number of individuals; k = number of study effects; M_r = sample-size weighted mean uncorrected correlation; 95% CI M_r = 95% confidence interval around the estimated M_r; V_r = variance of uncorrected effects; M_ρ = sample-size weighted mean correlation corrected for dependent variable unreliability (mean rho); 95% CI M_ρ = 95% confidence interval around the estimated M_ρ; V_ρ = variance of corrected effects.

an outcome (Sanna, 1999), and research suggests that a pessimistic outlook may be wiser in preparing for and responding to possible negative outcomes (Rundmo, 2000; Sweeny & Shepperd, 2007). In effect, workers in safety contexts where a hazardous exposure or event is regarded as serious or consequential (relative to illness, disease, or death) may be harnessing the benefits of negative states (such as negative affect) to prepare for and prompt action to avoid the negative outcomes. In doing so, they are engaging in safe work behavior.

Furthermore, we note two interesting and unanticipated findings. First, in the low hazard condition, the less and highly engaging forms of training had comparable mean effects for both knowledge acquisition and safety performance. These findings may have been affected to some degree by the second-order sampling of studies. This point is especially relevant for the two knowledge-acquisition mean effects in the low hazard severity condition, which are based on relatively small numbers of studies and have wide confidence intervals. These confidence intervals are 2 to 3 times as wide as the respective confidence intervals in the high hazard condition, where the latter intervals are based on larger numbers of studies. Nevertheless, the overall pattern of findings across the two dependent variable categories, knowledge acquisition and safety performance, is noteworthy. Substantively, this pattern of findings suggests a potential boundary condition for the usefulness of highly engaging forms of training. That is, when hazard severity is low, more standardized and less socially engaging training methods may be sufficient to efficaciously produce desired or optimal training outcomes. More research comparing less and highly engaging forms of training under low hazard severity conditions with respect to safety and health knowledge and performance as the dependent variables is needed before one can be more confident in concluding that there is a possible boundary condition for training engagement.

Another interesting finding is that the lowest effects for knowledge acquisition or safety performance were in the high hazard, low training engagement conditions. There are perhaps two related explanations for this pattern of findings. First, properly dealing with hazards that have severe injury or illness potential may require more procedural knowledge and skill development (e.g., using a self-contained breathing apparatus for dealing with radiological waste) than working with hazards that have lower potential for severe injury (e.g., using a loose-fitting disposable face mask when painting). As discussed above and consistent with our general findings concerning the effect of more versus less engaging forms of training, less engaging forms of training (e.g., a lecture, a pamphlet) would not necessarily lead to the development of more advanced procedural knowledge and skill needed within an area such as respiratory protection. Second, in line with our arguments related to the social construction of dread and an understanding of threat vulnerability, less engaging forms of training (with respect to hazards with severe injury/illness potential) may inappropriately signal that hazards and threat vulnerability are minor when in fact that they are not. The result being a potential backlash effect where the motivation to acquire the procedural knowledge and skill for handling such hazards is deflated.

From a practical perspective, our findings in regard to the dread factor are important. Given the breadth of occupations and industries included in this meta-analysis and noting that these findings apply to workers in over 16 countries, the observed learning and performance differences between less engaging and highly engaging training in the high hazardous event/exposure condition have broad implications for the design and delivery of safety-related interventions on a worldwide basis. That is, efforts to increase the capacity of private sector and public sector workers to deal with hazards of an ominous nature, such as those relating to emergency events and exposures to highly hazardous substances, would be well advised to consider the potential benefits of highly engaging forms of training when hazard event/exposure is high. We offer this observation noting that when work involves dealing with hazards of an ominous nature, workers are not necessarily receiving and experiencing the benefits of highly engaging training. While our observation is based on the fact that the number of training evaluation studies in the literature is much lower for highly engaging safety training in comparison to less engaging types of training, we note that this observation is also consistent with literature indicating that safety training is not more prevalent in occupations and industries where workers face potential exposure to hazards with severe injury potential (Smith & Mustard, 2007).

Potential Limitations and Directions for Future Research

While we have relied on dialogical theories of experiential theories of learning as the basis for our psychological mechanisms and hypotheses, we recognize that this proposed psychological mechanism for our findings is an unmeasured variable. Thus, alternative explanatory mechanisms might be proposed for the obtained effects. We encourage research and, in particular, experimental studies that attempt to test expectations in relation to the dread factor and to measure affective and motivationally relevant cognitions that serve as mediating variables in our causal arguments.

Another potential limitation of this investigation is that we did not have adequate data to control for several factors (e.g., sex and position within organization) that are known to influence risk perceptions. For many of the studies, with the exception of several studies and samples within the health care sector (e.g., nursing), the samples were predominantly male. Likewise, the samples in our studies were predominantly line workers, with few safety training studies involving managers.

Furthermore, while our studies were based in over 16 different countries, studies from the United States dominated the set. As safety training continues on a worldwide basis, a useful future research direction would be to consider the joint influence of national cultural values, training engagement, and hazards on safety knowledge acquisition and performance. This suggestion is made based on some evidence that cultural values such as uncertainty avoidance are related to training engagement (Burke, Chan-Serafin, Salvador, Smith, & Sarpy, 2008). That is, as uncertainty avoidance increases, the level of training engagement decreases. This effect is expected to be due to organizations in cultures that place a high value on avoiding uncertainty tending to favor more structured, less engaging approaches to safety training.

In terms of future research concerning the role of work context and environment (i.e., hazardous event/exposure), we believe the hazard scoring system employed in this investigation has reasonable potential for advancing the understanding of effects associated with physical hazards in many types of work environments. The present hazard scoring system relies on the dichotomization of hazards as low and high relative to an available and standardized (across industries and occupations) hierarchy of workplace hazards. Notably, this system is flexible in the sense of permitting gradations in hazard categorization for up to seven hierarchically ordered categories should a researcher's question call for the consideration of more fine-grained hazard distinctions. To our knowledge, the hazard scoring system within this research (i.e., the Bureau of Labor Statistics' OIICS) has not been employed in other behavioral, management, or pubic health research to examine effects associated with hazardous work environments. Typically, hazards are recognized in these literatures but are infrequently scored and examined as situational variables. Notable exceptions include the O*NET work context ratings, which reflect job analysts' ratings of potential exposure to job hazards (see Strong, Jeanneret, McPhail, Blakley, & D'Egidio, 1999), and the idiosyncratic trade association scheme reported by Sinclair et al. (2003).

Conclusion

The current study demonstrates the interactive influence of the level of engagement of safety training and hazard event/exposure severity on the development of safety knowledge and performance. Importantly, in relation to knowledge acquisition and safety performance, we have found that highly engaging safety training is more effective than less engaging safety training when hazardous event/exposure severity is high, whereas highly and less engaging safety training have comparable levels of effectiveness when hazardous event/exposure severity is low. More broadly, we hope, in conducting this study, not only that we have contributed to an understanding of the role that work context (i.e., workplace hazards) plays in relation to different levels of active learning to improve worker safety but that we have also underscored the value of a social constructionist lens to studying workplace safety.

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