OVERVIEW OF RESEARCH ON MINE EMERGENCY SKILLS

Michael J. Brnich, Jr., Charles Vaught,
Henry P. Cole, and William Wiehagen

U.S. Bureau of Mines

ABSTRACT

The Bureau's research in human resource development combines social science and instructional theory and design. Part of this effort is concerned with how miners generally behave under life-threatening conditions. The present paper summarizes work intended to enhance individuals' responses to underground mine emergencies by developing innovative strategies to teach and measure "soft skill" competency at the mining site. The way in which workers respond to emergencies is placed within the practical confines of two key areas: 1) studies of how to teach and assess mine emergency skills; and, 2) investigations into how best to provide effective training for procedural tasks such as self-contained self-rescuer (SCSR) donning.

INTRODUCTION

In April 1984 the U.S. Bureau of Mines initiated a program of research to develop performance-based teaching and evaluation methods for measuring nonroutine mine health and safety skills. The research had three related intents. First, it was designed to identify those critical skills workers need in order to cope with emergencies in underground coal mines. Events such as those requiring first aid or self-rescue and escape are infrequent from the perspective of individual miners. It is therefore difficult to maintain workers' proficiency in the skills necessary to cope with these types of situations. A second intent was to make rank-and-file miners the focus of instruction on these nonroutine skills. Thus, it was deemed advisable to develop methods by which to teach and test coal miners on what they must know and do to function in emergencies with only the resources available to them on their working sections. The third intent was to apply recent developments in instructional design and human performance measurement to this task of producing effective methods for teaching and assessing workers' proficiency in critical skill areas. Working with the Bureau of Mines, a multidisciplinary team of researchers from the University of Kentucky (USBM Contract H0348040) began research in October 1984.

BACKGROUND AND RATIONALE

Much of the earlier work in critical skills teaching and testing has been concerned with the training of medical practitioners, flight crews, and military personnel (Halff, et al., 1986; Berner, 1984; Giffin and Rockwell, 1984; McGuire, 1984; Babbott

and Halter, 1983; Jones and Keith, 1983; Brecke, 1982; Dugdale, et al., 1982; Elstein, et al., 1981; Gilbert, 1975). This work was reviewed for the purpose of adapting its theories and methods to the problem of how to prepare rank-and-file miners to respond to nonroutine events. In addition to identifying and reviewing related research, the project team conducted a series of field interviews and collected performance data that helped identify further the specific skills mine workers need in order to deal with emergencies underground.

Both the earlier research and project studies suggested that people often get into difficulty as emergencies develop because they fail to recognize impending problem situations and therefore delay taking action. Individuals also have difficulty with the information gathering, decision making, and judgment tasks required for effective initial response to emerging events. Both areas of deficiency may go unaddressed in mining, because problem solving skills are not usually a part of the instruction workers receive in annual refresher classes.

Formal and periodic health and safety training of rank-and-file miners typically focuses upon the teaching of specific information and techniques such as learning the specifications for and use of fire extinguishing equipment, discussing the federal requirements for maintaining mine ventilation, reviewing the mine's roof control plan, and providing descriptions of the mine's evacuation and escape procedures. This type of factual information and procedural knowledge, while an appropriate component of annual refresher training, is not sufficient to assist miners in practicing the broader array of skills required to identify and solve complex underground mine emergency problems.

Consequently, a series of performance-based instructional materials were developed for the purpose of enhancing miners' proficiency in nonroutine mine emergency situations. The structure of these materials was influenced by a rather large amount of research concerning the role of simulation exercises in teaching problem recognition and problem solving skills. Their content was based on two primary sources: (1) interviews with hundreds of miners, mine rescue personnel, emergency medical technicians, and others who had experienced or investigated some aspect of mine emergencies, and (2) official reports from various state and federal accident investigations.

Much of the remainder of this paper describes the development, properties, and field test results of materials whose intended use is to teach and/or assess proficiency in critical skill areas, and the outcome of investigations into how best to provide effective training for the procedural task of donning a self-contained self-rescuer. A concluding section discusses the impact these efforts are having on training in the mining industry.

