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Effective Hazard Recognition Training Using a Latent-Image, Three-Dimensional Slide Simulation Exercise

By E. A. Barrett and K. M. Kowalski

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

U.S. Department of the Interior
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UNITED STATES DEPARTMENT OF THE INTERIOR
Bruce Babbitt, Secretary

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By E. A. Barrett[1] and K. M. Kowalski[2]

ABSTRACT

The U.S. Bureau of Mines (USBM) conducted experiments to determine if training using a latent-image, three-dimensional (3-D) slide simulation exercise improved miners' ability to recognize roof and rib hazards. The effectiveness of this innovative type of classroom training was investigated by measuring workers' performance on a hazard recognition task. The study was unique in that hazard recognition skills were assessed in the workplace using actual coal mine roof and rib hazards. Results showed that training with a latent-image, 3-D slide simulation exercise significantly improved each subject's performance on the in-mine hazard recognition task. Further, the USBM researchers concluded that transfer of learning from the classroom to the workplace occurred.

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INTRODUCTION

In mining, as in other production-related industries, the safety of workers is dependent upon many interrelated factors. One of the more important safety factors is the miner's ability to *recognize* hazards in the workplace. This ability to perceive hazards is, perhaps, more difficult to achieve in underground mining than in general industry because the work environment is confined, dark, and inherently dangerous because of the influences of hidden (unknown) conditions. Further complicating the situation is a setting that is continuously changing as mining advances. Workers must be alert and always cognizant of their immediate surroundings, particularly the conditions of the roof and rib.

It is hypothesized, therefore, that the safety of miners depends to a rather large degree upon their individual skill in *recognizing* dangerous conditions. The information needed to *recognize* hazards is often available in the form of visual cues found throughout the workplace. Even though workers' knowledge of ground control may be extensive because of years of mining experience, they may not necessarily be competent in recognizing ground hazards that indicate danger. This seems apparent as officials attempt to explain why veteran miners continue to become accident victims each year. New miners, of course, must rely entirely on training for the acquisition of hazard recognition skills. Clearly, all miners, both experienced and inexperienced workers, have a need for specialized training in recognizing hazardous ground conditions.

Studies of mine hazards and their effect on worker safety in the production process are common throughout the mine health and safety literature. However, there has been limited research on the *recognition* of these hazards. In one of the few relevant studies, Blignaut (*1*)[3] investigated hazard recognition among gold miners in 1979 for the Chamber of Mines in South Africa. He investigated the effects of skill on visual search and concluded that visual search performance depends significantly upon search skills. In subsequent work, Blignaut (*2*) examined the ability of mine workers to differentiate between safe and dangerous rock. In this study, he confirmed that visual skills training significantly improved this ability. In the latter investigation, Blignaut found that skills training consisting of subjecting trainees to exercises in detection was more effective than training that provided workers only with verbal information about specific hazards. His hazard detection exercises included the use of stereoscopic [three-dimensional (3-D)] slides for depicting the ground hazards found in gold mines.

Numerous studies in the literature indicate that perceptual judgments are susceptible to training. The most extensive base of information that links training with the improvement of visual skills appears in military studies on target detection (*3-5*). Here, research indicates that skill improvement in target acquisition can indeed be taught, improved, and even accelerated through effective training. In other visual search studies—for example, Schneider and Shiffrin (*6*) and Shiffrin and Schneider (*7*)—performance of subjects was shown to change both qualitatively and quantitatively with extended training. These researchers applied a two-process theory of human information processing to detection, search, and attention phenomena. The theory includes **automatic** processing (not demanding of attention) and **controlled** processing (demanding of attention). The eventual automatization of the detection process, in general, is affected by perceptual training in the detection of hazard cues or situations. The quality, variability, and mode of presentation of these training experiences are important variables in predicting what skills accrue from the training.

This report addresses the issue of effective training for teaching miners to recognize roof and rib hazards. An innovative form of instruction that combines latent-image simulation exercises with 3-D slides was developed for this purpose. Experiments were conducted to answer the research question: Can training using a latent-image, 3-D slide simulation exercise improve a miner's ability to recognize roof and rib hazards? The work is in support of the U.S. Bureau of Mines' (USBM's) mission to enhance the safety of mining.

BACKGROUND

Training in the "recognition and avoidance of mine hazards" is mandated in the U.S. Code of Federal Regulations (CFR), Title 30, Part 48 for both underground and surface miners, as well as for those working at surface areas of underground mines. Generally, the training focuses on hazards associated with workers' job responsibilities. They include, among others, electrical hazards and common mining hazards associated with ground, escapeways,

[3]Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

moving vehicles, first aid, mine gases, transportation, and communication.

The ground hazards segment of the training typically consists of a review of the mine's approved roof control plan and, perhaps, instruction on how to sound or pry down (scale) loose roof. It may also include instruction in the recognition or awareness of dangerous roof and rib conditions, such as geologic irregularities, ineffective support, and loose rock occurrences.

Most ground hazard recognition training is conducted in a classroom and consists of looking at visuals of the hazards and/or engaging in group discussions about problems observed in the workplace. Both of these approaches have certain shortcomings. Even though the discussions provide important safety information for the worker, they usually occur after a particular incident happens. Response to a hazard that led to an accident in a mine is usually swift in comparison with the response to a hazard with similar "potential" for causing an accident. The latter is viewed as a situation "to observe" for future concern and action. This is "crisis management" in dealing with groundfall hazards.

The problem with looking at visuals of hazards in the classroom lies in assuming that periodically showing hazards to workers will have some effect when the miner happens to come across them in the workplace. The concern with transfer of learning from the classroom to the mine is rarely addressed in this traditional type of training model. Transfer of learning can only occur when a person's learning in one situation influences, positively, his or her performance in other situations.

Methods of mine safety training have not changed appreciably for many years. An earlier USBM study concluded that, in annual refresher training, mine trainers tended to rely heavily on the same instructional materials year after year and that innovative teaching techniques (games or simulations) were fairly common but were usually limited to the factual recall of safety information *(8)*.

The objective of all mandated mine training is not only to meet the letter-of-the-law, but also to ensure that mining activities are performed in a safe manner. One concern with most mandated training is that because it is repeated on a regular basis, instructors have a difficult time maintaining trainees' interest in the subject matter. Trainers attempt to vary the content of material being presented, but unfortunately have a limited supply of appropriate, meaningful subject materials available to them. The training materials in this report, therefore, were developed in response to this continuing search for innovative and effective instructional materials and methods for the mining industry.

The need for improved training in the recognition of roof and rib hazards has been reported by the USBM *(9-10)*. This need was identified from two sources, each of which disclosed deficiencies in the abilities of some miners to recognize dangerous ground conditions. In the first source, circumstances leading to roof fall fatalities documented in official U.S. Mine Safety and Health Administration (MSHA) accident investigation reports during the past 10 years were reviewed. It was noted that the apparent failure of miners to recognize hazardous roof conditions contributed to many of the accidents. In one, for example, an "undetected" kettlebottom separated from the roof near the face and caused a fatality. In another, an "undetected" loose piece of roof, a "horseback formation," fell from between the roof bolts and caused fatal injuries to a worker. The primary contributing factor in these accidents, as reported, was the failure to "detect" a hazardous condition, in these cases, loose rock. The visual information available to the miners at the moment of these accidents may have been concealed because of rock dust, inadequate lighting, or other obstructions in the immediate area. In any case, this source of evidence suggests an ongoing need for improving miners' skills in recognizing hazardous roof conditions.

