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Performance and evaluation of small construction safety training simulations

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Background	Back- and fall-related injuries occur frequently in construction and are costly in terms of workers' compensation claims and lost productivity. Interventions are needed that address the susceptibility to these injuries.
Aims	The purpose of this study was to develop and test a safety training intervention for small construction companies (≤10 employees) in Kentucky, USA. This paper will focus on the performance and evaluation of these simulation exercises, not their effectiveness in preventing injuries.
Methods	The intervention consisted of six latent-image narrative simulation exercises targeted at prevention of back- or fall-related injuries, which emphasized both the economic impact of injuries and the benefits of individual and organizational prevention strategies. Participants included owner-operators, supervisors and employees. Analyses were completed to determine participant scores on the intervention along with their perceptions of the quality, realism and applicability of the training.
Results	Mean pooled performance scores (percentage correct) were 83.3% [standard deviation (SD) = 8.9, n = 143] for three back simulations and 85.2% (SD = 8.9, n = 159) for three fall-related simulations. Mean total evaluation scores (percentage of maximum) were 83.1% (SD = 11.6) and 85.5% (SD = 11.7) for the back and fall simulations, respectively. Quality and realism evaluation scores were significantly higher than scores for applicability to work.
Conclusion	Simulations were well received as safety training exercises. Given the heterogeneous work classifications found in small construction companies, it may be preferable to target safety intervention content to specific trades rather than aim for generality across trades.
Key words	Evaluation studies; intervention studies; occupational safety; prevention and control; workplace injuries.
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Introduction

Back and fall injuries contribute to a great number of lost work days. In Kentucky, USA, strains due to heavy lifting accounted for 18 806 (42%) of injuries and falls accounted for 9855 (20%) of all lost-time injuries reported in 2000 [1]. In 1998, injuries to the back and shoulder accounted for more than one-third of lost-time construction injuries and ~20% of lost-time construction injuries resulted from falls [2].

The frequency and potential severity of back and fall injuries make them costly in terms of workers' compensation claims and lost productivity. The disproportionate number of lost work days attributed to work-related fall and back injuries provided a rationale for developing

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simulation exercises to address work situations in construction that increase susceptibility to these types of injuries.

In Kentucky, as nationally in the US, small construction firms (≤10 employees) far outnumber larger contractors [3,4]. These companies are too small, too dispersed and too numerous for effective regulatory oversight from state or federal agencies charged with protecting workers from illness and injury. In addition, small construction companies rarely have formal employee safety programs.

Unfortunately, workers' compensation statistics in Kentucky do not include company size as a variable by which companies can be identified. Therefore, relatively little was known about claims experience or perceptions of injury risk and safe versus unsafe work behaviors among employees and owners of small construction companies in the state.

To reach the desired target population for this project, a partnership was formed between the Kentucky Injury Prevention and Research Center (KIPRC) and Kentucky Employers' Mutual Insurance (KEMI). KEMI is the workers' compensation state fund insurer for Kentucky and, therefore, the largest carrier for small business operations in the commonwealth. This partnership permitted recruitment of small construction companies statewide for participation in the intervention. KEMI estimated company size to be ≤10 employees based on the company's insurance policy payroll estimate. If the payroll was estimated at $10 000 or less, the company was considered to have 10 or fewer employees.

Translation of injury data into interactive narrative simulation exercises for the prevention of occupational injuries has been extensively researched in the mining industry, where 62 exercises have been developed and field-tested [5,6]. Narrative simulations have also been used with small family farming operations [7].

Narrative thinking involves knowing and understanding the world through stories heard, lived and told [8,9]. These stories commonly reflect trade-offs in which safety is compromised in the interest of maintaining productivity, for example saving time by not using fall protection [10].

