Relative Effectiveness of Worker Safety and Health Training Methods

Michael J. Burke, PhD, Sue Ann Sarpy, PhD, Kristin Smith-Crowe, PhD, Suzanne Chan-Serafin, BA, Rommel O. Salvador, MBA, and Gazi Islam, BA

Objectives. We sought to determine the relative effectiveness of different methods of worker safety and health training aimed at improving safety knowledge and performance and reducing negative outcomes (accidents, illnesses, and injuries).

Methods. Ninety-five quasi-experimental studies (n = 20991) were included in the analysis. Three types of intervention methods were distinguished on the basis of learners' participation in the training process: least engaging (lecture, pamphlets, videos), moderately engaging (programmed instruction, feedback interventions), and most engaging (training in behavioral modeling, hands-on training).

Results. As training methods became more engaging (i.e., requiring trainees' active participation), workers demonstrated greater knowledge acquisition, and reductions were seen in accidents, illnesses, and injuries. All methods of training produced meaningful behavioral performance improvements.

Conclusions. Training involving behavioral modeling, a substantial amount of practice, and dialogue is generally more effective than other methods of safety and health training. The present findings challenge the current emphasis on more passive computer-based and distance training methods within the public health workforce. (*Am J Public Health*. 2006;96:315–324. doi:10.2105/AJPH.2004.059840)

An understanding of how best to implement worker safety and health training is a critical public need in light of the tragic events of September 11, 2001, as well as ongoing efforts to prepare emergency responders and professionals in related areas to do their jobs safely and effectively.[1] The need to gain a better understanding of the effectiveness of safety and health training is also apparent in a broader context given that millions of injuries and illnesses are reported annually in private industry workplaces,[2] and health and safety training is globally recognized as 1 means of reducing the costs associated with such events.[3] Indeed, researchers from different fields, including business, psychology, engineering, and public health, have long recognized the need for comprehensive, systematic evaluations of safety and health training to address these types of critical public- and private-sector concerns.[4–7]

The conclusion from several narrative reviews has been that most training interventions lead to positive effects on safety knowledge, adoption of safe work behaviors and practices, and safety and health outcomes.[5,8,9] However, these qualitative reviews are speculative as to the specific factors that enhance the relative effectiveness of safety and health training interventions in reducing or preventing worker injury or illness.[10–12] Notably, a fundamental question remains unresolved within the scientific literature: What is the relative effectiveness of different *methods* of safety and health training in modifying safety-related knowledge, behavior, and outcomes?

Attempts to address similar broad-based questions related to the benefits of work-related health and safety interventions[13] have revealed the need for a large-scale, quantitative analysis of the extant literature. Results from such an analysis would not only help improve safety and health training programs but also provide evidence of the benefits of these programs, securing both new and continued support from the public as well as the private sector.

With these ends in mind, this study was designed to meta-analytically examine the effectiveness of different types of worker safety and health training, across industries and occupations, from 1971 to the present. In the section to follow, we describe different methods of worker safety and health training and offer hypotheses concerning the relative effectiveness of these methods.

SAFETY AND HEALTH TRAINING STRATEGIES

Methods of safety and health training range from passive, information-based techniques (e.g., lectures) to computer-based, programmed instruction and learner-centered, performance-based techniques (e.g., hands-on demonstrations). Lectures, one of the least engaging methods of safety and health training, are commonly used to present health- and safety-related information. Other common passive techniques include videos and pamphlets or other types of written materials.

Methods of training that can be categorized as moderately engaging incorporate knowledge of results, for example feedback interventions in which performance information is provided in small groups, allowing learners to correct their mistakes. Feedback is also a characteristic of programmed instruction, a method of training designed to present information in a standardized manner, such as on a personal computer or in a workbook format. An extensively used moderately engaging method, computer-based instruction, has been created for the entire gamut of workplace health and safety topics, including occupational safety, industrial safety, systems safety, fire protection, hazardous materials and waste disposal and storage, industrial hygiene, risk management, and safety engineering and design.[14]

The most engaging methods of safety and health training focus on the development of knowledge in stages[15] and emphasize principles of behavioral modeling.[16] Behavioral modeling involves observation of a role model, modeling or practice, and feedback designed to modify behavior. These methods also include hands-on demonstrations associated with behavioral simulations, which require active participation from the trainee.

In the case of behavioral simulations and hands-on training, interactions between trainees and trainers will frequently go beyond 1-way feedback to engage trainees in dialogue concerning knowledge acquired or actions taken. Such dialogue, in either a virtual or actual context, is important because it is posited to enhance quality of reflection (thinking) with respect to actions taken.[17–19] This action-focused reflection is regarded as the key to knowledge acquisition and transfer of training, in that it forces the trainee to infer causal and conditional relations between events and actions, leading to development of strategies for handling unforeseen events and initiating and promoting self-regulatory motivational processes (e.g., self-monitoring and self-efficacy expectations).

Consistent with these arguments, there is ample evidence in the training literature that active approaches to learning are superior to less active approaches.[20] Therefore, as training moves along the continuum from more passive information-based methods (e.g., lectures) to the most engaging methods (e.g., behavioral modeling and hands-on demonstrations), we hypothesize that greater knowledge acquisition and more transfer of training to the work setting will occur (thereby improving behavioral safety performance and reducing negative safety and health outcomes).

METHODS

Search and Inclusion Criteria

We identified relevant studies published between 1971 (i.e., subsequent to passage of the US Occupational Safety and Health Act of 1970 [29 USC §651-678]) and 2003 by searching the PsycInfo, PubMed, and ABI-Inform electronic databases using phrases such as "health and safety training," "safety training intervention," and "error management and intervention." In addition, we manually searched 19 journals and the reference sections of relevant publications. This process yielded 709 studies from a wide variety of fields, including occupational medicine, industrial hygiene, management, and applied psychology. We assessed all reports of an empirical nature to determine whether they met our criteria for inclusion in the meta-analysis.

Inclusion criteria were as follows. First, the study had to involve a *quasi-experimental design* (i.e., a study approximating a true experiment but not allowing for control of all relevant variables because of its field setting).[21] Second, participants had to be recruited from a *working population* (this population could include youth workers). Third, the *method of intervention* (e.g., lecture, programmed instruction, behavioral modeling, or simulation) had to be clearly identified and had to involve the development of job-relevant safety knowledge.

Fourth, the study was required to include at least 1 of the following types of dependent variables: *safety knowledge* (i.e., self-rating or test of knowledge), *safety performance* (i.e., self-ratings or supervisor, coworker, or observer ratings of safety-related behavior), or *safety and health outcome* (i.e., measure of accidents, illnesses, or injuries). Fifth, the training intervention and data had to be assessed at the *individual level of analysis.* Finally, the statistical information necessary to calculate an *effect size* (d) had to be available. A large number of studies were excluded because they contained inadequate statistical information or were not field experiments of health and safety training effectiveness. Of the originally identified 709 studies, 95 met the inclusion criteria.

Coding of Studies

An extensive coding protocol was developed to include the following information: (1) method of safety and health training, (2) duration of training, (3) dependent variable (i.e., safety knowledge, behavioral safety performance, or safety and health outcomes) used in all posttraining assessments, (4) reliability of dependent variable, (5) occupational classification, and (6) country of study. All reliability estimates[22] (i.e., estimates of the consistency with which variables were measured) for knowledge tests were internal consistency estimates[23] (i.e., α coefficients), and the majority of reliability estimates for the performance measures were interrater estimates (e.g., correlation between 2 trained observers' assessments of workers' performance).

