DEVELOPMENT AND EVALUATION OF A TRAINING EXERCISE FOR CONSTRUCTION, MAINTENANCE AND REPAIR WORK ACTIVITIES

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ABSTRACT

Recent studies have shown that miners performing construction, maintenance, and repair (CMR) work activities in the conduct of their jobs incur from 39 to 65 percent of all reported injuries in the mining industry. The number is particularly high at surface aggregate operations; however, the problem exists at all mining locations and commodities. To address this issue, an interactive, (3-D) slides training exercise, Hazard Recognition Training Program for Construction, Maintenance and Repair Activities, was developed. The purpose of the exercise is to teach workers to recognize CMR hazards in the workplace and to deal with them using accepted safe work procedures. It was field tested using a total of 340 persons from surface mining operations in six states. The subjects were tested before and after the training intervention to determine if objectives of the instruction were achieved. Results indicated that 71 percent of the participants showed improvement in their test scores. Following the posttest, subjects responded to a seven question Likert scale. These questions related to the validity of the exercise and the utility of the training program. More than 93 percent of the miners reported that they "learned something new from the training" and over 94% said they "would use these practices to work more safely".

INTRODUCTION

A review of 1995 injury data by a large aggregate mining company in the United States showed that a high percentage of incidents within their operation occurred to miners who were performing CMR work activities in the conduct of their jobs [1]. It was thought that similar findings may also exist throughout other segments of the mining industry. To investigate this issue, a group of mine safety practitioners from The National Institute for Occupational Safety and Health (NIOSH), the Mine Safety and Health Administration (MSHA), and the mining industry, including the large aggregate mining company, met at NIOSH's Pittsburgh Research Laboratory. At the meeting, the extent to which injuries may be attributed to construction, maintenance, and repair work activities, and possible strategies for reducing these numbers were discussed.

In order to proceed, however, it was deemed necessary that everyone agree on a single definition of "construction, maintenance and repair". After reaching a consensus, the definition (see Appendix A) was applied to narratives of 604 incidents that occurred over a period of three years at the large aggregate producer's mining operations. It was concluded that 65% of these incidents resulted from employees performing CMR work activities. A follow up inter-rater reliability assessment showed the level of agreement among the four raters (two representatives from NIOSH, one from MSHA and one from industry) to be 94%.

Other evidence of the extent of CMR injuries among miners was documented in a NIOSH-funded investigation by Lehman and Layne [2]. In this study, the consensus definition was applied to narratives of 21,024 injuries for all commodities (both surface and underground locations) throughout the U.S. mining industry during the same three-year period. It was determined that 39% of these injuries occurred to employees who were performing CMR work activities.

After reviewing narratives of incidents and discussing factors that contributed to these injuries, the group of mine safety practitioners agreed that an appropriate strategy for reducing CMR injuries would be to develop a meaningful training intervention. The goal of the training would be to increase employee awareness of hazards and also advise safe construction, maintenance and repair practices for workers to follow. An interactive, 3-D slides CMR training program called Hazard Recognition Training Program for Construction, Maintenance, and Repair Activities was subsequently developed to accomplish these objectives. [3] The purpose of this paper is to document its' development and evaluation.

THE "HAZARD RECOGNITION TRAINING PROGRAM FOR CONSTRUCTION, MAINTENANCE, AND REPAIR ACTIVITIES"

Overview

The Hazard Recognition Training Program for Construction, Maintenance, and Repair Activities is an 80-page teaching document that includes a set of three (3-D) slide reels, each containing seven scenes. The slides depict various construction, maintenance and repair work activities at non-coal, surface mining operations. They provide visual references from which class discussions emanate as trainees focus on the hazards of the particular CMR work activity being depicted.

The concept of *degraded images* is incorporated into the (3-D) slides. Both instructional aids, (3-D) slides and *degraded images*, have been shown in earlier studies to be effective for training miners to recognize and respond to hazards [4, 5, 6].