Narrative simulations are reality-based exercises that translate key information into powerful and memorable mental images that allow the participant to experience a work situation or dilemma vicariously [5]. At key decision points with potential implications for injury or prevention, participants respond to a series of questions about what should take place or what the likely consequences of a course of action would be. This provides advantages over didactic instruction. Specifically, they require active responses from the learner and provide immediate feedback to reinforce correct decisions and redirect incorrect responses [11]. Therefore, it has been argued that simulations are more likely to change behavior than are didactic presentations of the same material [5,6].

Through focus group interviews, common themes that underlie unsafe work behaviors can be identified and used to develop interactive narrative simulations [12]. We conducted a series of eight focus group interviews of owner-operators and employees of 52 small construction firms (≤10 employees) in different geographic regions throughout Kentucky (n = 64). Focus groups were used to gather contextual material to develop a series of six narrative simulations pertaining to back and fall injuries in small construction companies. Examples of contextual insights gained from the focus groups included: identification of economic stressors; methods of evaluating or attempting to minimize risk of injury; and the long-term economic and social costs of both stressors and injuries (e.g. time and productivity lost in seeking and training replacements, damage to reputation as a safe company). Themes generated from the focus groups are shown in Table 1.

Lastly, because back and fall injuries are so common, an implicit assumption of the study was that it would be possible to develop simulations that would be relevant to workers across trades. That is, by focusing on activities such as lifting heavy objects or climbing ladders and common contingencies such as hurrying work or taking safety shortcuts, simulations could be developed that would not depend highly on the specific trades of participants. The purpose of this study was to evaluate the newly developed safety training simulation exercises and not to determine the effectiveness of the intervention in reducing injuries. The focus of the evaluation was participants' performance on the simulations and their perceptions of simulation quality, realism and applicability to their work.

Methods

Design

The study was conducted using a two-group, quasi-experimental design with a no-treatment control group. The intervention consisted of a series of three simulation exercises administered together. In the first year, the three simulations focused on back injuries; in the second year, they focused on fall-related injuries.

Sample

Sampling strategies and recruitment issues are detailed extensively elsewhere [13]. Briefly, companies were randomly selected from KEMI policyholders with standard industrial classification (SIC) codes in general,

Table 1. Themes embedded in simulation exercises

Title	Themes	Type of work	Injury event	Injury type
Bob's Builders	Inexperienced worker Hurry/pacing Coaching Improper lifting	Block laying	Yes	Back
Rogers' Remodeling	Clutter Planning Communication	Residential remodeling	Prevented	Back
Smitty's Drywall	Fatigue Workload Clutter Hurry Improper lifting	Drywall installation	Yes	Back
Up on the Roof	Inexperienced worker Planning Fall protection	Roof repair	Prevented	Fall
Deck Dilemma	Work site conditions Clutter Planning	Exterior deck	Yes	Fall
Off to a Late Start	Inexperienced workers Coaching Checking equipment	Vinyl siding installation	Yes	Fall

heavy and special construction trades with reported payroll <$10 000.

Companies in the intervention sampling frame received written invitations on project letterhead that clearly identified the project as a joint endeavor of KEMI and KIPRC. Letters were signed by the chief executive officer of KEMI and the project principal investigators and mailed to selected company owners. Project staff attempted to follow up on mailed invitations with a telephone contact to the company owner to further explain the study and the participation incentive (a 10% premium discount at policy renewal), answer questions and encourage participation.

On confirmation of eligibility to participate and the owner's agreement to participate, intervention packets were mailed. Owner-operators, supervisory personnel and employees were eligible. Intervention packets were to be distributed by the company owner to workers, completed at home and then mailed directly back to the investigators by the worker. Thus, owners were blind to employees' responses. The intervention packet consisted of an invitation to participate, informed consent, instructions for completion of simulations and measures, pre-test safety climate and demographic measures, three simulation exercises with associated evaluation questionnaires and an immediate post-test safety climate questionnaire. Return postage materials were also included.

Consenting participants were asked to provide their names and addresses on index cards so that they could receive follow-up materials, including a master answer booklet with detailed rationales for all simulation items. Approximately 4 months later, participants were mailed a delayed post-test and retrospective pre-test safety climate measure.