In terms of classification of training methods, lectures, films, and video-based training were classified as the least engaging methods; programmed instruction techniques, including computer-based instruction and feedback techniques, were classified as moderately engaging training methods; and behavioral modeling, simulation, and hands-on training were categorized as the most engaging training methods. All study characteristics pertaining to hypothesis tests were double coded; disagreements between coders were settled by the first author.

Statistical Analyses

Initially, we computed d statistics using the procedures described by Shadish and colleagues[24] and Lipsey and Wilson.[25] In the case of studies in which gains or losses because of training were expressed as a proportion or a percentage, we estimated d statistics via an arcsine transformation, which results in a conservative estimate of d values.[25]

Subsequently, we employed the Raju et al.[26] meta-analysis procedure because this procedure allows effects to be corrected for unreliability associated with the dependent variable. Such corrections produce more accurate estimates of population-level effects and permit more appropriate comparisons of mean effects across different types of dependent variables.[27] In our set of studies, mean reliability values weighted according to sample size were 0.67 for safety knowledge, 0.86 for safety performance, and 0.96 for safety-related outcomes. Notably, the Raju et al. procedure allows computation of asymptotically derived standard errors for mean corrected (disattenuated) correlations in fixed-effect and random-effect forms.[28] Therefore, before using this procedure, we transformed d statistics to correlations via maximum-likelihood estimates.[27]

For most studies that reported multiple effects within our dependent variable categories (e.g., effects for 2 dimensions of behavioral performance), we computed an average effect. In a few exceptions, we judged 1 effect more appropriate (e.g., because it was based on a more clearly defined dependent variable), and we included this effect in our analyses. This procedure ensured independence of study effects within any particular effect size distribution.

TABLE 1—Effects From Each Study and Each Dependent Variable: Meta-Analysis of Safety and Health Training Effectiveness, 1971–2003

	Disattenuated Effect Size		
Study	Safety Knowledge	Safety Performance	Safety and Health Outcomes
Alavosius and Sulzer-Azaroff[29]	...	0.42	...
Albers et al.[30]	0.90	...	...
Arcury et al.[31]	0.32	0.39	...
Arnetz and Arnetz[32]	0.20	...	...
Askari and Mehring[33]	0.43	...	...
Azizi et al.[34]	...	0.96	...
Baker[35]	...	2.33	...
Barnett et al.[36]	0.30	...	...
Bosco and Wagner[37]	1.45	...	...
Calabro et al.[38]	2.44	...	...
Caparez et al.[39]	1.53	...	...
Carlton[40]	3.67	0.56	...
Carrabba et al.[41]	...	0.29	0.20
Chaffin et al.[42]	...	0.19	...
Chhokar and Wallin[43]	...	0.86	...
Cohen and Jensen[44]			
Plant 1	...	0.12	...
Plant 2	...	0.42	...
Cole et al.[45]	...	0.60	...
Coutts et al.[46]	0.82	...	...
Curwick et al.[47]	1.27	...	...
Daltroy et al.[48]	0.99	...	...
Daltroy et al.[49]			
Mailhandlers	...		-0.02
Clerks	...		0.01
DeVries et al.[50]	...	0.60	...
Dortch and Trombly[51]			
Group 1 vs group 3	...	1.60	...
Group 2 vs group 3	...	1.51	...
Eckerman et al.[52]	2.35	...	...
Evanoff et al.[53]	...	...	0.39
Ewigman et al.[54]	0.43	0.69	...
Feldstein et al.[55]	...	...	0.37
Fox and Sulzer-Azaroff[56]	...	0.72	...
Froom et al.[57]	...	1.55	...
Gerbert et al.[58]	1.04	0.23	...
Girgis et al.[59]	0.10	0.37	...
Goldrick[60]			
78 nurses	1.65	...	...
66 nurses	1.78	...	...
Haiduven et al.[61]	...	...	0.61
Hopkins[62]	...	0.59	...
Hultman et al.[63]	...	1.61	...
Hurlebaus and Link[64]	0.94	...	...
Infantino and Musingo[65]	...	...	0.58

Continued

A number of effect sizes for combinations of training method and dependent variable were based on within-subject designs. To examine the possible effects of study design on our results, we conducted separate meta-analyses of studies involving within-subject designs and studies involving between-subjects designs (we also conducted separate analyses for distributions that included both types of study designs). In addition, because of the lack of pretraining information in many studies, effects for between-subjects studies were based on posttest-only comparisons of control and training groups. In a few cases in which the control or comparison group was noncomparable (e.g., the groups had different amounts of work experience) or the comparison group was trained with a less engaging method than the focal trained group (and in which pretraining and posttraining data were available), study effects were based on within-subject data for the trained group or groups.

RESULTS

Description of Studies

Ninety-five studies[29–123] conducted between 1971 and 2003 in 15 countries were included in the present meta-analyses (Table 1). These studies comprised 126 independent samples, 20 991 participants (the sum of the independent samples), and 147 safety training effect sizes. The 43 samples from the health care occupations represented the largest occupational group.

Safety and Health Training Methods

Table 2 presents the results of tests of our hypotheses based on data gathered within the first posttraining assessment. For reporting purposes, mean effect sizes (d statistics), along with number of effects (k) and total sample sizes (n) pertaining to hypothesis tests, are presented for (1) studies involving between-subjects designs, (2) studies involving within-subject designs, and (3) the combined (overall) distributions of effects. As a result of the complex nature of r-to-d transformations for d values in our overall analysis (which generally fell outside the straightforward transformation range for d of –0.41 to 0.41),[27] limits of the confidence intervals for the mean effects and variances of effect

TABLE 1—*Continued*

Inman and Blanciforti[66]	. . .	0.21	. . .
Knobloch and Broste[67]	. . .	1.02	. . .
Komaki et al.[68]			
Makeup department	. . .	0.85	. . .
Wrapping department	. . .	0.76	. . .
Komaki et al.[69]			
Department 1	. . .	0.37	. . .
Department 2	. . .	0.29	. . .
Department 3	. . .	0.20	. . .
Department 4	. . .	0.26	. . .
Leslie and Adams[70]	. . .	0.18	0.91
Ludwig and Geller[71]	. . .	0.06	. . .
Ludwig and Geller[72]			
Participative goal setting	. . .	1.15	. . .
Assigned goal setting	. . .	1.07	. . .
Lueveswanij et al.[73]	1.21	. . .	. . .
Luskin et al.[74]	0.91	. . .	. . .
Lynch et al.[75]			
Combined sample	0.72	. . .	. . .
Medical personnel	. . .	0.58	. . .
Nursing personnel	. . .	0.43	. . .
Lynch and Freund[76]	0.64	0.30	. . .
Maples et al.[77]	. . .	. . .	0.79
Marsh and Kendrick[78]	0.76	. . .	. . .
Martyny et al.[79]	0.10	. . .	. . .
Materna et al.[80]	. . .	1.68	. . .
Mattila[81]	. . .	0.29	. . .
Mattila and Hyodynmaa[82]			
Office building site		0.36	. . .
Apartment building site		0.39	. . .
McCauley[83]	. . .	1.27	. . .
Melhorn[84]			
Standard rivet gun training	. . .	. . .	0.34
Vibration-dampening rivet gun training	. . .	. . .	0.13
Michaels et al.[85]			
Carpenters	0.92	. . .	. . .
Construction laborers and pipe caulkers	0.52	. . .	. . .
Custodial assistants	0.40	. . .	. . .
Dental assistants/hygienists and dentists	0.80	. . .	. . .
Electricians	0.79	. . .	. . .
Engineers and high-pressure plant tenders	0.78	. . .	. . .
Plumbers	0.78	. . .	. . .
Print shop workers	0.56	. . .	. . .
Traffic device maintainers	0.94	. . .	. . .
Nasanen and Saari[86]	. . .	0.55	0.63
Parenmark et al.[87]	. . .	. . .	0.73
Parkinson et al.[88]	0.67	0.51	. . .
Peters[89]	0.35	. . .	. . .
Porru et al.[90]	0.40	. . .	. . .