The second source of information suggesting the need for improved training in hazard recognition was noted in related USBM field studies *(11)*. Experiments were conducted primarily to obtain empirical evidence of the effectiveness of using 3-D slides to depict ground hazards. The results showed that 3-D slides were significantly more effective than the traditional two-dimensional (2-D) slides for depicting the hazards. In conducting the experiments, both experienced and inexperienced subjects were asked to view and describe the roof and rib hazards observed in 2-D slides and 3-D slides. The expectation was that subjects with more mining experience looking at 3-D slides would score highest in the study and those with less mining experience looking at 2-D slides of the same hazards would score lowest. These outcomes were indeed confirmed. However, low performance scores of many experienced subjects indicated that their hazard recognition skills were below an acceptable critical skills criterion level. For critical skills (like those involved in hazard recognition), a recognition rate of at least 90% is deemed a reasonable standard for mastery of that skill. A lower performance score is viewed as undesirable because the real-world consequences can be severe. In summary, both of these sources, the MSHA investigative reports and the USBM's 3-D slide studies, indicated deficiencies in some miners' hazard recognition skills.

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LATENT-IMAGE SIMULATION EXERCISES

Latent-image simulation exercises are performance-based instructional materials that were adapted for teaching problem-solving skills to miners. The exercises, originally developed for the mining industry in the 1980's by the University of Kentucky under a USBM contract (*12*), are modeled after those previously designed for teaching and testing the proficiency of aviation, medical, and military personnel. They are based on research about how people solve problems and make judgments and decisions, particularly in emergency situations.

"Latent image" is a process in which words, printed on paper with invisible ink, are revealed after a special developing pen is drawn over them. This special pen, called a "latent-image developer," contains ink-developing fluid and is similar in appearance to a "magic marker." The latent-image process is used on the simulation exercise answer sheets where messages are printed to explain whether a response is correct or incorrect and the consequences of choosing that response.

Latent-image simulation exercises offer several advantages over other familiar types of simulation (for example, role playing and hands-on task training) currently used in mine training. Two principal advantages are (1) an unfolding of information and consequences (on the answer sheet) contingent upon the responses that the trainee selects and (2) an immediate, corrective feedback about these consequences and the correctness of answers selected.

More than 65 latent-image simulation exercises dealing with preventing and controlling mine emergencies have been completed to date. The content of the exercises includes such annual refresher topics as first aid, haulage, mine ventilation, electricity, and roof bolting. The materials relate to surface and underground mining, coal, and noncoal, as well as preparation plants and mills. It was determined by the USBM that the content of these latent-image exercises has enormous appeal to trainees. In one study, latent-image simulation exercises rated highly among miners and trainers in terms of authenticity, relevance, and utility (*13*).

LATENT-IMAGE SIMULATION EXERCISES WITH THREE-DIMENSIONAL SLIDES

The USBM modified the latent-image exercise's format by adding 3-D slides to form a latent-image, 3-D slide simulation exercise. This innovative concept combines the salient benefits of 3-D slides with the instructional advantages of latent-image simulation to form a truly unique training instrument (*11*). It figuratively "places" miners in a problem-solving situation that is realistically visualized for them in 3-D slides. The main advantage of latent-image exercises is the realism of the problem-storyline. The 3-D slides add to that realism and offer opportunities to teach a wider set of skills.

It was shown in USBM research that 3-D slides are significantly more effective for depicting hazards than traditional 2-D slides (*11*). This study concluded, following field evaluations, that miners viewing 3-D slides achieved a much greater hazard recognition rate than miners viewing 2-D slides. It was also noted that mining experience was not a factor in achieving this recognition rate primarily because of the superior fidelity of 3-D slides. The realism of 3-D slides permitted all subjects, regardless of experience, to actually "see" more hazards in the slides.

The training effectiveness of a latent-image, 3-D slide simulation exercise for skill improvement in recognizing hazards and how this resultant learning transferred to the workplace was largely unknown. To this end, the USBM studied the effectiveness of an exercise and training transfer by conducting two small sample hazard recognition experiments. The experiments used an exercise developed specifically for the investigation called "D. R. Light."

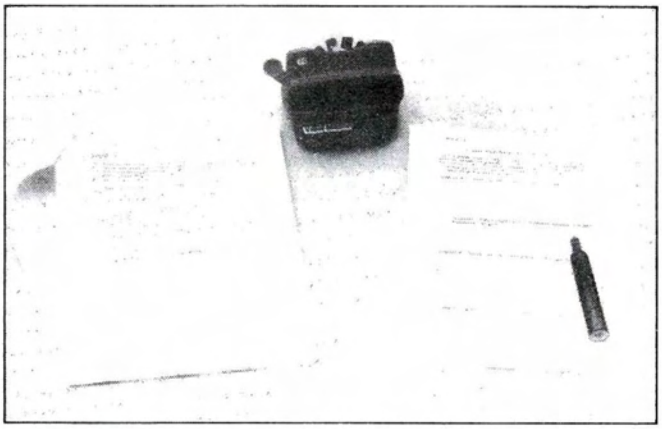
D. R. LIGHT TRAINING EXERCISE

"D. R. Light" is a latent-image, 3-D slide simulation exercise that consists of 10 questions and seven 3-D slides. The slides depict hazards associated with two types of underground coal mine roof conditions—high fall areas and loose, broken top around roof bolts. The components of the exercise are a problem booklet (appendix A), answer sheet booklet (appendix B), 3-D slide viewer, circular 3-D slide reel, and latent-image pen. All of these are shown in figure 1.

The problem booklet contains an initial page of general instructions followed by a page of background information and a description of the problem situation. In the background segment, the trainee is informed that he or she is an experienced roof bolter operator whose helper, named D. R. Light, has little underground mining experience. Information is then provided about the coal seam, the immediate roof, and the types of roof bolts that were installed in the mine.

The problem situation in which the miners find themselves is described next in the problem booklet. Briefly, on a recent run of the escapeways, the section boss notices that the brow of a high fall area has begun to deteriorate. ("High fall" refers to a location where the roof rock has fallen out and the remaining top is resupported.) The face boss then asks the bolter operator and his or her helper to follow the escapeway out and take down any loose top at this particular high fall area. Figure 2 shows the roof condition around the periphery of the high fall area in question. After correcting this condition, a second roof problem is encountered by the miners. They notice a condition where bolts are exposed because the immediate roof rock has fallen from around the installed bolts. This top is sometimes referred to as "chandelier" roof (figure 3).