This paper focuses on performance and evaluation of the simulations to determine their validity and acceptability among workers, supervisors and owners of small construction firms in Kentucky. Development, testing and results for the safety climate measure and comparisons between intervention participants and controls are discussed elsewhere (P. Kidd, M. Parshall, S. Wojcik and T. Struttmann, in preparation).

Intervention and evaluation

Simulation structure and scoring

The simulations were presented as a typed problem booklet with appropriate line drawings to augment the story. Answers and their rationales were printed in answer booklets using a 'latent-image' format (i.e. with answers printed in invisible ink). By marking responses with a latent-image marking pen (included in the intervention packet), participants 'developed' the invisible ink and received immediate feedback on their selections.

Each question represented a particular decision point in the story for which there were multiple possible responses. Questions could have either multiple correct response options or only one correct response. Examples of both types of questions are shown in the Appendix. When the invisible ink was developed, correct and incorrect responses were immediately identified and appropriate feedback and direction were provided (see the Appendix).

The foregoing response formats yield two types of correct choices (i.e. choosing a 'correct' response or not

choosing a distracter) and two types of incorrect choices (not choosing a 'correct' response or choosing a distracter). Accordingly, exercise performance scores reflect the total number of correct choices made by a participant. Each question (i.e. decision point with multiple responses) contributed an equal percentage of the total score (number of questions divided by 100). This permits comparison of scores across participants without overvaluing decisions with more response options or those with details that might have greater salience for workers in a particular trade in a given simulation. Because a series of three simulations with a common focus (i.e. back injury/prevention or fall injury/prevention) constituted the intervention, scores were pooled across simulations with a common focus to allow examination of mastery of common content, issues and decisions.

Simulation evaluations

Each simulation answer booklet was accompanied by a 20-item, Likert-type, evaluation questionnaire. Based on prior experience with similar evaluations [5–7], we anticipated that the questionnaire items would coalesce around three dimensions. This expectation was supported by principal axis factor analysis, with varimax rotation for each evaluation questionnaire.

The three evaluation dimensions were labeled: exercise quality (three items), realism (three items) and applicability to work (nine items). Scores for each evaluation domain were normalized as a percentage of the maximum possible for each subscale.

Data analysis

Data were analyzed using SPSS for Windows 9.0 (SPSS Inc., 1998). Demographic variables were analyzed descriptively with measures of central tendency and variability appropriate to the level of measurement of a given variable. Inferential analyses included independent and dependent Student's *t*-tests and one-way analysis of variance with post hoc Fisher's least significant difference tests as appropriate. To adjust for multiple comparisons, $P < 0.01$ was the criterion for statistical significance.

Psychometric analyses for the simulations included item-to-question and item-to-total correlations and the Kuder–Richardson-20 (KR-20) statistic for internal consistency. Interpretation of internal consistency statistics is problematic, however, because simulation exercises typically violate two underlying assumptions for reliability estimates. Specifically, items are not sampled from a single domain (cf. questions A and B in the Appendix) and, for questions with only one correct response, items are not independent because participants are instructed to choose again if they do not choose the best option initially (see question B in the Appendix). These violations of underlying assumptions are unavoidable, because the simulations must portray credibly complex contingencies in a work situation and because they function as learning and decision-making exercises in addition to testing knowledge.

Results

Sample characteristics

Workers from a variety of small construction trades in Kentucky completed the simulations (39% general contractors, 13% plumbing/heating/air conditioning, 11% electrical, 11% excavation and 26% other special trades). Three back simulations were completed by 143 individuals from 73 companies. The three fall simulations were completed by 159 individuals from 92 companies.

In general, the level of experience in construction was high. Among owner-operators and supervisory personnel, the mean [standard deviation (SD)] years of experience were 18.8 (11.3) and 20.9 (11.0) in, respectively, the first and second intervention years. For non-supervisory employees, the corresponding experience levels were 9.2 (8.0) and 8.8 (8.0) years, respectively.