Continued

size distributions are presented only in correlation (*r*) form in Table 3.

The findings reported in Table 2 are consistent with the expectation that the more engaging a method of training, the greater the effects of safety and health training on knowledge acquisition. Overall, mean knowledge acquisition effect sizes for the least engaging, moderately engaging, and the most engaging safety training interventions (for both types of study designs combined) were 0.55, 0.74, and 1.46, respectively. As indicated by the confidence intervals for these effects (Table 3), the effects were significantly different from each other. Furthermore, although training durations were, on average, greater in the case of more engaging training methods, training duration and level of engagement were only weakly (and nonsignificantly) associated in the knowledge category studies (as well as the performance category studies). These findings rule out training duration and a strict observational learning effect as a plausible rival explanation for the present results.[124]

A small subset of studies (i.e., 7) that included knowledge measures allowed us to examine maintenance or decay in terms of the effectiveness of safety training. In 5 studies involving training at low levels of engagement, the average effect decreased approximately 50% (i.e., from 0.55 to 0.28) during periods ranging from 1 week to 1 year after the initial assessment. The effect in the lone study involving moderately engaging training decreased approximately 15% (from 3.37 to 2.85) over 4 weeks, and the effect in the single study involving highly engaging training was maintained at 1.84 over a 4-week period. More research and better reporting of primary study results are needed before definitive conclusions can be reached about decay of safety and health training effectiveness over time.

With respect to improvements in behavioral safety performance, the mean overall effects associated with safety and health training interventions in the least engaging, moderately engaging, and most engaging categories were 0.63, 0.62, and 0.74, respectively. Although these effects were not significantly different from each other, it is notable that the confidence interval for the latter effect was predominantly outside the range of the

TABLE 1—*Continued*

Ray et al.[91]	...	0.69	...
Ray et al.[92]	...	0.38	...
Reber and Wallin[93]	...	0.20	...
Reber et al.[94]	...	0.95	0.68
Reddell et al.[95]	...	...	0.88
Rhoton[96]	...	...	0.98
Rundio[97]	1.85	...	...
Saarela[98]	...	...	0.20
Saarela et al.[99]			
Tankers	...	...	-0.27
Ferries	...	...	-0.21
Saari[100]	...	0.46	...
Saari and Nasanen[101]	...	0.55	0.31
Sadler and Montgomery[102]			
Leader-directed group	...	0.39	...
Standard lecture	...	0.25	...
Schwartz[103]	...	...	1.39
Seto et al.[104]	1.45	1.48	...
Streff et al.[105]	...	0.29	...
Sulzer-Azaroff and de Santamaria[106]			
Department 1	...	...	0.43
Department 2	...	...	0.66
Department 3	...	...	0.62
Department 4	...	...	0.16
Department 5	...	...	0.53
Department 6	...	...	0.13
Symes et al.[107]	0.45	...	...
Troup and Rauhala[108]	...	0.97	...
Uwakwe[109]	0.57	0.07	...
van Poppel et al.[110]	...	...	0.17
Vaught et al.[111]			
Hands-on training	...	0.51	...
Computer-based training	...	-0.33	...
Videman et al.[112]	...	1.33	0.11
Wang et al.[113]	1.74	0.73	0.58
Wertz et al.[114]	0.47	...	...
Whitby et al.[115]	0.25	0.83	...
Williams and Geller[116]	...	0.21	...
Williams and Zahed[117]			
Lecture method	3.67	...	...
Computer-based training	3.37	...	...
Wolford et al.[118]	...	0.44	...
Wong et al.[119]	...	0.23	...
Wynn and Black[120]	0.97	...	...
Yarall[121]			
Worksite B	0.67	1.12	...
Worksite C	0.80	2.07	...
Yassi et al.[122]	...	0.29	0.09
Zohar et al.[123]	...	1.21	...

Note. Effects are expressed as *d* statistics corrected for dependent variable unreliability.

respective confidence intervals for the effects of the least engaging and moderately engaging training methods.

Our findings are generally consistent with the expectation that as level of engagement in training increases, training will have greater effects in terms of reductions in negative safety and health outcomes. For the overall distributions, the mean effects associated with the least engaging, moderately engaging, and the most engaging safety and health training methods were 0.20, –0.13, and –0.48, respectively, and these effects were significantly different from each other. It should be noted that the least engaging and moderately engaging distributions were each influenced greatly by a single study involving a large sample size and a small effect.

DISCUSSION

Here we assessed theoretical expectations concerning the relative effectiveness of different methods of worker safety and health training aimed at modifying safety-related knowledge, behaviors, and outcomes. This is the first investigation focusing on such training, to our knowledge, that has included all studies published since 1971 and has involved a scientifically rigorous approach. Although the number of studies examining illnesses, injuries, and accidents was not sufficient to allow separate consideration of these categories of safety and health outcomes, the quality of the database was adequate for testing general hypotheses.

As mentioned, our results are consistent with the proposition that as the method of safety and health training becomes more engaging, the effect of training is greater in terms of knowledge acquisition and reductions in negative outcomes. Our results concerning behavioral performance were more equivocal but nevertheless provided consistent support, in the case of both between-subjects and within-subject study designs, for the effectiveness of more engaging training methods. Together, these findings address calls for research on safety and health interventions, including those of the National Occupational Research Agenda.[10–12,125] More specifically, our results speak to the goals of the intervention effectiveness research

TABLE 2—Training Method Results: Meta-Analysis of Safety and Health Training Effectiveness, 1971–2003

Training Method/Study Design	Safety Knowledge			Safety Performance			Safety and Health Outcomes		
	n	*k*	M_Δ	n	*k*	M_Δ	n	*k*	M_Δ
Least engaging (overall)	4097	18	0.55	2356	20	0.63	1950	3	0.2
Between-subjects studies	1071	7	0.58	1509	12	0.65	…	…	…
Within-subject studies	3026	11	0.54	847	8	0.58	…	…	…
Moderately engaging (overall)	3021	19	0.74	1864	31	0.62	4528	19	−0.13
Between-subjects studies	1121	5	0.66	1044	10	0.74	3846	7	−0.04
Within-subject studies	1900	14	0.79	820	21	0.47	682	11	−0.66
Highly engaging methods (overall)	886	12	1.46	2019	16	0.74	3068	9	−0.48
Between-subjects studies	609	7	1.27	1914	12	0.72	1588	6	−0.25
Within-subject studies	277	5	1.89	105	4	1.14	1480	3	−0.74

Note. n = total number of individuals; *k* = number of effects; M_Δ = estimated mean *d* statistic corrected for dependent variable unreliability (mean Δ).