PAPER AND PENCIL SIMULATIONS

Trainers conducting annual refresher classes tend to transmit large amounts of information to their students through the traditional methods of lecturing, demonstrating tasks, showing films, and leading group discussions. This approach to teaching is common in all types of classrooms, from technical to higher education. It is dictated by the perceived need to impart large amounts of material in short periods of time, and by the limited opportunities instructors have to develop more sophisticated approaches. Such traditional instruction produces learning that is largely "inert" (Bransford et al., 1986; Halpern, 1984; Cole, 1971). Students tend to remember the factual details of the material for only a relatively short time, and to have difficulty using this information to solve problems in their lives and work. Moreover, they often find this type of approach to be boring.

Various studies have indicated that instruction focused upon solving problems associated with real world tasks is superior to traditional methods of teaching factual information. A drawback is that the problem solving approach may take more of a teacher's time, in terms of both preparation and administration, while covering fewer facts and concepts. However, when instruction is arranged to present realistic, complex problems requiring individuals to gather and organize information, to recall and apply relevant facts, and to use skills necessary in coping with actual predicaments, "active" knowledge is produced. That is, students are more nearly able to apply what they have learned in the classroom to their lives and work. Under such learning conditions, they are also likely to be highly motivated (Resnick, 1987; Chipman, et al., 1985; Segal, et al., 1985; Mayer, 1983).

Using accident reports and the help of experienced mine safety personnel, project personnel have developed and authenticated more than 60 simulated predicaments that require problem solving in two large skill domains: first aid, and self-rescue and escape. The majority of these simulations are in the form of paper and pencil exercises that are written from the perspective of the person working the problem, and that utilize latent image ink in their response sections.

Each simulation is contained in a problem booklet that begins with a scenario presented succinctly in simple language. Line drawings of such things as a mine map and an illustration of the accident scene are included to help further define the predicament. After studying the situation a miner works the problem, which unfolds over time, by responding to a series of choice points offered one to a page. At each of these steps in the exercise an individual is required to gather information, make decisions and take action, marking his or her choice(s) on a separate answer sheet. Brackets on the answer sheet enclose an invisible message for each course of action listed as one of the possible responses to a particular question. When the miner makes a decision and selects an alternative, he or she marks between the brackets on the answer sheet with a special pen. The message immediately becomes visible, assessing the relative "correctness" of such a response and giving additional information that would normally result from taking that action in the real world.

In such fashion a worker can experience, vicariously, an array of mine emergencies. At some stages in any particular problem it may be unclear what series of actions is necessary in order to avoid or lessen the impact of an impending or ongoing accident. Just as in real life, however, the individual knows something of what has happened in the past, and, if he or she is wise, can anticipate what choices (or failures to choose) and what actions will likely alter future events for better or worse. The exercises are designed to teach this "mine wiseness" as they simultaneously assess a miner's proficiency in dealing with the problems presented.

A Case Example: Worker Responses to a Mine Fire An example of such an exercise is one entitled "Escape From a Mine Fire" (EMF). In the fall of 1988, a mine fire occurred that forced the evacuation of three section crews from a large underground coal mine in the eastern United States (Miller and Borda, 1988). While all workers escaped and no lives were lost, numerous errors were committed as miners attempted to evacuate their working sections and find their way to safety.

As part of an on-going research project investigating worker response to mine fires, 16 miners who escaped this fire were interviewed. Data from the interview transcripts were used as a basis for the development of a paper-and-pencil simulation exercise intended to teach and assess miners' ability to cope with a variety of mine fire contingencies. The exercise was designed in such a way that working it would reinforce appropriate choices and correct errors in miners' reasoning and

decision-making. Specifically, the problem calls for demonstration of a range of capabilities with the following required performances and conditions: (1) comprehending the value of accurate and prompt communication concerning the location and size of a mine fire; (2) recognizing the purpose and utility of designated assembly points for evacuation of mining sections; (3) anticipating the probable rate and direction of smoke movement through a hypothetical mine section; (4) formulating escape strategies given limited information; (5) recalling facts about the effects of carbon monoxide and oxygen deficiency, along with the capabilities and limitations of filter self-rescuers and self-contained self-rescuers; (6) ordering priorities when faced with a hostile environment and the inability of all miners to escape; and (7) judging the merits and risks of using self-contained self-rescuers for the rescue of miners trapped in smoke. The format and teaching method of this exercise has been perfected through the extensive research and field testing of problems under the Measuring Mine Health and Safety Skills project (USBM Contract H0348040) discussed earlier.