Simulation performance

Performance data in Table 2 show mastery scores (percentage correct) by simulation. The pooled mean performance scores for the three back and three fall simulations were 83.3 (SD = 8.9) and 85.2% (SD = 8.9), respectively. Detailed item analysis for all simulations is available elsewhere [13].

The performance and evaluation pooled scores from the three simulations in each year were not significantly correlated with age, education, experience, job position, or number of career injuries reported. There were no significant differences in overall simulation performance between owner-operators or supervisors versus non-supervisory personnel. There was no significant correlation between evaluation scores and simulation

Table 2. Performance results for simulation exercises

Simulation title	Mean	SD	Mode	*n*	KR-20
Back simulations					
Bob's Builders	79.71	10.09	83	143	0.45
Rogers' Remodeling	86.42	11.84	95	143	0.61
Smitty's Drywall	83.70	10.71	97	142	0.67
Pooled score	83.3	8.9			
Fall simulations					
Up on the Roof	87.84	10.53	100	158	0.55
Deck Dilemma	78.80	10.33	85	158	0.63
Off to a Late Start	89.05	11.65	100	157	0.68
Pooled score	85.2	8.9			

performance. Thus, evaluation scores were unrelated to subjects' feelings about how well or poorly they had performed.

Simulation evaluation

On the whole, evaluations were favorable. Each subscale for each simulation evaluation had good to excellent internal consistency. Tables 3 and 4 summarize the evaluation subscale and total scores and internal consistency estimates (Cronbach's α) for the back and fall simulations, respectively. Subscale scores for realism and exercise quality were significantly higher than scores on the applicability to work subscale in both years, with $t(139) \geq 7.1$, $P < 0.001$ for the back simulations and $t(144) \geq 3.7$, $P < 0.001$ for the fall simulations.

Simulation evaluation scores for the fall simulations (Table 4) showed modest increases on the applicability to work subscale for each of the simulations relative to the back simulation evaluations (Table 3). However, this translated into only a marginal overall improvement in evaluation scores (~2 percentage points on average).

Discussion

The lack of differences by employment position (owner-operators/supervisors versus non-supervisory personnel) mirrored findings from qualitative analysis of the focus groups from which simulation themes were derived. In those focus groups, we did not find any systematic differences by employment status in terms of opinions or attributions about safety issues, risks, protective factors, or desirable and undesirable traits of workers with respect to safety [13]. Thus, our data suggest that the safety attitudes and values of owners, and their ability to hire and retain workers who either share those values or in whom they can be instilled, are critically important in small construction companies. To

Table 3. Simulation evaluation scores for back simulations

				Percentiles			
Simulation title	Subscale	Mean %	SD	25th	Median	75th	Cronbach's α
Bob's Builders (n = 136)	Applicability to work (nine items)	76.14	17.02	64	78	91	0.94
	Realism (three items)	87.84	13.53	80	93	100	0.81
	Quality (three items)	84.31	13.83	80	87	93	0.72
	Total evaluation (%)	82.77	11.57	76	83	92	
Rogers' Remodeling (n = 138)	Applicability to work (nine items)	77.60	16.99	68	79	91	0.95
	Realism (three items)	87.05	12.68	80	87	100	0.78
	Quality (three items)	85.65	13.06	80	87	100	0.73
	Total evaluation (%)	83.44	12.12	76	84	94	
Smitty's Drywall (n = 135)	Applicability to work (nine items)	77.30	18.72	67	78	93	0.96
	Realism (three items)	87.16	13.50	80	87	100	0.83
	Quality (three items)	85.58	14.80	80	87	100	0.81
	Total evaluation (%)	83.35	12.91	75	83	95	
	Pooled score	83.1	11.6				