Figure 1



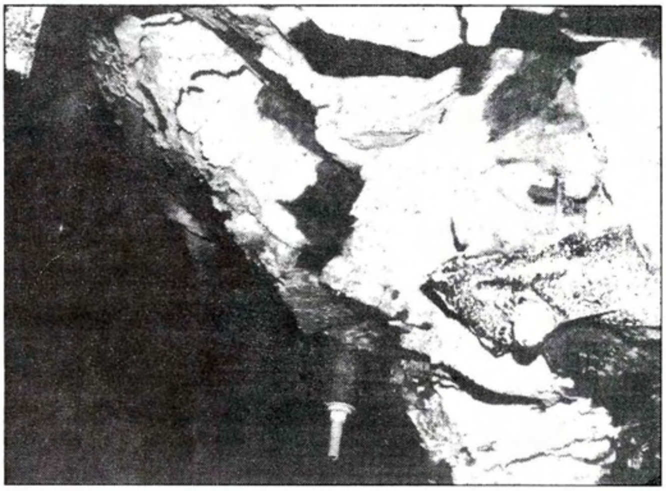
D. R. Light latent-image, 3-D slide simulation exercise.

The next 10 pages of the booklet present a progressive series of questions related to the problem situation. A story is presented using these questions and the trainee is asked to select appropriate actions from the alternatives listed. Six of the ten questions involve viewing an accompanying (3-D) slide. The questions proceed through the following sequence of events (labelled questions A through J in the problem booklet in appendix A):

1. Assessing a potential roof hazard (view slide 1).
2. Deciding on the initial action to be taken after a closer inspection of the hazard (view slide 2).
3. Deciding what action to take after examining the brow of a high fall area (view slide 3).
4. Identifying potential outcomes associated with this type of hazard.
5. Determining the best way to secure the roof area.
6. Determining the best way to proceed with correcting the roof problem.
7. Examining another section of mine roof and identifying potential hazards (view slide 4).
8. Assessing the adequacy of the roof support system in another place (view slide 5).
9. Determining the best action to remedy chandelier roof.
10. Identifying effective types of roof control to support chandelier roof (view slides 6 and 7).

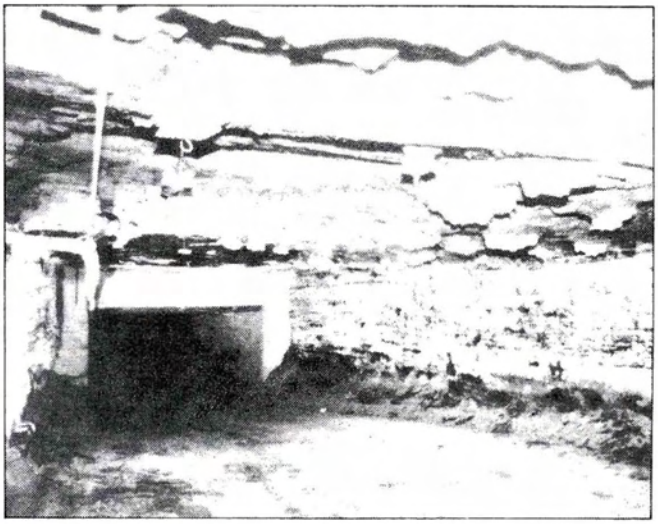
For each question, the trainee determines his or her response(s) and uses the latent-image pen on the accompanying answer sheet to reveal whether the choice(s) is(are) correct or incorrect. In the process of responding to the questions, feedback is provided in the form of information contained within the answer brackets.

Figure 2



Loose roof rock around brow of high fall area.

Figure 3



Chandelier roof condition in mine entry.

The authenticity of the D. R. Light training exercise in terms of the background information, problem situation, accompanying questions, and 3-D slides was validated by mining personnel who are experts on the subject of mine roof support. Formal field testing of the exercise followed. The field tests involved the carefully controlled administration of the exercise to 69 miners of varying degrees of job responsibility and experience at 3 different geographic locations. In addition to working the exercise, subjects in the field test sample were asked to provide certain demographic information and to rate the exercise for validity, relevance, quality, and utility. Findings from the subject's evaluations were positive with respect to using the D. R. Light exercise for miner training. Over 80% of the miners responded in the affirmative when asked (1) whether the exercise problem was a realistic one, (2) if working the exercise helped them to remember important things, (3) if the oral and written instructions were clear, (4) if scoring procedures were easy to understand, and (5) whether the exercise was easy to read. Over 80% reported that the exercise was not too long, that they enjoyed working the exercise, and that the graphics were easy to understand. And finally, about 74% of the field test subjects reported having learned something new from working the exercise. A composite summary of all field test data with applicable interpretations is presented in appendix C.

The two experiments described in the next sections were conducted using the D. R. Light training exercise for teaching and assessing two samples of miners. The samples were small, six in the first experiment and five in the second, primarily because the experimental methodology required that workers be pulled out of production at the mine site to participate. To minimize this inconvenience, the number of subjects was limited. The sample size was deemed sufficient by the researchers to obtain knowledge of whether the notion of an in-mine hazard recognition task could, indeed, be completed and yield meaningful results. The statistical analyses subsequently employed on the data support this decision.

EXPERIMENT 1

Introduction

The subjects of the first experiment were six experienced coal miners who, by law, required health and safety training following a 3-year layoff from mining. They had a mean age of 31 years and averaged 4.5 years of underground experience. The miners' underground experience occurred several years prior to the experiment because the mine was closed and all workers were furloughed at that time. The experiment coincided with the resumption of normal mine operations and the six workers being recalled to begin mine rehabilitation and restoration. During the idle period, none of the miners worked underground. Their previous job classifications were either shuttle car operator or continuous miner operator. As mandated in 30 CFR 48, the workers were required to receive 40 hours of *newly employed experienced miner* training before starting work. They participated in the USBM's experiment during the hazard recognition portion of this required comprehensive training.

Methodology

By drawing names, the miners were randomly assigned to either a control group or an experimental group. Each group consisted of three miners. The instruction phase of the study consisted of having just the experimental group work through the D. R. Light training exercise. This was done at the mine's training center and took approximately 30 minutes to complete. At the end of this period, no group or individual discussions were held. (Normally, class discussion is an important part of the training and generally follows the completion of an exercise.) Each miner worked individually through his or her problem booklet and responded to the 10 questions. When instructed to do so for a given question, the subjects viewed the appropriate 3-D slide. After the directions were explained to both groups, no further discussion was held during the training and each miner worked at his or her own rate.

To examine the effectiveness of this training, a hazard recognition performance assessment task was set up in the coal mine. Twelve hazard assessment areas were identified in a mile-long route traversing two of the mine's major entries. The areas were marked by spray painting the letters A through L on the ribs of the entries. No hazards were artificially prepared at any area; those naturally existing were recorded and became the key for the recognition task. There were a total of 20 possible points on the task. Several of the areas had multiple hazards and some had no hazards—that is, the roof conditions were good. A perfect score reflected the identification of no hazards at two of the stations, one hazard at three stations, two hazards at six stations, and three hazards at one station. The sequence of hazards, the points, and the description of the hazards at each location are shown in table 1.