The EMF exercise underwent two rounds of field testing. A preliminary round involved authentication of the content of the exercise by a group of 14 nationally recognized mine fire and mine rescue experts. The second round of field testing was conducted at four sites with six groups of experienced miners.

The field test involved carefully controlled administration of the revised exercise to 134 underground coal miners. The individuals in the sample represented three major job categories found in the underground mining industry. These include: (1) miner-laborers (24.5%) who are hourly employees and who are engaged in various jobs related to the extraction and transportation of coal; (2) maintenance-technical staff (45.3%) who are electricians, mechanics, surveyors, and other personnel who work underground in and around the sections; and (3) supervisors-managers (30.2%), salaried employees including employees from section foremen through mine superintendents. Of the individuals in the sample, 54.5% reported either some training, special certification, and/or routine performance in at least one of seven areas of expertise. These areas of expertise include: (1) foreman; (2) mine safety committee; (3) mine rescue; (4) CPR; (5) advanced first aid; (6) EMT; and (7) advanced life support.

Each person who worked the simulation was asked to complete a standard 10 item rating form. The first three items on the form were designed to elicit the miners' evaluation of the authenticity of the problem and its value as a training device. The remaining items dealt with the functionality of the exercise and its design. While the workers in the sample were highly experienced, all persons reported that the exercise was authentic and would help them remember important things. In addition, nearly 94% reported that they learned something new.

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 get low scores, the answer is 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, that 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.

The answers to the EMF exercise questions discriminated properly among persons with high total scores and other persons with low total scores. For this sample, 85% of the answers discriminated positively, two discriminated negatively, and only about 12% failed to discriminate. This is a good pattern of item discrimination, and one indication that the exercise is valid.

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. The exercise discriminated between self-reported levels of mine technical training. Persons who reported they had completed mine rescue and related advanced technical training significantly out scored (mean = 84.1) persons who did not report these advanced levels of training (mean = 75.5). This is another indication that the exercise is valid.

The exercise also discriminated among the three major job categories represented in the sample. For example, the average total score for the regular miners in the sample was 71.1 with a standard deviation of 11.03, while the comparable values for the supervisors and managers in the sample was 85.8 with a standard deviation of 7.38. These results provide yet another indication that the exercise is valid.

For critical skills like those involved in this exercise, a performance criterion of mastery of at least 90% 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. The metric used in this analysis is the exercise total score expressed in percent correct performance. For the sample, only 16.3% of the individuals attained performance scores at or above the 90% mastery level criterion. The field test sample for the exercise contained a large proportion of technical and supervisory personnel. Both of these groups generally have more training in mine emergency procedures, mine rescue, and escape procedures than regular working miners. For this reason, the mastery level of the critical exercise skills may be expected to be lower among regular working miners, a hypothesis also supported by the data.

Given the basic and critical nature of the skills involved in this exercise, it is desirable that workers' performance scores exceed the 90% mastery level. Although the exercise is designed at the basic skill level, and although many of the miners in the sample performed well, a number of persons made errors in critical skills that should be learned to perfection. Both the miners and trainers who participated in the field tests report the exercise is useful for teaching and reinforcing these critical skills concerned with escaping from a mine fire.

The EMF simulation exercise is but one example of the array of simulation exercises that have been developed. Other simulations have been produced that present scenarios involving first aid emergencies, hazardous roof and rib conditions, electrical troubleshooting, and fire fighting to name a few. Additional simulations focusing on topics such as travelling through smoke when escaping a mine fire and how to properly don and use SCSR's are under development.