Three-dimensional slides were reported by the former U.S. Bureau of Mines (The safety and health research functions of the former U.S. Bureau of Mines were transferred to NIOSH in 1996) to be effective for teaching miners to recognize various geologic and mining-induced irregularities that may cause ground failures. As such, they serve as an excellent proxy for training miners to recognize cues that distinguish various types of hazards.

The *degraded image* concept was originally developed and used for military target detection training. *Degraded images* are scenes where the subjects are partially hidden from view, observed from an eccentric angle, viewed through haze or dust, inadequately illuminated, or otherwise obstructed so as to camouflage the target. Military research has shown that pilots who were trained with less than ideal (or degraded) visuals were more successful in subsequent identification of targets than those trained using ideal (or highlighted) pictures of targets.

In the 80-page CMR training program, 61 pages constitute a comprehensive Instructor's Guide and the other 19 pages contain information that trainers may use for handouts and overheads. The Instructor's Guide includes the following sections: Introduction; Performance Objectives; Instructor Guidelines; Classroom Format; Key Concepts; Materials; Instructional Method; Instructor's Notes; Key Concepts by Scene; and List of Hazards by Scene. The materials for handouts and overheads include: the definition of CMR work activities; a classroom format; inter-rater reliability results; the Pretest/Posttest (with answer key); and a student handout containing safe work practices.

Exercise Development

The initial step in developing the exercise was to identify key concepts (topic areas) to be incorporated into the training program. This was accomplished, in part, through discussions with, and recommendations from, a multi-disciplinary group of professionals who provided expertise in choosing the concepts. Individuals in this group are proficient in one or more of the following areas: mining, industrial, and safety engineering; education and training; enforcement; ergonomics; and mine labor/management. Seventeen key concepts were identified. They include: Communications; Confined Spaces; Electrical; Elevated Work; Ergonomics; Excavation and Trenching; Falling Materials; Fire Safety; Hand Tools; Hazard Communication; Health Hazards; Lockout/Tagout; Machine Guarding; Material Handling; Mobile Equipment; Personal Protective Equipment; and Welding/Cutting.

The next step was to prepare a broad account of information about each of the key concepts. This material also includes best practices for dealing with CMR hazards and explicit discussion notes to serve as a resource for trainers.

Concurrently, visuals depicting construction, maintenance and repair activities at noncoal surface mines were obtained using specialized (3-D) photographic equipment. The slides, which correspond to the 17 key concepts, demonstrate various hazardous conditions and situations relating to all of the concept areas.

A first draft of the CMR training program was then prepared and sent to various industry, academia and MSHA representatives for authentication. Their comments and recommendations were considered and some of them were incorporated into the draft.

The next step in the development process was to pilot test the exercise. The purpose of the pilot study was to use the instructional materials and evaluation procedures in a "trial run" with a small number of subjects and make any necessary changes prior to field testing. Two pilot tests were conducted. The first included representatives from industry, MSHA, NIOSH and academia. The pretest was administered, the exercise presented, and the posttest and evaluation followed. The second pilot test was conducted at the MSHA Mine Academy with representatives from MSHA's Field Services Division. Identical presentation procedures were followed for both pilot tests. Based on comments from the participants, some changes were made to the exercise content, particularly use of appropriate terminology for mining equipment, work processes, and mine conditions. The pilot test experiences also helped to establish consistency in presenting the exercise for field testing. In particular, they helped to structure parameters of the training program with regard to allocation of total time for each concept and specific time for follow up discussions. After considering all recommendations and suggestions, those that were judged to improve the exercise were incorporated into a final draft.