TABLE 3—Training Method Results in Correlation Form: Meta-Analysis of Safety and Health Training Effectiveness, 1971–2003

Training Method/Study Design	Safety Knowledge					Safety Performance					Safety and Health Outcomes				
	n	*k*	M_ρ	95% CI	V_ρ	n	*k*	M_ρ	95% CI	V_ρ	n	*k*	M_ρ	95% CI	V_ρ
Least engaging (overall)	4097	18	0.26	0.22, 0.29	0.01	2356	20	0.28	0.24, 0.32	0.02	…	…	…	…	…
Between-subjects studies	1071	7	0.27	0.20, 0.34	0.02	1509	12	0.29	0.24, 0.33	0.04	1950	3	0.1	0.15, 0.06	0.01
Within-subject studies	3026	11	0.25	0.21, 0.29	0.01	847	8	0.28	0.21, 0.35	0.00	…	…	…	…	…
Moderately engaging (overall)	3021	19	0.33	0.30, 0.37	0.03	1864	31	0.28	0.23, 0.32	0.03	4528	19	−0.06	−0.09, −0.03	0.01
Between-subjects studies	1121	5	0.29	0.23, 0.35	0.06	1044	10	0.32	0.26, 0.37	0.05	3846	7	−0.02	−0.05, 0.01	0.00
Within-subject studies	1900	14	0.36	0.32, 0.41	0.01	820	21	0.22	0.15, 0.27	0.00	682	12	−0.32	−0.38, −0.23	0.04
Highly engaging methods (overall)	886	12	0.58	0.52, 0.64	0.03	2019	16	0.34	0.30, 0.38	0.01	3068	9	−0.23	−0.26, −0.19	0.01
Between-subjects studies	609	7	0.52	0.45, 0.60	0.02	1553	10	0.33	0.29, 0.38	0.01	1588	6	−0.12	−0.17, −0.07	0.00
Within-subject studies	277	5	0.71	0.59, 0.83	0.02	105	4	0.46	0.31, 0.61	0.03	1480	3	−0.34	−0.38, −0.29	0.01

Note. n = total number of individuals; *k* = number of study effects; M_ρ = estimated mean correlation corrected for dependent variable unreliability (mean ρ); CI = confidence interval around estimated M_ρ; V_ρ = estimated variance of effects.

agenda, including not only *what* interventions are most effective in enhancing worker safety and health but also *why* they are effective.

Our findings indicate that the most engaging methods of safety training are, on average, approximately 3 times more effective than the least engaging methods in promoting knowledge and skill acquisition. An alternative way to differentiate the effects of the most engaging methods on knowledge gain from the effects of other methods is to compute "common language" effect sizes.[126] In a given study, the probability of a randomly selected individual from the most engaging training group exceeding a randomly selected individual from the least engaging training group in terms of knowledge acquired was 0.74; the analogous probability was 0.70 in a comparison of randomly selected individuals from the most engaging and moderately engaging groups. The magnitudes of such differences alone have broad organizational and public policy implications for the manner in which safety and health training—in particular, mandated training—is delivered.

Unexpectedly, the least, moderate, and most engaging safety and health training methods had somewhat comparable overall mean levels of effectiveness with respect to improvements in behavioral performance. We cautiously interpret this pattern of results to be a function of the fact that the training methods classified as least engaging and moderately engaging were often associated with more fundamental, routine types of tasks (e.g., applying sunscreen, inserting hearing devices, keeping work areas clear of obstacles), whereas the methods classified as most engaging often involved advanced, complex work activities (e.g., properly handling needles to avoid exposure to bloodborne pathogens, selecting and using respirators to avoid neurotoxic exposures). We suspect that differences in the complexity of performance tasks, coupled with suboptimal measures of more complex tasks, influenced our results.[4,127]

Our findings indicate that the most engaging methods of safety training are, on average, most effective in reducing negative outcomes such as accidents. The greater effectiveness of more engaging, hands-on training in reducing negative outcomes and increasing knowledge acquisition lends support to the calls of researchers and practitioners advocating the design and implementation of learner-centered, participatory approaches to worker safety and health training,[74,128–130] and such a finding is consistent with the results of previous meta-analytic studies of training evaluation in other domains.[131] Furthermore, our findings are consistent with recommendations in other areas of the literature advocating for the active involvement of workers so that the advanced knowledge necessary for fault prevention can be developed (e.g., anticipatory responses to problem situations in manufacturing contexts).[132,133]

In a broader sense, the present results provide guidance for the design and delivery of educational interventions targeted toward the public health workforce.[134–136] Efforts to increase the capacity of this workforce as well as the capacity of the public to respond to threats, react to emergency events, and simply engage in safe behavior must be achieved, in part, through continued education programs.[1,137–139] Designing and implementing effective training is central to these efforts.

Our results have important implications that should be considered in light of the current push toward greater use of distance learning training in preparing the public health workforce.[140–143] Our findings suggest that, to the extent possible, computer-based and distance learning methods should, in some manner, include active participation on the part of learners (e.g., modeling, feedback, and dialogue) to enhance their knowledge acquisition and increase their preparedness. To date, most computer-based and distance safety training has been rather passive, including directional feedback rather than facilitating the types of dialogue that would engender action-focused reflection.[144] Our recommendations concerning active worker participation and dialogue as accompaniments to computer-based and distance learning methods of health and safety training are fully consistent with theoretical models concerning distance learning and education.[145,146]

Another important finding of this study relevant to the design and evaluation of safety and health training was that between-subjects and within-subject study designs yielded similar results with respect to knowledge acquisition. Despite cautionary issues concerning potential threats to the internal and external validity of within-subject study designs,[147] our results demonstrate that studies involving such designs provide theoretically interpretable findings that are consistent with findings from between-subjects studies in the domain of worker safety and health training. Given that within-subject designs generally involve greater statistical power than between-subjects designs[27] and that withholding safety and health training from a comparison group (or locating a control/comparison group) for the purpose of program evaluation is often ethically questionable in safety-related work, our findings encourage greater use of within-subject designs in evaluating safety and health training.

The meta-analytic results described here are also necessary building blocks for any effort aimed at estimating the incremental costs or benefits of different types of safety and health training.[148] Such information is particularly important given today's increased pressures to justify and improve health and safety investments.[12] Our results suggest that moderately and highly engaging training methods are, on average, more time consuming and probably more expensive in the short term but that they are potentially less costly and more effective in the long term while better ensuring worker and public safety.

In addition, the trends in the magnitudes of our results across dependent variable categories are consistent with predictions from job performance theories. Job performance theories posit that interventions (e.g., safety and health training) are expected to have their greatest impact on more proximal outcome variables such as knowledge acquisition and their least impact on more distal, low-base-rate phenomena such as accidents. The reasoning is that knowledge acquisition is expected to mediate the relationships between such interventions and their more distal outcomes.[8,149] Accordingly, in evaluating the effectiveness of interventions, safety and health training researchers and practitioners need to focus much more on the development of well-designed, standardized measures of safety knowledge. Furthermore, because training effects for relatively distal outcomes such as on-the-job performance and injuries are likely to be more affected by intervening, time-related variables than training effects for relatively proximal measures such as knowledge assessments, we stress the need for future research examining the influence of situational variables (i.e., organizational safety climate, opportunities to apply knowledge and skills, type of work, country/culture, and so on)[150,151] on safety and health training effectiveness.