Table 4. Simulation evaluation scores for fall simulations

				Percentiles			
Simulation title	Subscale	Mean %	SD	25th	Median	75th	Cronbach's α
Up on the Roof (n = 153)	Applicability to work (10 items)	81.62	17.12	69	86	98	0.94
	Realism (four items)	86.80	15.04	80	90	100	0.80
	Quality (five items)	87.71	11.80	80	92	100	0.71
	Total evaluation (%)	84.99	12.43	77	88	96	0.93
Deck Dilemma (n = 156)	Applicability to work (10 items)	82.42	17.16	72	86	100	0.96
	Realism (four items)	86.89	14.20	80	90	100	0.80
	Quality (five items)	87.28	12.02	76	88	100	0.73
	Total evaluation (%)	85.05	12.97	77	88	97	0.94
Off to a Late Start (n = 151)	Applicability to work (10 items)	85.51	15.91	78	90	100	0.96
	Realism (four items)	89.27	13.69	85	95	100	0.84
	Quality (five items)	87.13	12.46	76	92	100	0.71
	Total evaluation (%)	86.75	11.78	78	90	97	0.93
	Pooled score	85.5	11.7				

some extent, this may offset or compensate for limited access to formal structured safety programs.

The simulation exercises emphasized cognitive engagement with commonly encountered work situations. By focusing on situations rather than tasks, we hoped that participants would find them highly realistic and applicable to their work. At a minimum, the simulation exercises needed to demonstrate satisfactory evaluation scores in these three areas for there to be adequate transfer of concepts and issues into the work arena. The results presented here suggest that owners and employees found the simulations realistic but not as applicable to their work as we had hoped. However, given the generally high level of construction experience in the sample, the consistently high realism scores suggest at least some degree of content validity in the exercises.

Internal consistency reliability for the applicability to work items was uniformly high across all simulations. Thus, the lower scores for this domain were not artifacts of the evaluation questionnaire structure or item content. For judgements of realism and exercise quality, 75% of the sample gave a rating of at least 80% of the maximum possible, whereas <50% of the sample gave ratings in that range for applicability to work.

Because each back injury exercise in the first year was titled after a particular trade or activity (e.g. masonry, carpentry, drywall; see Table 1), participants who worked in other trades may have prejudged simulation content to be less applicable to their trade or primary work activity. We in fact received a number of interventions returned uncompleted with comments indicating that the individual did not complete the simulation because they were not in that line of work. Therefore, we made the titles of the fall simulations more general (i.e. without reference to the particular trade or work situation depicted in the story) in the hope that the participants would not prejudge the applicability of a given exercise to their work. This appeared to result in slight improvement of the applicability to work scores in year 2 (cf. Table 4 with Table 3), but they remained lower than the exercise quality or realism scores. Therefore, designing safety training using scenarios intended to be generic enough to apply across trades may compromise perceived applicability to work, even when participants find the materials realistic and well prepared.

We believe our findings may be indicative of a more general problem faced by investigators interested in impacting safety practices in the small construction business sector. Despite evaluations from a highly experienced sample that suggested the exercises were well constructed and realistic, we clearly fell short of the mark in terms of perceived applicability to work. Fully 60% of our sample were engaged in work that was classified as 'special trades'. We suggest that the conceptualization of 'small construction companies' as a workforce sector may make sense from a standpoint of descriptive socioeconomic classification, but may not reflect the way in which owners and employees of such companies perceive the nature of their work, classify their occupational identities, or evaluate occupational injury risks.

One strength of this study is that the simulations were designed with significant input from the user population and thus embedded concepts and beliefs common to them. We do not have any clear evidence of effectiveness in terms of reducing injuries or worker compensation claims, but our data support the realism and overall quality of the exercises from the point of view of participants. It may be the case that these exercises were valued more as a reinforcement of good safety practices than as a source of new knowledge or impetus for behavioral change. In this highly experienced sample, reinforcement of good safety practices appears to have been valued in its own right and may even be as valuable as teaching new knowledge and skills in helping safe workers remain safe. More study is needed to identify the link between safety training reinforcement and health, injury and economic outcomes.