Performance assessment was conducted as all six subjects walked through the mine and attempted to identify the hazards. The experimental group received the classroom instruction with the D. R. Light training exercise prior to the walk-through, whereas the control group did not. However, once data were collected from the control group on the underground task, the D. R. Light exercise was administered as part of their required new miner comprehensive training. The control group training was not necessary for the experiment.

Table 1.—Experiment 1: Points and hazards at each station

Station	Points[1]	Description of hazards
A	1	Loose, slabbing top.
B	1	Broken top, chandelier roof condition.
C	2	Numerous slips visible in roof; loose, broken top; chandelier roof condition.
D	1	No hazards, good top.
E	2	High fall area with loose, hanging brow; large, loose layered separations in roof.
F	2	Loose concretions in roof, bad top, extensive chandelier roof condition.
G	1	No hazards, good top.
H	3	Slips apparent in top, loose concretions in roof, severe jointing and loose rock in top.
I	2	Loose clay veins on both ribs of entry, vertical rib fractures at corners of pillar.
J	1	Large slip in roof extending across entry.
K	2	Low, hanging roof slab; large concretion in roof.
L	2	Loose, hanging roof bolts; bad top; chandelier top everywhere.

[1]Total possible score = 20 points.

In the underground walk-through, each miner was given a pencil and clipboard with 12 sheets of paper labeled A through L. The miners were instructed to walk as a group along the designated route and stop at each station. Here, they had 1 minute to identify all ground conditions they recognized in the roof at each stop. They were asked to write their observations on the sheets provided using either mining terminology or, if needed for clarification, lay terminology. In addition to the written description, the miners were to indicate whether each condition was hazardous or nonhazardous. The written responses were done individually, and at no time were group members permitted to discuss the hazards with each other. The researchers provided no feedback during the entire experiment.

Results

There were a total of 20 possible points for the underground hazard recognition task. Table 2 shows the individual subject scores, both the number correct and the corresponding percentage correct, as well as the means and standard deviations for both the control and experimental groups. All subjects in the experimental group who had the D. R. Light training prior to the walk-through scored higher in the recognition task than the control group, who did not receive training prior to the walk-through.

Given the small sample size, the Fisher randomization t-test was applied to the data. The test confirmed with 95% confidence the hypothesis that the mean score for the experimental group was significantly greater than the mean score for the control group.

Although the training given to the control group was not part of the experimental methodology (referred to as a hold-out experimental design) but necessary for their required retraining, it is still interesting to look at the results. Also included in table 2 are the performance scores of both groups for the D. R. Light exercise. Means and standard deviations were computed for both the number correct and the corresponding percentage correct. A perfect score on the exercise is 46 points.

To determine if the control group performed significantly different in the D. R. Light exercise because of their walk-through experience, a Fisher randomization t-test was applied to the scores. The results showed that the mean scores of the two groups were not statistically significantly different. The walk-through experience did not significantly increase the training scores.

Table 2.—Experiment 1: Performance scores on D. R. Light training exercise and in-mine hazard recognition tasks

Group and subject	D. R. Light[1]		In-mine hazard recognition		D. R. Light[2]	
	Number correct	% correct	Number correct	% correct	Number correct	% correct
Control:						
1	—	—	11	55	41	89
2	—	—	13	65	40	87
3	—	—	8	40	44	96
Mean	—	—	10.7	53.3	41.7	90.6
Std dev ...	—	—	2.5	12.6	2.1	4.5
Experimental:						
4	41	89	18	90	—	—
5	38	83	16	80	—	—
6	40	87	15	75	—	—
Mean	39.7	86.2	16.3	81.7	—	—
Std dev ...	1.5	3.3	1.5	7.6	—	—

Std dev Standard deviation.

[1]Dashes indicate that D. R. Light training exercise was not administered to control group prior to in-mine hazard recognition task.

[2]Dashes indicate that D. R. Light training exercise was not administered to experimental group following in-mine hazard recognition task.

Discussion

In the underground hazard recognition task, only one of the six miners reached a 90% proficiency level. As discussed earlier in this report, a 90% proficiency level is deemed a reasonable standard for mastery of a critical skill. None of the three miners who performed the recognition task before training achieved better than 65% proficiency. This suggests that, at least for this group of miners who had not worked underground recently, regardless of their prior mining experience, there was a deficiency in their hazard recognition skills. This conclusion positively correlates with the USBM findings noted earlier in this report. A comparison of the control group of miners with the experimental group who were trained using the D. R. Light exercise revealed that the trained group did perform significantly better on the in-mine hazard recognition task. It would appear that the improved scores in the experimental group were attributed to the training received. The results of this experiment suggest that a latent-image, 3-D slide simulation exercise, such as D. R. Light, has potential for improving the hazard recognition skills of miners and that transfer of learning from the classroom to the mine can take place.

Since the group studied in the experiment was quite small, the results must be interpreted with caution. The research does, however, illustrate the feasibility of conducting an in-mine hazard recognition task in the underground workplace.

EXPERIMENT 2

Introduction

A second investigation was conducted to further examine the effect of training using the D. R. Light latent-image, 3-D slide simulation exercise. In contrast to the first experiment, though, these subjects were currently employed miners rather than ones being retrained following a layoff. It was of interest to determine whether findings would be consistent for this group and whether their hazard recognition performance prior to training would meet an acceptable criterion level for critical skills performance.

This experiment assessed the hazard recognition performance of five miners whose mean age was 36 years and average underground mining experience was 11.4 years. Their experience ranged from 4 to 16 years, and four of the five had more than 11 years underground. The miners were a "sample of convenience" selected by the section shift boss. They participated in the study when asked to break away from their regular job responsibilities on the shift.

Methodology

The repeated measures design used in this experiment included the following three steps: (1) pretesting of all miners on a hazard recognition task during a walk-through, (2) training using the D. R. Light training exercise, and (3) a posttest on the same hazard recognition task during a second walk-through. As in the first experiment, the hazard recognition task was set up in the mine. Ten hazard assessment areas were identified along a 1-mile route in a main intake aircourse. A total of 17 points were given for the recognition task; a perfect score reflected the identification of no hazards at two stations, one hazard at three stations, two hazards at three stations, and three hazards at two stations. Table 3 shows the sequence of hazards, the points, and the description of the hazards at each location.

Table 3.—Experiment 2: Points and hazards at each station

Station	Points[1]	Description of hazards
A	2	Wet, loose shaley top; loose, immediate roof along rib.
B	2	Loose slickensided top; broken roof, some fallen.
C	1	Separated roof visible in one direction only.
D	1	Clay vein, hanging rock in roof.
E	3	Slip across intersection, clay vein in rib and roof, vertical fracture at pillar corner.
F	2	Chandelier roof, rib fracturing and crumbling.
G	1	Good top, no hazards.
H	3	Clay veins in both ribs; loose, slickensided broken roof; high roof fall area with slickensided top.
I	1	Loose, slickensided top.
J	1	Good top, no hazards.