We also encourage future primary empirical research addressing some of the limitations of the present meta-analysis (e.g., primary studies related to distributions with small numbers of effects). Moreover, we encourage primary and meta-analytic research designed to extend our study and examine safety and health training relative to more specific safety knowledge, safety performance, and safety and health outcome variables, in addition to examining the role of individual difference variables (e.g., worker motivation, work experience). Our future success in promoting safe work behaviors and reducing the negative consequences of unsafe behaviors will largely depend on our ability to improve our conceptualizations and communications of the effectiveness of safety and health training interventions. ■

About the Authors

Michael J. Burke is with the Organizational Behavior Area, A.B. Freeman School of Business, and the Department of Environmental Health Sciences, School of Public Health and Tropical Medicine, Tulane University, New Orleans, La. Sue Ann Sarpy is with the South Central Center for Public Health Preparedness and the Department of Environmental Health Sciences, School of Public Health and Tropical Medicine, Tulane University. Kristin Smith-Crowe is with the David Eccles School of Business, University of Utah, Salt Lake City. Suzanne Chan-Serafin, Rommel O. Salvador, and Gazi Islam are with the Department of Organizational Behavior, A.B. Freeman School of Business, Tulane University, New Orleans.

Requests for reprints should be sent to Michael J. Burke, PhD, A.B. Freeman School of Business, Tulane University, New Orleans, LA 70118 (e-mail: mburke1@tulane.edu).

This article was accepted April 1, 2005.

Contributors

M.J. Burke and S.A. Sarpy originated the study, supervised the research, interpreted the statistical analyses, and wrote the article. K. Smith-Crowe organized the literature searches and the gathering of primary studies and conducted the statistical analyses with the assistance of S. Chan-Serafin, R.O. Salvador, and G. Islam.

All of the authors participated in coding of study characteristics and reviewed and commented on drafts of the article.

Acknowledgments

Michael J. Burke would like to express his appreciation to the Institute of Work Psychology at the University of Sheffield, which generously supported the completion of this work during fall 2004. This article was based, in part, on Michael J. Burke's presidential address presented at the 19th Annual Conference of the Society for Industrial and Organizational Psychology, April 2004, Chicago, Ill.

We would like to thank Ann Anderson (Tulane University School of Public Health and Tropical Medicine) for commenting on the final version of this article. In addition, Ronald Landis (Department of Psychology, Tulane University) and Arthur Brief (Freeman School of Business, Tulane University) commented on other aspects of the study, including our interpretation of the findings.

Human Participant Protection

No protocol approval was needed for this study.

References

1. Rudman WB, Clarke RA, Metzl JF. *Emergency Responders: Drastically Underfunded, Dangerously Unprepared.* New York, NY: Council on Foreign Relations; 2003.

2. Bureau of Labor Statistics. *Workplace Injuries and Illnesses in 2001*. Washington, DC: US Dept of Labor; 2002. USDL publication 02-687.

3. Overman S. Ireland: Safety program can cut SME insurance costs. Available from: http://www.shrm.org/global/news_published/CMS_011278.asp. Accessed January 15, 2005.

4. Burke MJ, Bradley J, Bowers HN. Health and safety training programs. In: Edwards JE, Scott J, Raju NS, eds. *The Human Resources Program Evaluation Handbook.* Thousand Oaks, Calif: Sage Publications; 2003: 429–446.

5. Colligan MJ, Cohen A. The role of training in promoting workplace safety and health. In: Barling J, Frone MR, eds. *The Psychology of Workplace Safety.* Washington, DC: American Psychological Association; 2004:223–248.

6. Ford JK, Fisher S. The transfer of safety training in work organizations: a systems perspective to continuous learning. *Occup Med.* 1994;9:241–259.

7. Vojtecky MA, Berkanovic E. The evaluation of health and safety training. *Int Q Community Health Educ.* 1984;5:277–286.

8. Burke MJ, Sarpy SA. Improving safety and health through interventions. In: Hoffman DE, Tetrick L, eds. *Health and Safety in Organizations: A Multilevel Perspective.* San Francisco, Calif: Jossey-Bass Publishers; 2003: 56–90.

9. Cohen A, Colligan MJ. *Assessing Occupational Safety and Health Training.* Cincinnati, Ohio: National Institute for Occupational Safety and Health; 1998. NIOSH publication 98-145.

10. Dannenberg AL, Fowler CJ. Evaluation of interventions to prevent injuries: an overview. *Inj Prev.* 1998;4:141–147.

11. *National Occupational Research Agenda: An Update.* Washington, DC: US Dept of Health and Human Services, National Institute for Occupational Safety and Health; 2003. NIOSH publication 2003-148.

12. Goldenhar LM, LaMontagne AD, Katz T, Heaney C, Landsbergis P. The intervention research process in occupational safety and health: an overview from the National Occupational Research Agenda intervention effectiveness research team. *J Occup Environ Med.* 2001;43:616–622.

13. van der Klink JJL, Blonk RWB, Schene AH, van Dijk FJH. The benefits of interventions for work-related stress. *Am J Public Health.* 2001;91:270–276.

14. Huddock SD. The application of educational technology to occupational safety and health training. *Occup Med.* 1994;9:201–210.

15. Anderson JR. *Cognitive Psychology and Its Implications.* New York, NY: Freeman; 1985.

16. Bandura A. *Social Foundations of Thought and Action.* Englewood Cliffs, NJ: Prentice Hall; 1986.

17. Hacker W. Action regulation theory: a practical tool for the design of modern work processes? *Eur J Work Organ Psychol.* 2003;12:105–130.

18. Holman D. A dialogical approach to skill and skilled activity. *Hum Relations.* 2000;53:957–980.

19. Holman D, Pavlica K, Thorpe R. Rethinking Kolb's theory of experiential learning in management education. *Manage Learning.* 1997;28:135–148.

20. Frese M, Zapf D. Action as the core of work psychology: a German approach. In: Triandis HC, Dunnette MD, Hough LM, eds. *Handbook of Industrial and Organizational Psychology.* Palo Alto, Calif: Consulting Psychologists Press; 1994:271–340.

21. Isaac S, Michael WB. *Handbook in Research and Evaluation.* 3rd ed. San Diego, Calif: Educational and Industrial Testing Services; 1995.

22. Cronbach LJ. *Essentials of Psychological Testing.* 5th ed. New York, NY: Harper & Row Publishers; 1990.

23. Cronbach LJ. Internal consistency of tests: analyses old and new. *Psychometrika.* 1988;53:63–70.

24. Shadish WR, Robinson L, Lu C. *ES: A Computer Program for Effect Size Calculation.* St. Paul, Minn: Assessment Systems Corp; 1999.

25. Lipsey MW, Wilson DB. *Practical Meta-Analysis.* Thousand Oaks, Calif: Sage Publications; 2001.

26. Raju NS, Burke MJ, Normand J, Langlois G. A new meta-analytic approach. *J Appl Psychol.* 1991;76: 432–446.

27. Hunter JE, Schmidt FL. *Methods of Meta-Analysis.* Newbury Park, Calif: Sage Publications; 1990.

28. Burke MJ, Landis R. Methodological and conceptual challenges in conducting meta-analyses. In: Murphy K, ed. *Validity Generalization: A Critical Review.* Mahwah, NJ: Lawrence Erlbaum Associates; 2003: 287–309.