MOTOR TASK TRAINING FOR SELF-CONTAINED SELF-RESCUERS

Studies conducted by University of Kentucky researchers under the contract, and continued by the Bureau of Mines, cast doubt on whether workers have been trained in such a way that they have acquired this skill. The inherent complexity of the donning procedure, the infrequency of hands-on training, the failure of training materials to order critical tasks early in the sequence, even the normally recommended donning position all may contribute to miners' inability to install the devices properly. The research reported in this section presents the development of a more efficient donning procedure, and assesses the impact SCSR research has had on the mining industry.

In preliminary interviews with more than 50 mine safety experts, Cole et al. (1986) recorded several accounts of miners' failure to use SCSR's in situations which clearly called for their installation. The prevailing assumption among those respondents offering such accounts was that the individuals involved knew how to put their apparatus on, but didn't because of poor judgment, panic, or both. A report on the Greenwich Collieries explosion (Fasak & Cavanaugh, 1984), however, alerted the researchers to the possibility that workers simply might not know how to don the devices. It was with a question about the adequacy of current SCSR task training that the project personnel began.

The researchers first conducted an extensive review of existing training materials. They found logical problems which indicate a lack of task analysis prior to the development of the materials. The following problems, which are discussed in detail elsewhere (Vaught & Cole, 1986), run counter to that protocol: First, the recommended donning position was difficult under most mining conditions, and impossible for miners working in thin coal seams. Second, the donning sequence appeared inefficient, placing secondary tasks such as strap adjustment ahead of some of the steps necessary to isolate one's lungs from the ambient atmosphere. Third, the materials did not present a simplified, easy-to-remember set of procedural rules to help miners order the complex array of tasks needed to get the apparatus on in an emergency.

Logical problems with instructional content were not the only indicators that generally available SCSR training may be insufficient. It was found that a majority of underground miners never had hands-on experience with the apparatus (Cole & Vaught, 1986). This was a cause for concern in view of the evidence suggesting that infrequently used procedural skills must be overlearned if proficiency is to be maintained, and that the overlearning of procedures having a motor component requires hands-on training (Johnson, 1981; Hagman & Rose, 1983). Given the critical nature of SCSR donning, the industry's tendency to rely upon audiovisual programs or demonstrations by an instructor instead of upon performance trials by the trainees seemed less than optimal.

Based on these findings, a new donning procedure known as the 3+3 method was developed. An instructional package containing an instructor's manual and short videotape demonstration were prepared for field testing. The 3+3 training method presents a generic procedure for all SCSR's in use (CSE, Draeger, MSA and Ocenco). It offers the following: (1) a donning position (kneeling) which is easy and efficient; (2) a donning sequence which moves critical steps (those tasks necessary to isolate one's lungs) ahead of the others; and (3) a set of consolidated procedural rules that facilitate retention.

With the 3+3 training method, donning proficiency can be assessed with the 3+3 evaluation form distributed by the National Mine Health and Safety Academy as part of the SCSR instructional package. The 3+3 evaluation system allows researchers to make reasonably fine distinctions among donning proficiency levels. For example, Bureau personal constructed a five-fold typification initially, depending upon the degree of

proficiency demonstrated. The proficiency ratings used were: Fail - failure by a worker to isolate the lungs; Poor - the miner's lungs were isolated but he or she is not escape ready; Marginal - the worker's lungs are isolated but he or she forgot one or more steps necessary to secure the apparatus; Adequate - the miner is escape worthy and performed all donning steps correctly, though not in the order recommended by the 3+3 method; Perfect - the miner is escape worthy because he or she performed a perfect 3+3 sequence.