[1]Total possible score = 17 points.

Procedures for the walk-through hazard recognition task and the training intervention were the same as those used in the first experiment. Immediately after the miners received training they repeated the walk-through. The route for the hazards and the actual hazards were identical for both the pretest and posttest. The miners were instructed to refrain from discussion regarding the task or the training until after the posttest.

Results

To determine whether performance scores on the hazard recognition task increased significantly from the pretest to the posttest, a Fisher's exact matched-pairs test was applied to the two sets of scores. The results indicated, with 95% confidence, that the posttraining scores were significantly greater than the pretraining scores. The number and percentage of correct responses for the hazard recognition task on both the pretraining and posttraining walk-throughs are shown for each individual subject in table 4. The means and standard deviations for each of these scores are also provided. As in the first experiment, the training resulted in scores that were significantly higher in terms of the number of hazards recognized by the miners after receiving training.

The scores for the miners on their performance in the D. R. Light training exercise are also presented in table 4. As in the first study, a perfect score is 46. As noted, the exercise scores were quite homogeneous and are similar to those of experiment 1.

Discussion

Although it appears the D. R. Light training exercise resulted in higher performance on the in-mine hazard recognition task by the sample of experienced miners, their performance was unexpectedly low. These miners had been working underground, and the fact that the recognition task took place in locations familiar to them underscores the seriousness of their low performance level.

It is interesting that the ranks of the training task scores and posttest hazard recognition scores are quite different, with miner 4 tieing for highest in training but lowest in posttest score. On the other hand, miner 3 ranked lowest in training score and highest in posttest score. It is possible that the inconsistency in performance between training scores and posttest recognition scores may be due to the nature of the training exercise. Latent-image simulation exercises provide additional information when incorrect answers are selected. Those scoring lower in the exercises perhaps gained enough information and became sensitized to the hazards for the posttest. The sample is quite small, however, and the data from experiment 1 are not consistent with this hypothesis.

Table 4.—Experiment 2: Pretraining and posttraining performance scores on in-mine hazard recognition tasks and D. R. Light training exercise

Subject	In-mine hazard recognition, pretraining		D. R. Light		In-mine hazard recognition, posttraining	
	Number correct	% correct	Number correct	% correct	Number correct	% correct
1	7	41	43	93	10	59
2	3	18	42	91	7	41
3	9	53	40	87	12	71
4	4	24	43	93	6	35
5	7	41	42	91	8	47
Mean	6.0	35.3	42.0	91.3	8.6	50.6
Std dev	2.4	14.4	1.4	2.7	2.4	14.2

Std dev Standard deviation.

CONCLUSIONS AND RECOMMENDATIONS

Results from the two experiments showed that training with a latent-image, 3-D slide simulation exercise significantly improved each subject's performance on an in-mine hazard recognition task. In addition, the researchers concluded that there was transfer of learning from the classroom to the workplace based on the subjects' performances on the in-mine recognition task. The small sample size in both experiments suggests prudence in the generalization of the results.

In the future, latent-image, 3-D slide simulation exercise training could be applicable for instruction on other types of mining hazards. Of particular interest would be electrical hazards, lockout-tagout procedures, machine and equipment guarding practices, safe machine mounting and dismounting, general housekeeping practices, pretrip equipment inspection, and other specific safety topics. Depicting the potential hazards associated with these activities in 3-D slides and combining them with latent-image classroom simulations could enhance the judgment and decision making skills of miners. This study introduced an improved method of training for recognizing ground hazards that demonstrates a relationship between valid instruction and improved worker performance. It is suggested that other methods of training to strengthen miners' hazard recognition skills should also be explored. The goal of improved training is to enhance the ability of individuals to recognize and respond to dangers in the mining workplace and thus improve the health and safety of the miner.

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APPENDIX A.—SAMPLE PROBLEM BOOKLET

D. R. Light

Problem Booklet

Mining Systems and Human Engineering
U.S. Bureau of Mines
Pittsburgh, Pennsylvania

November 1990

Instructions

Read the problem situation described on the next page. Then answer each of the 10 questions. Do them one at a time. Some questions will ask you to look at one or more 3-D slides. Follow the directions for each question. Look at the appropriate slide or slides, then continue on with the exercise. Don't jump ahead, but you may look back to earlier questions and your answers. Most questions direct you to choose only one answer unless you are told to "Try again!" Some questions tell you to select as many answers as you think are correct. Follow the directions for each question.

After you have selected your choice to a question, look up the number for that choice on the answer sheet. Rub the special pen between the brackets for that choice. A hidden message will appear that tells you if the choice is correct and provides you with additional information. When you finish you will learn how to score your performance.

Background

You are a roof bolter with five years job experience.

Your helper, D. R. Light, has one year underground experience.

This coal mine has recently been reopened after being idle for several years.

The coal seam is slightly more than six feet thick.

The immediate roof of the mine is approximately 3 1/4 feet of shale. Above this is 4 1/2 feet of limestone.

The following types of bolts are used for roof support: mechanical, resin, or combination (mechanical/resin).

Problem

The section boss is required to walk the escapeways leading out to East Mains each week looking for hazardous conditions. If any are found, he must see that corrections are made. On his last run two days ago, he noticed that the roof and brow in the high fall area at the mouth of 2 North has started to deteriorate. He felt the situation could become hazardous, however, he didn't feel it was urgent at that time. Today the continuous miner is down, so he asks you and D.R. to follow the escapeway out to the high fall area. You are to make corrections and, if necessary, take down any loose top. Turn the page and answer the first question.

D.R. Light

Question A

After receiving instructions from the face boss, you and D.R. load a supply jeep with scaling bars, posts, cap blocks and wedges. You head outby to the mouth of 2 North. You arrive and park the vehicle near the edge of the high fall area. You start to inspect the roof beginning at the center of the dome, which you estimate to be thirty feet high. LOOK AT SLIDE 1.

How does the roof look to you? (Choose only ONE unless directed to "Try again!")

1. The roof is OK because there are more than enough bolts in place throughout the cavity.

2. Assume that the roof is safe, since it is too high to conduct a sound and vibration test.

3. Even though the roof at the center of the dome is very high, you suspect a hazardous condition near the center.

4. The roof is safe. All bolts and plates appear to be in good contact with the immediate roof.

5. The roof is not safe because the absence of rockdust on the surface indicates that sloughing has recently occurred.

6. The roof looks good. Don't be concerned about it.

D.R. Light

Question B

You and D.R. have identified this area as potentially hazardous. LOOK AT SLIDE 2. This is a close-up view of the hazardous condition. What should you do? (Choose only ONE unless directed to "Try again!")

7. By standing on the jeep, scale the top with a bar to remove the loose slab .

8. Report the situation to your section boss. You can't reach the top with the equipment you have with you.

9. Do nothing. You've seen roof like this before and it never caused a problem. You should not be concerned.

10. Add additional support to prevent the top from sloughing.

Question C

You and D.R. decide to take a closer look around the high fall area before you report to your section boss. The lower edge of the cavity, directly above where D.R. is standing, catches your attention. This is what you see. LOOK AT SLIDE 3.