29. Alavosius MP, Sulzer-Azaroff B. The effects of performance feedback on the safety of client lifting and transfer. *J Appl Behav Anal.* 1986;19:261–267.

30. Albers JT, Li Y, Lemasters G, Sprague S, Stinson R, Bhattacharya A. An ergonomic education and evaluation program for apprentice carpenters. *Am J Ind Med.* 1997;32:641–646.

31. Arcury TA, Quandt SA, Austin CK, Preisser J, Cabrera LF. Implementation of EPA's Worker Protection Standard training for agricultural laborers: an evaluation using North Carolina data. *Public Health Rep.* 1999;114:459–468.

32. Arnetz JE, Arnetz BB. Implementation and evaluation of a practical intervention programme for dealing with violence towards health care workers. *J Adv Nurs.* 2000;31:668–680.

33. Askari E, Mehring J. Human immunodeficiency virus/acquired immunodeficiency syndrome training from a union perspective. *Am J Ind Med.* 1992;21: 711–720.

34. Azizi E, Flint P, Sadetzki S, et al. A graded work site intervention program to improve sun protection and skin cancer awareness in outdoor workers in Israel. *Cancer Causes Control.* 2000;11:513–521.

35. Baker DJ. Effects of video-based staff training with manager-led exercises in residential support. *Ment Retard.* 1998;36:198–204.

36. Barnett PG, Midtling JE, Valasco AR, et al. Educational intervention to prevent pesticide-induced illness of field workers. *J Fam Pract.* 1984;19:123–125.

37. Bosco J, Wagner J. A comparison of the effectiveness of interactive laser disc and classroom video tape for safety instruction of General Motors workers. *Educ Technol.* 1988;28:15–22.

38. Calabro K, Weltge A, Parnell S, Kouzekanani K, Ramirez E. Intervention for medical students: effective infection control. *Am J Infect Control.* 1998;26: 431–436.

39. Caparaz A, Rice C, Graumlich S, Radike M, Morawetz J. Development and pilot evaluation of a health and safety training program for foundry workers. *Appl Occup Environ Hyg.* 1990;5:595–603.

40. Carlton RS. The effects of body mechanics instruction on work performance. *Am J Occup Ther.* 1987;41:16–20.

41. Carrabba JJ, Field WE, Tormoehlen RL, Talbert BA. Effectiveness of the Indiana 4-H tractor program at instilling safe tractor operating behaviors and attitudes in youth. *J Agricultural Safety Health.* 2000;6:179–189.

42. Chaffin DB, Gallay LS, Wooley CB, Kuciemba SR. An evaluation of the effect of a training program on worker lifting postures. *Int J Ind Ergonomics.* 1986;1: 127–136.

43. Chhokar JS, Wallin JA. A field study of the effect of feedback frequency on performance. *J Appl Psychol.* 1984;69:524–530.

44. Cohen HH, Jensen RC. Measuring the effectiveness of an industrial lift truck safety training program. *J Safety Res.* 1984;15:125–135.

45. Cole BL, Mallet LG, Haley JV, et al. *Research and Evaluation Methods for Measuring Nonroutine Mine Health and Safety Skills.* Vol. 1. Lexington, Ky: US Bureau of Mines; 1988.

46. Coutts MC, Graham K, Braun K, Wells S. Results of a pilot program for training bar staff in preventing aggression. *J Drug Educ.* 2000;30:171–191.

47. Curwick CC, Reeb-Whitaker C, Connon CL. Reaching managers at an industry association conference: evaluation of ergonomics training. *Am Assoc Occup Health Nurs J.* 2003;51:464–469.

48. Daltroy LH, Iversen MD, Larson MG, et al.

Teaching and social support: effects on knowledge, attitudes, and behaviors to prevent low back injuries in industry. *Health Educ Q.* 1993;20:43–62.

49. Daltroy LH, Iversen MD, Larson MG, et al. A controlled trial of an educational program to prevent low back injuries. *N Engl J Med.* 1997;337:322–328.

50. DeVries JE, Burnette MM, Redmon WK. AIDS prevention: improving nurses' compliance with glove wearing through performance feedback. *J Appl Behav Anal.* 1991;24:705–711.

51. Dortch HL, Trombly CA. The effects of education on hand use with industrial workers in repetitive jobs. *Am J Occup Ther.* 1990;44:777–782.

52. Eckerman DA, Lundeen CA, Steel A, Fercho HL, Ammerman TA, Anger WK. Interactive training versus reading to teach respiratory response. *J Occup Health Psychol.* 2002;7:313–323.

53. Evanoff BA, Bohr PC, Wolf LD. Effects of a participatory ergonomics team among hospital orderlies. *Am J Ind Med.* 1999;35:358–365.

54. Ewigman BG, Kivlahan CH, Hosokawa MC, Horman D. Efficacy of an intervention to promote use of hearing protective devices by firefighters. *Public Health Rep.* 1990;105:53–59.

55. Feldstein A, Valanis B, Vollmer W, Stevens N, Overton C. The Back Injury Prevention Project pilot study. *J Occup Environ Med.* 1993;35:114–120.

56. Fox CJ, Sulzer-Azaroff B. Increasing completion of accident reports. *J Safety Res.* 1987;18:65–71.

57. Froom P, Kristal-Boneh E, Melamed S, Shalom A, Ribak J. Prevention of needle-stick injury by the scooping-resheathing method. *Am J Ind Med.* 1998;34:15–19.

58. Gerbert B, Maguier B, Badner V, et al. Changing dentists' knowledge, attitudes, and behaviors relating to AIDS: a controlled educational intervention. *J Am Dent Assoc.* 1988;51:668–672.

59. Girgis A, Sanson RW, Watson A. A workplace intervention for increasing outdoor workers' use of solar protection. *Am J Public Health.* 1994;84:77–81.

60. Goldrick BA. Programmed instruction revisited: a solution to infection control in service education. *J Cont Educ Nurs.* 1989;20:222–227.

61. Haiduven DJ, DeMaio TM, Stevens DA. A five-year study of needlestick injuries: significant reduction associated with communication, education, and convenient placement of sharps containers. *Infect Control Hosp Epidemiol.* 1992;13:265–271.

62. Hopkins BL. *An Investigation of the Durability of Behavioral Procedures for Reducing Workers' Exposures to a Suspect Carcinogen.* Cincinnati, Ohio: National Institute for Occupational Safety and Health; 1984.

63. Hultman G, Nordin M, Ortengren R. The influence of a preventive educational programme on trunk flexion in janitors. *Appl Ergonomics.* 1984;15:127–133.

64. Hurlebaus A, Link S. The effects of an aggressive behavior management program on nurses' levels of knowledge, confidence, and safety. *J Nurs Staff Dev.* 1997;13:260–265.

65. Infantino JA, Musingo SY. Assaults and injuries among staff with and without training in aggression control techniques. *Hosp Community Psychol.* 1985;36:1312–1314.

66. Inman C, Blanciforti L. *Observed Versus Reported Behaviors and a Theoretically-Based Eye Injury Intervention for Carpenters: Injury Insights.* Itasca, Ill: National Safety Council Research and Statistical Services; 2003.