EXERCISE EVALUATION

The CMR training program was developed as a synergistic exercise in which trainees actively participate throughout the entire instructional period. As such, the resulting discussions vary with each training class because the information being shared is directly related to the knowledge, experience, skills, and interests of those in the class. This exchange is essential as it contributes to achieving the stated learning objectives; however, because of this interaction, it is inherently impossible to attribute any "pretest to posttest" improvement in test scores entirely to the training. Even using a control group to which no training intervention is applied, scores for the experimental group are still affected by the major competing explanation, i.e. variability of class discussions. Internal validity, therefore, cannot be achieved regardless of the experimental design and, it would be unrealistic to propose that any improvement in scores is tied entirely to the CMR training exercise. However, this is not to suggest that higher test scores may not be partially due to the training. It is reasoned that if results show a substantially large number of subjects scoring higher in the posttest, then the CMR training must have had a positive effect.

Experimental Design

Because of inability to eliminate the *confound* described above, a simple one-group, repeated measures pretest-posttest experiment was designed to determine if miners' test scores would improve following the CMR training intervention. A non-probability haphazard sample consisting of miners representing the noncoal, surface mining industry in six States were selected. They were measured both before and after the CMR training exercise (independent variable). The dependent variable is the change in scores between the pre- and posttests.

Subjects

The subjects were voluntary participants from mine training classes, safety seminars, or conference workshops at various locations in six states. This "sample of convenience" consisted of 340 persons in 12 nonequivalent groups, ranging in class size from 18 to 61 individuals. They were located in PA, WV, VA, NC, AL, and WY.

Their job classifications varied from hourly employees to supervisors. There were 119 job classifications represented. For reporting purposes, the subjects were categorized as miner-laborer; technical; and supervisory. Examples of each include welder, laborer, and truck driver for miner-laborer; project manager, engineer, and trainer for technical; and foreman, quarry supervisor, and plant manager for supervisor.

Field Tests

Twelve field tests were conducted. Each was structured so that the same sequence of events occurred at all locations. The chronological succession began with the pretest, followed by the CMR training exercise, in which persons viewed slides and discussed hazards, and ended with the posttest. No direct, follow up discussions of the pretest questions were held. The total training time needed for each field test was approximately two and one-half hours. The pretest and posttest contained twenty identical true or false questions. Each question was grounded in one or more of the focus areas identified as content material.

After the posttest, subjects completed (1) a demographic information form which asked for job title, years experience in the job, age, and years experience in mining, (2) a seven question Likert scale which related to the validity of the exercise and utility of the training program, (3) a strong point/weak point query which asked for their opinions on the overall strengths and weaknesses of the CMR training program. Table I depicts these results.

Table I: Demographics of Subjects						
	N	Range	Minimum	Maximum	Mean	Std. Deviation
Age	223	44	19	63	38.89	10.49
Yrs. Exp. In Job	202	35	0	35	9.55	8.30
Yrs. Exp. In Mining	212	42	0	42	13.59	9.58
Yrs. At Mine	195	35	0	35	10.51	8.87
Valid N	173					

Results

The results of the field tests are presented in three parts. The first part looks at subjects' improvement in scores from pretest to posttest following the training; the second part describes miners' self-reporting evaluation of the training; and the third part summarizes participants' opinions on the strong and weak points of the program. Improvement in test scores is defined as subjects getting one or more additional correct answers in the posttest than in the pretest. If the number of correct answers from pretest to posttest decreased or stayed the same, then no improvement was recorded.

Test Scores: 71% of the subjects (241 of 340) showed improvement in their posttest scores following the manipulation (training). The mean score among all subjects (N=340) in the pretest was 14.49 correct answers; standard deviation was 2.57. The mean score among all subjects in the posttest was 16.01 correct answers; standard deviation was 2.28. Of subjects who just showed improvement in the posttest (N=241) the mean score was 16.47 correct answers; standard deviation was 2.13. Tables II, III, IV, and V show these results.

Of the 241 subjects who showed improvement, 34.9% increased their scores by 1 correct answer; 29% increased their scores by two; and 19.9% improved by three additional correct answers in the posttest. Table VI shows these results.