What should you do now? (Choose only ONE unless directed to "Try again!")

11. Immediately yell to D.R. to move away from the edge of the high fall area into the main entry.

12. Ask D.R. to take a close look at the edge of the cavity and see what he thinks about it.

13. Move to where D.R. is standing and help him inspect the top.

14. Continue with your inspection of the roof and return to this area later.

Question D

You recognized the roof hazard and yelled to D.R. to move away from the brow. He is now standing where he is safe. However, before you and D.R. can begin to make corrections you should recognize the extent of the problem. What are the hazards here? (Select as MANY as you think are correct.)

15. The slab could break off and fall at any time.

16. There are too few bolts holding the slab up.

17. There is a small gap between the slab and the main roof.

18. The wrong types of roof bolts were used.

19. The slab is large and is probably very heavy.

20. Other parts of the roof near the loose slab may also be separated from the main roof.

WHEN YOU HAVE MADE YOUR SELECTION(S) DO THE NEXT QUESTION.

Question E

You and D.R. decide the area near the brow should be immediately dangered off and the problem corrected. However, this entry is the primary escapeway out of your section. What should you do now? (Choose only ONE unless directed to "Try again!")

21. Begin to correct the problem. The escapeway probably won't need to be used until you are finished.

22. Begin working. **If** anyone comes out the escapeway, detour them around the high fall area until you're finished.

23. Danger the area off and begin to correct the problem.

24. Send D.R. to the face to tell the boss that you have to danger off and correct a roof problem. Since this is the primary escapeway, the boss should tell the miners to use the secondary escapeway.

Question F

D.R. returns from the face after telling the section boss that the primary escapeway will be dangered off until the roof problem is corrected. While at the face, D.R. also reported the roof condition at the center of the cavity. He returns with a longer bar and pipe to scale down the loose slab. Now it's time to start working. You danger off the entry. What should you do next? (Choose only ONE unless directed to "Try again!")

25. Start to scale the loose top in the dome using the longer bar and pipe.

26. Set temporary supports at random around the high fall area and then scale down the loose top.

27. Set temporary supports under the good roof adjacent to the brow and begin to scale down the top.

28. Begin to pound the bad roof area near the brow using a wood post.

Question G

You and D.R. have safely and successfully pulled down the roof slabs. You leave the temporary posts in place until the fresh roof can be bolted. This should be done immediately, so you proceed to the face to get a jackleg drill and some bolts. The face boss sees you and gives you another job. When you finish rebolting, he wants you to take a look at the roof in East Mains just outby 2 North.

Roof conditions within the cavity, as well as the outside edge (or brow) of high fall areas can be a continuing source of problems. After high falls have been resupported, workers tend to pay little attention to the roof because it's assumed to be safe. These areas need to be examined on a regular basis. LOOK AT SLIDE 4.

What roof hazards do you see? (Select as MANY as you think are correct.)

29. Loose, broken roof rock.

30. Slickensided roof.

31. Loose hanging roof bolts.

32. Sloughing of rock between bolts.

33. Rusted bolts.

34. Hanging slabs of rock at the brow of the high fall area.

WHEN YOU HAVE MADE YOUR SELECTION(S) DO THE NEXT QUESTION.

Question H

You complete bolting at the high fall area and remove the temporary posts. You and D.R. walk to East Mains and look at the roof. LOOK AT SLIDE 5.

What can you tell about this roof? (Choose only ONE unless directed to "Try again!")

35. There are more than enough bolts in the roof, so support is OK.

36. Most of the bolts and bearing plates are in contact with the roof, so the roof is adequately supported.

37. This is an older area of the mine. Since the roof is still intact, it will probably remain that way for a long time.

38. There is significant rock sloughing between bolts, so the bolts are probably not supporting the roof.

Question I

You saw in SLIDE 5 what is sometimes called "chandelier roof". The support of this mine roof appears uncertain. It is difficult to predict how long the root will remain in place. Spalling of rock between bolts may cause the roof support to be ineffective. What can be done with this roof? (Choose only ONE unless directed to "Try again!")

39. Nothing. It will probably stay up as long as the entry remains open.

40. Additional roof support should be added to the left side of the entry.

41. Leave it alone if it appears solid after the roof is sounded.

42. Additional roof support should be added across the width of the entry.

D.R. Light

Question J

Chandelier roof is a condition that generally develops in a mine roof of shale or claystone. The rock around roof bolts deteriorates and sloughing occurs. This deterioration of rock, commonly called "slaking", is usually caused by moisture in the mine air. Some mines install "tempering chambers" to remove moisture from incoming air. Others, particularly if the mine has a serious problem, spray sealants to protect the roof from moisture. In some mines, however, chandelier roof is a problem that can be corrected by spot bolting. LOOK AT SLIDES 6 and 7.

These are examples of more advanced rock spalling between bolts. In addition to rebolting with similar bolts, what are some other effective types of additional support that can be used for chandelier roof? (Select as MANY as you think are correct.)

43. Wood headers under steel bearing plates.

44. Steel I beams or wood beams.

45. Lengths of structured steel channel.

46. Woven steel/wire mesh.

END OF PROBLEM

Scoring your performance

1. Count the total number of responses you colored in that were marked "Correct". Write this number in the first blank on the answer sheet.

2. Count the total number of incorrect responses you colored in. Subtract this number from 27. Write the difference in the second blank on the answer sheet.

3. Add the numbers on the first and second blanks. This is your score.

The best possible score of 46 results from selecting all the correct answers and no wrong answers. The worst possible score of zero results from selecting all the wrong answers and no correct answers.

APPENDIX B.—SAMPLE ANSWER SHEET

D.R. Light

Answer Sheet for D. R. Light Exercise

Use this answer sheet to mark your selections. Rub the special pen gently and smoothly between the brackets. Don't scrub the pen or the message may blur. Be sure to color in the entire message once you have made a selection. Otherwise you may not get the information you need. The last part of the message will tell you what to do next.

Question A (Choose only ONE unless directed to "Try again!")

1. [ ]
   [ ]

2. [ ]
   [ ]

3. [ ]
   [ ]

4. [ ]
   [ ]

5. [ ]
   [ ]

6. [ ]
   [ ]

Question B (Choose only ONE unless directed to "Try again!")

7. [ ]
   [ ]

8. [ ]
   [ ]

9. [ ]
   [ ]

10. [ ]
    [ ]

Question C (Choose only ONE unless directed to "Try again!")

11. [ ]
    [ ]

12. [ ]
    [ ]

13. [ ]
    [ ]

14. [ ]
    [ ]

Question D (Select as MANY as you think are correct.)

15. [ ]
    [ ]

16. [ ]
    [ ]

17. [ ]
    [ ]

18. [ ]
    [ ]

19. [ ]
    [ ]

20. [ ]
    [ ]

Question E (Choose only ONE unless directed to "Try again!")

21. [ ]
    [ ]

22. [ ]
    [ ]

23. [ ]
    [ ]

24. [ ]
    [ ]

Question F (Choose only ONE unless directed to "Try again!")