Further work is needed to ascertain whether greater trade-specificity of content would lead to higher evaluation scores for applicability to work. In addition, studies need to be conducted to determine the effectiveness of this simulation intervention in reducing injuries and claims. Future research should examine the relationships among safety reinforcement interventions, new safety knowledge and safe work practices. It may be that reinforcement interventions, such as the simulations in this study, provide an added value to promoting safe work practices.

Conclusions

Disproportionate numbers of lost work days in construction trades are attributable to back and fall injuries. Six latent-image narrative simulations pertaining to back and fall injuries were developed and tested. Overall, intervention participants performed well on the simulations. Participants generally gave the simulations favorable evaluations, especially with respect to exercise realism and quality. We believe that the high level of experience in our sample justifies an assertion that members of the intervention group were, in essence, content experts whose evaluation data were consistent and credible. Given the heterogeneous work classifications found in 'small construction companies', we conclude that it may be preferable to target safety intervention content to specific trades rather than aim for generality across trades.

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Appendix: simulation question and answer formats (question A, multiple correct responses; question B, only one correct response)

Background

Joe is a carpenter working for Rogers' Remodeling. He has 2 years experience. The company owner, Mike Rogers, has recently sent Joe out on jobs alone. Mike has confidence in Joe's craftsmanship. Mike assigned Joe to a job of remodeling and expanding a kitchen. Joe is to remove old cabinets and install new ones.

You are an experienced carpenter who has been with the company for 10 years. You've been assigned to work with Joe later in the day after you finish at another job. Before Joe went out, Mike told him to be careful and do a good job. Mike also told Joe that you would be coming by later in the day to help him hang the cabinets.

Problem

Joe arrives on the job. The kitchen area is a mess. There are pieces of scrap 2 × 4s lying on the floor. Drywall scraps and concrete from jackhammering are lying around. There are PVC pipes for the new lines on the floor. Joe realizes that it would take at least a couple of hours to clean up this mess.

Question A

What should Joe do in this situation? (Choose as many as you think are correct)

1. Call the boss to tell him about the clutter and ask what he should do.
2. Clean it up himself.
3. Don't do anything about the mess, just get started.
4. Just clear his immediate work area.

Answers to question A

(Choose as many as you think are correct)

1. Correct. Mike needs to know the situation. He may need to send extra help or reschedule other work he had planned. He can't help solve a problem unless he knows about it.
2. Correct. Even though it is not his mess, working around all that clutter will slow Joe down and increase his chance of injury.
3. Joe shouldn't start the job until the job site is picked up. Remember, he will be adding to the mess by removing old cabinets.
4. This may help some, but still leaves clutter that Joe will have a hard time seeing when he takes down the

old cabinets and moves them out. He may trip or fall and get injured due to the clutter.

Joe decides to start the job. He is two hours into the job when you show up. You tell him that you finished your last job early and now you're here to help. Joe has taken down the old cabinets and they're on the kitchen floor. You survey the scene and say, 'What a mess!' Joe says, 'Hey, it was like that when I started! I'm just doing the best I can working around it.' Joe starts to take out a heavy cabinet. You see that he is reaching over too far and has poor footing. You say, 'Stop, you're gonna hurt your back.'

Question B

What should the two of you do first? (Choose only one unless directed to 'Try Again')

5. Start to take the cabinets out of the kitchen.
6. Call the sub[contractor]s who left the mess to complain about the situation.
7. Work together as a team to get the site cleaned up before hanging the cabinets.
8. You start installing new cabinets while Joe takes the old ones out to the dumpster.

Answers to question B

(Choose only one unless directed to 'Try Again')

5. Moving heavy cabinets around the clutter may cause either of you to trip, fall, or get a back injury. Try again.
6. It is best to let the boss handle calling the subcontractors. He can make it clear that they have cost him time and money. Try again.
7. Correct. It will go faster that way, plus it will be safer to work without all the clutter.
8. If Joe does this alone, he will still be lifting and carrying bulky objects while stepping over and around obstacles. Try again.