67. Knobloch MJ, Broste SK. A hearing conservation program for Wisconsin youth working in agriculture. *J Sch Health.* 1998;68:313–318.

68. Komaki J, Barwick KD, Scott LR. A behavioral approach to occupational safety pinpointing and reinforcing safe performance in a food manufacturing plant. *J Safety Res.* 1978;63:434–445.

69. Komaki J, Heinzmann AT, Lawson L. Effect of training and a component analysis of a behavioral safety program. *J Appl Psychol.* 1980;65:261–270.

70. Leslie JH, Adams SK. Programmed safety through programmed learning. *Hum Factors.* 1973;15:223–236.

71. Ludwig TD, Geller ES. Improving the driving practices of pizza deliverers: response generalization and moderating effects of driving history. *J Appl Behav Anal.* 1991;24:31–44.

72. Ludwig TD, Geller ES. Assigned versus participative goal setting and response generalization: managing injury control among professional pizza deliverers. *J Appl Psychol.* 1997;82:253–261.

73. Lueveswanij S, Nittayananta W, Robison VA. Changing knowledge, attitudes, and practices of Thai oral health personnel with regard to AIDS: an evaluation of an educational intervention. *Community Dent Health.* 2000;17:165–171.

74. Luskin J, Somers C, Wooding J, Levenstein C. Teaching health and safety: problems and possibilities for learner-centered training. *Am J Ind Med.* 1992;22:665–676.

75. Lynch P, Cummings MJ, Roberts PL, Herriott MJ, Yates B, Stamm WE. Implementing and evaluating a system of generic infection precautions: body substance isolation. *Am J Infect Control.* 1990;18:1–12.

76. Lynch RM, Freund A. Short-term efficacy of back injury intervention project for patient care providers at one hospital. *Am Ind Hyg Assoc J.* 2000;61:290–294.

77. Maples TW, Jacoby JA, Johnson DE, Ter Har GL, Buckingham FM. Effectiveness of employee training and motivation programs in reducing exposure to inorganic lead and lead alkyls. *Am Ind Hyg Assoc J.* 1982;43:692–694.

78. Marsh P, Kendrick D. Injury prevention training: is it effective? *Health Educ Res.* 1998;13:47–56.

79. Martyny JW, Buchan RM, Keefe TJ, Blehm KD. Impact of an OSHA onsite consultation program with an educational component on small businesses in Colorado. *Appl Ind Hyg.* 1988;3(6):12, 14–15.

80. Materna BL, Harrington D, Scholz P, et al. Results of an intervention to improve lead safety among painting contractors and their employees. *Am J Ind Med.* 2002;41:119–130.

81. Mattila M. Improving working practices and workplace safety through behavior analysis in the veneer industry. In: Das B, ed. *Advances in Industrial Ergonomics and Safety.* London, England: Taylor & Francis; 1990:957–961.

82. Mattila M, Hyodynmaa M. Promoting job safety in building: an experiment on the behavior analysis approach. *J Occup Accid.* 1988;9:255–267.

83. McCauley M. The effect of body mechanics instruction on work performance among young workers. *Am J Occup Ther.* 1990;44:402–407.

84. Melhorn J. A prospective study for upper-extremity cumulative trauma disorders of workers in aircraft manufacturing. *J Occup Environ Med.* 1996;38:1264–1271.

85. Michaels D, Zoloth S, Bernstein N, Kass D, Schrier K. Workshops are not enough: making right-to-know training lead to workplace change. *Am J Ind Med.* 1992;22:637–649.

86. Nasanen M, Saari J. The effects of positive feedback on housekeeping and accidents at a shipyard. *J Occup Accid.* 1987;8:237–250.

87. Parenmark G, Engvall B, Malmkvist AK. Ergonomic on-the-job training of assembly workers. *Appl Ergonomics.* 1988;19:143–146.

88. Parkinson DK, Bromet EJ, Dew MA, Dunn LO, Barkman M, Wright M. Effectiveness of the United Steel Workers of America coke oven intervention program. *J Occup Med.* 1989;31:464–472.

89. Peters RH. *Strategies for Improving Miner's Training.* Washington, DC: US Dept of Health and Human Services; 2002.

90. Porru S, Donato F, Apostoli P, Coniglio L, Duca P, Allision L. The utility of health education among lead workers: the experience of one program. *Am J Ind Med.* 1993;22:473–481.

91. Ray PS, Purswell JL, Schlegel RE. A behavioral approach to improve safety at the workplace. In: Das B, editor. *Advances in Industrial Ergonomics and Safety.* London, England: Taylor & Francis; 1990:983–988.

92. Ray WA, Taylor JA, Meador KG, et al. A randomized trial of a consultation service to reduce falls in nursing homes. *JAMA.* 1997;278:557–562.

93. Reber RA, Wallin JA. The effects of training, goal setting and knowledge of results on safe behavior: a component analysis. *Acad Manage J.* 1984;27:544–560.

94. Reber RA, Wallin JA, Chhokar JS. Reducing industrial accidents: a behavioral experiment. *Ind Relations.* 1984;23:119–125.

95. Reddell CR, Congleton JJ, Huchingson RD, Montgomery JF. An evaluation of a weightlifting belt and back injury prevention training class for airline baggage handlers. *Appl Ergonomics.* 1992;23:319–329.

96. Rhoton WW. A procedure to improve compliance with coal mine safety regulations. *J Organ Behav Manage.* 1980;2:243–250.

97. Rundio A Jr. Understanding microbiological concepts and computerized surveillance: enhancing professional practice. *Health Care Supervision.* 1994;12(3):20.

98. Saarela KL. An intervention program utilizing small groups: a comparative study. *J Safety Res.* 1990;21:149–156.

99. Saarela KL, Saari J, Alltonen M. The effects of an informational safety campaign in the shipbuilding industry. *J Occup Accid.* 1989;10:255–266.

100. Saari J. Management of housekeeping by feedback. *Ergonomics.* 1987;30:313–317.

101. Saari J, Nasanen M. The effect of positive feedback on industrial housekeeping and accidents: a long-term study at a shipyard. *Int J Ind Ergonomics.* 1989;4:201–211.

102. Sadler OW, Montgomery GM. The application of positive practice overcorrection to the use of hearing protection. *Am Ind Hyg Assoc J.* 1982;43:451–454.

103. Schwartz RK. Cognition and learning in industrial accident injury prevention: an occupational therapy perspective. In: Johnson JA, Jaffe E, eds. *Health Promotion and Preventive Programs: Models of Occupational Therapy Practice.* New York, NY: Haworth Press; 1989: 67–85.

104. Seto WH, Ching TY, Chu YB, Fielding F. Reduction of the frequency of needle recapping by effective education: a need for conceptual alteration. *Infect Control Hosp Epidemiol.* 1990;11:194–196.

105. Streff FM, Kalsher MJ, Geller ES. Developing efficient workplace safety programs: observations of response covariation. *J Organ Behav Manage.* 1993;13: 12–15.

106. Sulzer-Azaroff B, de Santamaria MC. Industrial safety hazard reduction through performance feedback. *J Appl Behav Anal.* 1980;13:287–295.

107. Symes AM, Graveling RA, Campbell SJ. *Risk Training and Materials Handling.* Edinburgh, Scotland: Institute of Occupational Medicine; 1992.