The job category of miner-laborer had the highest posttest score improvement following training with a mean of 2.4 additional correct answers (s.d. = 0.35). Improved scores for subjects classified as technical (T) averaged 2.0 more correct answers (s.d. = 0.61) and, for those classified as supervisory (S), subjects increased their scores by 1.9 additional correct answers (s.d. = 0.83)

Table II: Pretest/Posttest Comparison		
	Pretest Scores	Posttest Scores
N	340	340
Mean	14.49	16.01
Std. Deviation	2.57	2.28

Table III: Pretest scores

Correct Answers	Frequency	Percent	Cumulative Percent
1	1	.3	.3
5	2	.6	.9
6	1	.3	1.2
7	1	.3	1.5
8	2	.6	2.1
9	7	2.1	4.1
10	10	2.9	7.1
11	16	4.7	11.8
12	17	5.0	16.8
13	38	11.2	27.9
14	61	17.9	45.9
15	60	17.6	63.5
16	54	15.9	79.4
17	41	12.1	91.5
18	19	5.6	97.1
19	8	2.4	99.4
20	2	.6	100.0
Total	340	100.0	

Table IV: Posttest scores

Correct Answers	Frequency	Percent	Cumulative Percent
7	1	.3	.3
9	1	.3	.6
10	3	.9	1.5
11	11	3.2	4.7
12	7	2.1	6.8
13	26	7.6	14.4
14	35	10.3	24.7
15	38	11.2	35.9
16	57	16.8	52.6
17	71	20.9	73.5
18	46	13.5	87.1
19	34	10.0	97.1
20	10	2.9	100.0
Total	340	100.0	

Table V: Overall Test Results		
	Pretest Scores	Posttest Scores
N	241	241
Mean	14.10	16.45
Std. Deviation	2.58	2.13

Table VI: Test Score Improvements										
Improved Score	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
Number of subjects	84	70	48	17	11	4	4	2	0	1
Percent showing improvement	34.9	29.0	19.9	7.1	4.6	1.7	1.7	0.8	0.0	0.4

Trainees' evaluation: The analysis of the trainee rating scale responses show that more than 93% reported "learning something new from the exercise" and over 94% said they "would use some of the ideas presented to work more safely". (Percentages were determined by combining ratings of "4" and "3") Table VII shows these results.

The utility of the CMR exercise was estimated to be high as more than 94% of the subjects reported that "the way the material was presented is a good way to learn". The final measure of the exercise validity was judged to be high as more than 92% of the subjects indicated that "the visuals (3-D slides) helped explain concepts".

Strong Points/Weak Points: Nearly one-half of the participants (153 of 340) commented on the strengths and weaknesses of the training program. The leading remarks regarding strengths addressed the high degree of group discussion and class participation exhibited throughout the training sessions. Several participants commented: "a new interactive way to present material...I like the 3-D effect and interaction with students...allowed us to discuss and share information." Another common theme was the scope of realism brought to the visuals through the use of 3-D scenes. "The scenes offered a good perspective of general work areas." Approximately one-forth (84 of 340) of the subjects commented on the weak points of the training program. The consensus suggested that there were too many hazards introduced to adequately address all of them in the allotted time. "had to rush through scenes....too little time dedicated to all the hazards." Also, many of the comments suggested that additional visuals (overheads or videos) be used to support the concepts seen in the 3-D slides; "...if supporting images could be placed on a screen for all to see, it would be easier to explain hazards and safeguards." Others stated that the 3-D scenes were too restrictive and did not allow one to see the entire work environment.

CONCLUSION

The CMR training program was designed to teach hazard recognition skills and to present safe work procedures for miners who perform construction, maintenance, and repair work activities. These were addressed as the instructor and trainees proceed together through a series of (3-D) visuals showing CMR work activities at surface noncoal mines. During training classes, miners can vicariously experience workplace conditions because the slides realistically portray various construction, maintenance and repair activities that typically occur at surface operations. The instructor leads the participants in discussions as they consider the key points depicted in each scene.