In the final analysis, though, real-world competency would be determined by one's ability to use an SCSR in the manner for which it was intended: to escape an unbreathable atmosphere. Therefore, donning proficiency can be viewed using a simple two-category system. A miner can be described as being either "proficient" or "not proficient" in his or her ability to don an SCSR. A worker who performs either a perfect 3+3 sequence or an adequate sequence is considered proficient. If a miner performs at a level less than this, he or she is considered not proficient because the apparatus is not donned and secured properly. There is little doubt that a person who can put on and use an SCSR with some degree of competence will have a better chance of survival than someone who cannot.

Questions about the nature and quality of traditional training, and about the ability of workers to use the device, were translated into specific regulatory action in 1987. The resulting regulation required mine operators to include a hands-on component in their SCSR training (30 CFR Part 48). Miners are not usually refreshed or evaluated between training cycles even though it is ill-advised to assume that once-a-year practice in a classroom leads to SCSR competency. Better ties between training and performance, however, are only possible through the collection of proficiency data.

In the winter of 1989, the Bureau of Mines participated in an evaluation of SCSR donning trials at eight sites in the eastern United States (Vaught, et al., 1991). This study was designed as an empirical assessment of SCSR donning proficiency and as a means of providing a set of guidelines useful in determining, at a mine-wide level, the skills of underground workers.

At each mine, approximately 30 miners were selected randomly to participate in the study. In all, a total of 243 miners were evaluated. Donning proficiency was assessed using the 3+3 evaluation form. Proficiency profiles were developed for the samples at each of the mines in the study. Figure 1 can be used to differentiate performance patterns across the samples.

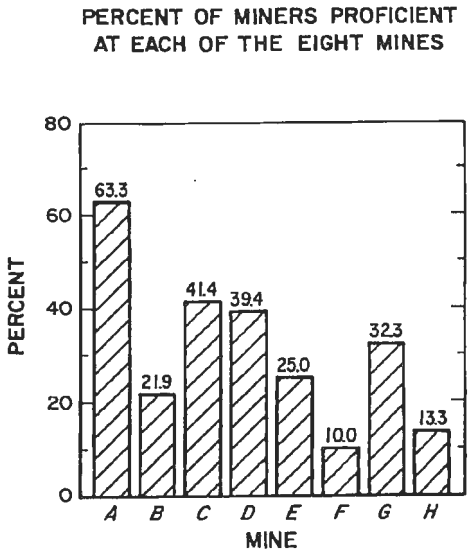

Figure 1.--Profile of donning proficiencies for the samples at the eight mines.

It can be seen that there was a notable amount of variation in the samples. Two factors seem to influence these patterns. First, the quality of training has an impact on how well people perform. Second, recency of practice provides a significant effect -- it has been established empirically that even well-trained individuals forget things over time.

Mine A, whose safety coordinator had just trained everyone (within one week of evaluation) using the 3+3 method, exhibited the highest degree of

proficiency. Mine C, whose miners had also been trained recently (within the past month), also had a significant number of workers who would be considered proficient. An interesting feature at Mine C, however, is the large percentage of people in the "marginal" category. This would seem to indicate that so-called secondary steps (such as strap adjustment and donning the goggles) either had not been stressed during training, or had been forgotten very quickly. Mine B, which had only six per cent failing to get their lungs isolated, had a disproportionate number of miners who performed poorly (50%). One miner's comment, which might explain this anomaly, was that they were taught to do the critical steps and delay securing the apparatus until they were on their way out of the mine. The two mines with the highest percentage of workers who must be considered less than proficient were Mine F (with only 10% proficient) and Mine H (only 13% proficient). It seems clear from this data that a sizable portion of workers in the samples would have difficulty donning and wearing their SCSR.

In a second SCSR donning study, skills degradation was more dramatic. In the Fall of 1989, a total of 169 miners were trained by Bureau personnel to don the CSE SR-100 PWSCSR using the Bureau's 3+3 method. Approximately 90 days after training, a sample of 77 workers from seven mines was selected for follow-up evaluations. In this sample, 49.3% failed to get their lungs isolated. The results from this study support conclusions drawn from prior Bureau research on SCSR donning skills retention: Even with good initial training, individuals who are not given an opportunity for repeated practice tend to forget quickly (Vaught, et al. 1988a).