108. Troup JDG, Rauhala HH. Ergonomics and training. *Int J Nurs Stud.* 1987;24:325–330.

109. Uwakwe CB. Systematized HIV/AIDS education for student nurses at the University of Ibadan, Nigeria: impact on knowledge, attitudes and compliance with universal precautions. *J Adv Nurs.* 2000;32:416–424.

110. van Poppel MN, Koes BW, van der Ploeg, T, Smid T, Bouter LM. Lumbar supports and education for the prevention of low back pain in industry: a randomized controlled trial. *JAMA.* 1998;279:1789–1794.

111. Vaught C, Brinch MJ, Kellner HJ. *Instructional Mode and Its Effect on Initial Self-Contained Self-Rescuer Donning Attempts During Training.* Pittsburgh, Pa: US Bureau of Mines; 1988.

112. Videman T, Rauhala H, Asp S, et al. Patient-handling skill, back injuries, and back pain: an intervention study in nursing. *Spine.* 1989;14:148–156.

113. Wang H, Fennie K, He G, Burgess J, Williams AB. A training programme for prevention of occupational exposure to bloodborne pathogens: impact on knowledge, behaviour and incidence of needle stick injuries among student nurses in Changsha, People's Republic of China. *J Adv Nurs.* 2003;41:187–194.

114. Wertz DC, Sorenson JR, Liebling L, Kessler L, Heeren TC. Knowledge and attitudes of AIDS health care providers before and after education programs. *Public Health Rep.* 1987;102:248–254.

115. Whitby M, Stead P, Najman JM. Needlestick injury: impact of a recapping device and an associated education program. *Infect Control Hosp Epidemiol.* 1991;12:220–225.

116. Williams JH, Geller ES. Behavior-based intervention for occupational safety: critical impact of social comparison feedback. *J Safety Res.* 2000;31:135–142.

117. Williams TC, Zahed H. Computer-based training versus traditional lecture: effect on learning and retention. *J Business Psychol.* 1996;11:297–310.

118. Wolford R, Larson M, Merrick D, et al. *A Comparison of Safety-and-Health Training of Painters in Alaska, Oregon, and Washington.* Washington, DC: Center to Protect Workers' Rights; 1997.

119. Wong ES, Stotka JL, Chinchilli VM, Williams DS, Stuart G, Markowitz SM. Are universal precautions effective in reducing the number of occupational exposures among health care workers? *JAMA.* 1991;265: 1123–1128.

120. Wynn JS, Black S. Evaluation of retention of safety and survival training content versus industry standard for training. *Air Med J.* 1998;17:166–168.

121. Yarall M. Educating for hearing conversation. *Occup Health.* 1986;10:333–335.

122. Yassi A, Cooper J, Tate R, et al. A randomized controlled trial to prevent patient lift and transfer injuries of health care workers. *Spine.* 2001;26: 1739–1746.

123. Zohar D, Cohen A, Azar N. Promoting increased use of ear protectors in noise through information feedback. *Hum Factors.* 1980;22:69–79.

124. Bandura A. *Social Learning Theory.* Englewood Cliffs, NJ: Prentice Hall; 1977.

125. Frone MR, Barling J. Common themes and future directions. In: Barling J, Frone MR, eds. *The Psychology of Workplace Safety.* Washington, DC: American Psychological Association; 2004:299–306.

126. McGaw KO, Wong SP. A common language effect size statistic. *Psychol Bull.* 1992;111:361–365.

127. Burke MJ, Sarpy SA, Tesluk PE, Smith-Crowe K. General safety performance: a test of a grounded theoretical model. *Pers Psychol.* 2002;55:429–457.

128. Lippin TM, Eckman A, Calkin KR, McQuiston TH. Empowerment-based health and safety training: evidence of workplace change from four industrial sectors. *Am J Ind Med.* 2000;38:697–706.

129. Wallerstein N, Baker R. Labor education programs in health and safety. *Occup Med.* 1994;9: 305–320.

130. Wallerstein N, Weinger M. Health and safety education for empowerment. *Am J Ind Med.* 1992;22: 619–635.

131. Burke MJ, Day R. A cumulative study of the effectiveness of managerial training. *J Appl Psychol.* 1986; 71:232–245.

132. Chmiel N, Wall T. Fault prevention, job design, and the adaptive control of advanced manufacturing technology. *Appl Psychol Int Rev.* 1994;43:455–473.

133. Wall TD, Cordery JL, Clegg CW. Empowerment, performance, and operational uncertainty: a theoretical integration. *Appl Psychol Int Rev.* 2002;51:146–169.

134. Institute of Medicine. *The Future of the Public's Health in the 21st Century.* Washington, DC: National Academy Press; 2003.

135. Potter MA, Ley CE, Fertman CI, Eggleston MM, Duman S. Evaluating workforce development: perspectives, processes, and lessons learned. *J Public Health Manage Pract.* 2003;9:489–495.

136. Cioffi JP, Lichtveld MY, Tilson H. A research agenda for public health workforce development. *J Public Health Manage Pract.* 2004;10:186–192.

137. Tilson H, Gebbie KM. The public health workforce. *Annu Rev Public Health.* 2004;25:341–356.

138. Allegrante J, Moon R, Auld E, Gebbie KM. Continuing education needs of the current health education workforce. *Am J Public Health.* 2001;91:1230–1234.

139. *Preparing for Emergencies: What You Need to Know.* Croydon, England: Health Ministries Government; 2004.

140. *The Public Health Workforce: An Agenda for the 21st Century.* Washington, DC: US Dept of Health and Human Services; 1997.

141. Ellery J. Training the public health education workforce. *Am J Public Health.* 2002;92:1052–1053.

142. Gebbie KM, Hwang I. Preparing currently employed public health nurses for changes in the health system. *Am J Public Health.* 2000;90:716–721.

143. Tilson H, Gebbie KM. Public health physicians: an endangered species. *Am J Prev Med.* 2001;21: 223–240.

144. Sneizek JA, Wilkinson DC, Wadlington PL, Baumann MR. Training for crisis decision-making: psychological issues and computer-based solutions. *J Manage Information Systems.* 2002;18:147–168.

145. Garrison DR. Theoretical challenges for distance education in the 21st century: a shift from structural to transactional issues. *Int Rev Res Open Distance Learning.* 2000;1:1–17.

146. Moore MG. Theory of transactional distance. In: Keegan D, ed. *Theoretical Principles of Distance Education.* New York, NY: Routledge; 1993:22–38.

147. Campbell DT, Stanley JC. *Experimental and Quasi-Experimental Designs for Research.* Chicago, Ill: Rand McNally; 1963.

148. Cascio W. *Costing Human Resources: The Financial Impact of Behavior in Organizations.* Cincinnati, Ohio: South-Western Publishing; 2000.

149. Campbell JP. Modeling the performance prediction problem in industrial and organizational psychology. In: Dunnette MD, Hough LM, eds. *Handbook of Industrial and Organizational Psychology.* Palo Alto, Calif: Consulting Psychologists Press; 1990:687–732.

150. Smith-Crowe K, Burke MJ, Landis RS. Organizational climate as a moderator of safety knowledge-safety performance relationships. *J Organ Behav.* 2003; 24:861–876.

151. Gutenberg RL, Arvey RD, Osburn HG, Jeanneret PR. Moderating effects of decision-making/information processing job dimensions on test validities. *J Appl Psychol.* 1983;68:602–608.