How effective is the training? Experimental results indicate that the training program helped mine employees recognize CMR type workplace hazards and also increased their knowledge of accepted safe work practices. Approximately seven out of ten subjects increased their test scores following training.

Table VII: Self-reporting Measure Results - Subjects' Rating of CMR Exercise

		Likert Scale					
		Strongly Agree			Strongly Disagree		
		4	3	2	1	Mean	Std.Dev.
The directions for working this exercise were clear	(N=335)	226	95	12	2	3.63	.59
The slides did not show actual working conditions	(N=335)	33	60	84	158	1.90	1.02
The visuals (3-D slides) helped explain concepts	(N=336)	192	118	16	10	3.46	.72
The safe work practices presented will not help me work safely	(N=336)	48	26	65	197	1.78	1.09
I will use some of the ideas presented to work more safely	(N=338)	222	96	9	11	3.57	.70
I learned something new from this exercise	(N=338)	221	92	20	5	3.57	.67
The way the material was presented is a good way for me to learn	(N=335)	215	101	16	3	3.58	.63

Were the subjects sensitized because of the pretest? Possibly; but somewhat less than suspected for two reasons. One, a moderately long period of time (more than two hours) lapsed between the pre- and post- tests and, two, the ensuing class discussions did not concentrate directly on the test questions; instead they focused on the visuals.

The self-reporting evaluation gave a clear indication of the meaningfulness of the CMR training. More than nine of ten subjects reported that they "learned something new from the exercise"; "would use some of the ideas presented to work more safely"; and "the (3-D) slides helped to explain concepts".

The CMR training program presents a realistic opportunity for miners to become more cognizant of the many hazards associated with construction, maintenance, and repair work activities and to learn about safe work practices for dealing with them. This experience may help workers to recognize unsafe situations and conditions in the safety of the classroom and prepare for events that are likely to occur in the real mining world.

To date, approximately 2,100 copies of the exercise have been distributed to the mining industry. The program is nonperishable and may be reused in training classes. The interactive format is favored by many trainers because it provides for active classroom participation as opposed to the traditional, passive teaching of facts and reviewing of injury data and incident narratives. However, the true impact of the CMR training program probably has not yet been realized. Follow-up observations to evaluate the impact of this program could improve the quality and effectiveness of future training materials. The lessons learned in the development of the training program, as well as the content of the exercise itself, should help to improve the health and safety of our nation's miners.

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APPENDIX A

GUIDELINES FOR CLASSIFYING CONSTRUCTION, MAINTENANCE AND REPAIR ACCIDENTS

Accidents may be classified as construction, maintenance or repair type accidents if they meet **at least one** of the following criteria: The definition of "construction" work activities: the building, rebuilding, alteration, or demolition of any facility or addition to existing facility at a surface mine, surface area of an underground mine or underground mine; including painting, decoration or restoration associated with such work, and the excavation of land connected therewith, but excluding shaft and slope sinking and work performed on the surface incidental to shaft or slope sinking. (36CSR23, Board of Coal Mine Health and Safety, West Virginia)

* The definition of "maintenance/repair" work activities: the constructing, installing, setting up, adjusting, inspecting, modifying, and maintaining and/or servicing machines or equipment. These activities may include; lubricating, cleaning or un-jamming of machines or equipment and making adjustments or tool changes, where the employee may be exposed to the unexpected energization or startup of the equipment or release of hazardous energy. (29CFR Part 1926. Lock out/tag out procedures, OSHA)

* All welding and cutting activities, use of non-powered and powered hand tool and those activities involving the use of both mobile and fixed cranes.

* All activities involving the assembly, disassembly, setting up and dismantling of equipment, machines and related components therein.

* All those activities including walking/ running/crawling and climbing if the activity was within the performance of construction, maintenance or repair work.

Note:
Classification of construction/maintenance/repair activities are made independent of employee occupation or job title.