25. [ ]
    [ ]

26. [ ]
    [ ]

27. [ ]
    [ ]

28. [ ]
    [ ]

Question G (Select as MANY as you think are correct.)

29. [ ]
    [ ]

30. [ ]
    [ ]

31. [ ]
    [ ]

32. [ ]
    [ ]

33. [ ]
    [ ]

34. [ ]
    [ ]

Question H (Choose only ONE unless directed to "Try again")

35. [ ]
    [ ]

36. [ ]
    [ ]

37. [ ]
    [ ]

38. [ ]
    [ ]

Question I (Choose only ONE unless directed to "Try again")

39. [ ]
    [ ]

40. [ ]
    [ ]

41. [ ]
    [ ]

42. [ ]
    [ ]

Question J (Select as MANY as you think are correct)

43. [ ]
    [ ]

44. [ ]
    [ ]

45. [ ]
    [ ]

46. [ ]
    [ ]

Finding your score

Number of "Correct" answers you colored in = (1)________________________

27 minus number of incorrect answers you colored in = (2)________________________

Add blanks one and two to get your total score = (3)________________________

Highest possible score = 46

Lowest possible score = 0

TRAINEE'S QUESTIONNAIRE

1) Name of exercise________________________DRLight________________________________

2) Your age_____3) Your sex_____M____ F 4) Years coal miner_________________________

5) Your job title________________________Surface______Underground___________________Check all the areas in which you have special training, certification, and/or that you routinely perform.

	Special Training	Certification	Routinely Perform
6) Mine foreman			
7) Mine safety committee			
8) Mine rescue			
9) Mining engineer			
10) Roof/rib control			
11) Geology			
12) Mine planning & design			
13) Roof bolter operator/helper			
14) Other (describe)___________________________			

Think about the exercise you just finished. Circle the number which tells how much you agree or disagree with the following statements.

	Definitely	Yes		Definitely No
15) This problem could happen in real life.	4	3	2	1
16) This exercise will help me remember something important if I am ever in a similar situation.	4	3	2	1
17) I learned something new from the exercise.	4	3	2	1
18) The exercise took too long to complete.	4	3	2	1
19) I liked working the exercise.	4	3	2	1
20) The instructor's directions were clear.	4	3	2	1
21) The written directions in the exercise were easy to understand.	4	3	2	1
22) The 3-D slides clearly showed mine roof conditions.	4	3	2	1
23) The scoring procedures were easy to understand.	4	3	2	1
24) The exercise was easy to read.	4	3	2	1

If you have anything more to say about the exercise, please write on the back of this page. Thank you.

APPENDIX C.—FIELD TEST RESULTS

D.R. Light

Summary of Field Test Results

The D.R. Light Exercise (DRL) underwent two rounds of field testing, including authentication and one formal field test. The authentication consisted of a small initial field test that produced too few data for meaningful statistical summaries. However, comments, criticism, and suggestions were gathered and used to revise and improve the exercise before the first formal field test. The first formal field test involved carefully controlled administration of the revised exercise to 69 miners in six classes at three different sites.

The attached tables are divided into two parts. The first part describes the people who participated in the field test and their evaluation of the exercise. The second part describes the measurement properties of the exercise.

Sample characteristics and miners' evaluations

Tables 1 through 3 describe demographic characteristics of the sample. Table 4 describes the number of persons in the sample who reported either some training, special certification, and/or routine performance of the eight areas listed as rows in the table. Inspection of these tables quickly reveals the numbers and types of persons involved in the field test of the exercise.

Table 5 reports the miner's judgment of the exercise quality and worth. Each person was asked to rate the value of the exercise on each of ten qualities. By checking a number on a scale, miners indicated to what extent the exercise displayed each quality. Inspection of the values in Table 5 reveals the percentage of miners who reported that the exercise 1) was realistic, 2) helped them to remember important things, 3) helped them learn something new, 4) was too long, 5) was enjoyable, 6) instructor's directions were clear, 7) written directions were clear, 8) illustrations were clear, 9) scoring procedures were easy to understand, and 10) was easy to read.

Psychometric properties

The next set of tables describe the psychometric (mental performance measurement) properties of the exercise. Table 6 presents summary data for each of the exercise questions, including the minimum, maximum, median, and mean question scores observed in the sample; the standard deviation and skewness of each question score; the squared correlation coefficient of each individual question score with the exercise total score; and the estimated reliability of the total exercise score if that particular question were dropped from the test. The last line in Table 6 reports the same information for the total exercise score. This information is obtained by summing question scores across the whole exercise. Each question is weighted such that a perfect score on each question sums to 100 for the exercise total score. Inspection of the table quickly presents the basic performance data for the sample.

The weighting of each question score to produce a total score of 100 is designed to allow comparison of the difficulty of different versions of the same exercise, or different exercises, even though these often have different numbers of questions. The total score of 100 is also a common convention for reporting test scores.

Table 7 reports the number of answers (options) to questions that discriminated properly between persons with high scores on the test and those persons with low scores. Tests that have multiple choice answers to questions must include some incorrect and some correct answers. The person who takes the test must choose among correct and incorrect answers (distractors) to each question. Persons who get a high total score on the test know more about the test content than persons who get low scores. Therefore, when data are aggregated from the whole sample of persons who took the test, wrong answers (distractors) to each question on the test should be significantly negatively correlated with the overall test score, and correct answers to questions should be significantly positively correlated with the exercise total score. When correct answers and wrong answers (distractors) behave this way, the answer (whether correct or incorrect) is said to positively discriminate between persons who know much about the content and those who know little. However, when persons who get high scores on the total test tend to pick wrong answers (distractors) more frequently than persons who said to reverse or negatively discriminate. The opposite case is also true. That is, when persons who get low scores on the total test score tend to pick a right answer to a question more frequently than persons who had high total test scores, get low scores, the answer isthat answer is also said to reverse or negatively discriminate. The discrimination values are used to identify and correct problems in the answers for questions. To be valid, the method requires an adequate sample of persons who exhibit a wide range of variability in their total test scores.

Table 7 reports the frequency with which answers to questions behaved in this desirable way. The table tells the percentage of answers to questions on the test that discriminated positively, negatively, or not at all among the ability levels represented in the field test sample.

Another way to look at the discrimination capability of a test is to divide the sample into groups of persons with greater or lesser levels of expertise. Table 8 reports the degree to which the exercise total score discriminated between persons in the sample with different levels of self-reported expertise. The means and standard deviations for these two groups are given as well as the F ratio and the p value.

Finally, the last table is another discrimination analysis for the total exercise score, this time between the self-reported major job categories represented in the sample. The category "miner/laborer" includes all working miners who are not supervisors, surveyors, engineers, etc. The "maintenance/technical" category includes all inspectors, engineers, surveyors, electricians, mechanics, and other technical and maintenance personnel who work in the mines and typically have special skills, and who move from section to section as they complete their work. The "supervisory/management" category includes all managers from the mine section foreman on up. The "other" category includes all other persons such as truck drivers, security personnel, office staff, and others who are not miners or laborers but who sometimes participate in annual refresher training classes.

The number of miners reported in the tables varies. This is because not all miners answered all of the questions on the trainee's questionnaire. Therefore, Tables 1 through 5 report the actual or valid percent of persons who responded to specific items on the trainee's questionnaire. The remainder of the psychometric tables report data for the number of persons who properly completed the exercise and fully completed the trainee questionnaire.

<u>Characteristics of the DRL Exercise</u>

Approximately 60 percent of the field test sample for the DRL Exercise consisted of maintenance/technical personnel, and another 35 percent of miners/laborers. Only 5 percent of the sample were supervisory personnel.

Approximately 25 percent of the sample reported training in geology or roof and rib control, which can be expected to contribute to high scores on the DRL exercise. The overall mean score for all groups was 88.9 with a standard deviation of 7.59. The exercise was generally easy for this sample of experienced miners and mine maintenance and technical personnel, many of whom have special training.

Examination of the results displayed in Table 7 reveals that the answers to the exercise questions discriminated properly among persons with high total scores and other persons with low total scores. Exactly 50 percent of the answers discriminated positively, none discriminated negatively, and 50 percent failed to discriminate. Although the sample is somewhat homogeneous with respect to age and experience, and biased toward technical personnel, this is a good pattern of item discrimination, and one indication that the exercise is valid.

Inspection of Table 8 reveals that the exercise failed to discriminate between self reported levels of mine technical training. Persons who reported they had completed mine engineering and related advanced technical training did not out score persons who did not report these advanced levels of training. Inspection of Table 9 reveals that the exercise also discriminated among the three major job categories represented in the sample. The present sample does not provide for a valid test of the exercise discrimination capability by training level or job category. The exercise might be expected to discriminate among levels of technical training and job categories if the sample were larger and more homogeneous with respect to age, experience, and level of technical training.

For critical skills like those involved in this exercise, a performance criterion of mastery of at least 90 percent or more of the exercise content is a reasonable standard for technically trained personnel. A lower performance standard for such critical skills is seen as undesirable because the consequences of errors and poor performance can be severe. Table 10 reports the degree to which miners in the field test sample exhibited mastery of the mine emergency judgment and decision making skills assessed by the DRL exercise. The metric used in this analysis is the exercise total score expressed in percent correct performance. The data in Table 10 reveal that 53.7 percent of this sample attained performance scores at or above the 90 percent mastery level criterion, and 91.0 percent scored at or above the 80 percent level.

Characteristics of the field test sample for DRL2 Exercise

(3 sites, 6 classes, n = 69)

Table 1: Age and experience of miners (years)

	n	mode	mean	s.d.
age	69	42	40.3	8.30
experience	69	15	16.3	6.64

Table 2: Gender distribution (%)

	n	frequency %
female	1	1.5
male	67	98.5

Table 3: Job classification

	n	frequency %
miner/laborer	24	35.8
maintenance/technical	40	59.7
supervisor/manager	3	4.5

Table 4: Self-reported level of expertise (frequency %)

category	training	certification	performance
foreman	14.7	58.8	7.4
mine safety committee	10.3	10.3	2.9
mine rescue	22.1	13.2	5.9
mining engineer	2.9	5.9	1.5
roof/rib control	19.1	13.2	14.7
geology	5.9	2.9	1.5
mine planning & design	5.9	8.8	7.4
roof bolter operator/helper	20.6	16.2	22.1
other	11.8	14.7	11.8

Table 5: Miners' rating of exercise validity, relevance, quality, and utility (frequency %)

content	detinitely yes			definitely no	mean	s.d.
	4	3	2	1		
problem could happen	77.6	20.9	1.5	0.0	3.8	0.46
help remember important things	46.3	47.8	4.5	1.5	3.4	0.65
learned something new	23.1	50.8	12.3	13.8	2.8	0.95
exercise too long	6.1	4.5	27.3	62.1	1.5	0.85
liked working the exercise	61.5	26.2	7.7	4.6	3.4	0.83
instructor's directions clear	79.1	20.9	0.0	0.0	3.8	0.41
written exercise directions clear	65.7	31.3	3.0	0.0	3.6	0.55
graphics easy to understand	49.3	40.3	7.5	3.0	3.4	0.75
scoring easy to understand	60.6	36.4	3.0	0.0	3.6	0.56
exercise easy to read	73.1	26.9	0.0	0.0	3.7	0.45

Psychometric properties of DRL Exercise

(printout date 10/5/90, 3 sites, 6 classes, n = 69)

Table 6: Question score and total score statistics

question	minimum score*	maximum score*	median	mean	s.d.	skewness	R^2_{QT}	alpha if question deleted
A	1.7	10.0	10.0	8.8	1.80	-2.21	0.13	0.58
B	5.0	10.0	10.0	9.2	1.26	-1.13	0.31	0.59
C	7.5	10.0	10.0	9.8	0.59	-3.84	0.23	0.60
D	1.7	10.0	8.3	7.6	1.96	-0.66	0.23	0.59
E	2.5	10.0	10.0	9.4	1.29	-3.01	0.32	0.56
F	5.0	10.0	10.0	9.5	1.20	-2.28	0.29	0.57
G	5.0	10.0	8.3	8.3	1.59	-0.44	0.28	0.56
H	2.5	10.0	10.0	9.4	1.69	-2.91	0.45	0.55
I	2.5	10.0	10.0	9.7	1.14	-4.50	0.30	0.55
J	2.5	10.0	7.5	7.2	2.80	-0.52	0.19	0.59
Total	55.8	100.0	90.0	88.9	7.59	-1.61	(alpha = 0.60)	

*The values reported are the minimum and maximum scores obseved, for this sample. The lowest possible score = 0.0 and the highest possible score = 10.0. When scores are summed across questions the highest possible score = 100 and the lowest possible score = 0.

Table 7: Proportion of answers discrimination positively, negatively, and not at all with exercise total score ($p<.10$)

positive	negative	no relationship
23/46 (50.0%)	0/46 (0.0%)	23/46 (50.0%)

Table 8: Discrimination between basic and advanced levels of mine technical training

	n	mean	s.d.	F ratio	p value
basic	15	86.6	10.18	1.56	0.215
advanced	51	89.4	6.53		

Questions that discriminate significantly at $p \leq .10$: none

Table 9: Discrimination between job categories

	n	mean	s.d.	F ratio	p value
miner/laborer	23	87.7	9.46	1.99	0.144
maintenance	39	89.8	5.63		
supervisor/manager	3	81.7	11.76		

Questions that discriminate significantly at $p \leq .10$: D, p=06

Table 10: Number and percent of miners attaining various levels of proficiency (n = 67)

exercise score	number at or above the score	percent at or above the score	cumulative percent
100	4	6.0	6.0
90-99	32	47.7	53.7
80-89	25	37.3	91.0
70-79	5	7.5	98.5
60-69	0	0.0	98.5
50	1	1.5	100.0
below 50	0	0.0	100.0