Perhaps the most significant variable in determining miners' SCSR donning proficiency is the manner in which they are trained. There are some general principles of motor task training which, when applied to SCSR instruction, will yield significant results. First, prepractice instruction is very important. This is the point at which the trainee is introduced to the task and shown what is expected of him or her. Research has indicated that attention to detail at this stage is critical if the trainer expects his or her people to become proficient. Second, the individual learning a motor task (such as how to put on an SCSR) must have the opportunity for thorough, consistent, hands-on practice. This practice should be repeated until the person achieves competence. Thoroughness means that the trainee should do all the steps in a task, and do them properly, just as he or she would in an actual situation. Consistency means that the person performs the task the same way every time. Third, feedback is necessary. There is an extensive body of literature showing that when a person performs a motor task, he or she must be allowed to do the task without interruption. Once the task is completed, however, the individual should be given detailed knowledge of his or her performance. If this is not done, little learning takes place. Fourth, for seldom-used motor skills (such as SCSR use), the person must have a periodic refresher in the form of practice. The primary requirements are attention to detail when training, feedback or knowledge of results, periodic follow-up evaluations, and the opportunity to practice when needed.

Once miners receive thorough hands-on training initially, a program providing opportunities for maintenance of SCSR donning skills is necessary. Periodic hands-on practice following initial training is the most desirable form of refresher. However, the concept of mental practice holds promise as an alternative to hands-on practice.

Bureau researchers conducted an experiment with two groups of mining personnel in order to assess the effectiveness of periodic hands-on practice. Both groups were trained on the Draeger OXY-SR 60B SCSR using the 3+3 method for donning SCSRs (Vaught, et al., 1988b). Following initial training, individuals in the first group (88 members) were given the chance to practice donning the SCSR at

least once during the course of fire drills and escapeway walks. Members of this group were also evaluated by a trainer and given feedback on their donning performance. Individuals in the second group (155 members) were not given the opportunity to receive periodic practice. Members of both groups were then sampled at various time intervals after initial training and their donning proficiency assessed.

As illustrated in figure 2, approximately 80% of the individuals in both groups were proficient in donning their SCSR one week after training.

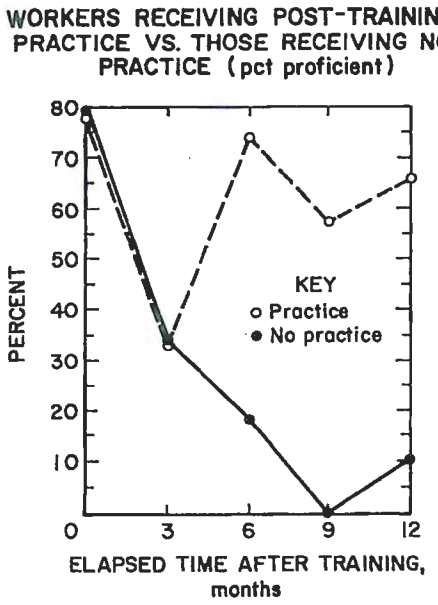

Figure 2.--Donning proficiencies for workers receiving post-training practice.

However, three months after training, only about 33% of the people from both groups sampled performed proficiently. At about 90 days after training, members of the practice group began receiving periodic donning practice. Additional followup evaluations were conducted at six, nine, and twelve months after training. As figure 2 shows, the practice group consistently had a higher percentage of miners who were proficient in donning their SCSR than did the group who did not receive practice. Clearly, periodic hands-on practice is desirable for maintaining SCSR donning proficiency.

Although a trainer may desire to provide hands-on SCSR donning practice to miners at his operation, this activity may not be considered practical. As an alternative, Bureau researchers developed an inexpensive memory aid to enhance SCSR donning proficiency (Vaught and Brnich, 1990). The device is designed to assist miners in maintaining procedural donning knowledge of the SCSR between practice opportunities.

One of the more remarkable findings from motor skills research deals with the effect mental practice has on concrete task performance. Various studies have shown that covert rehearsal can lead to a large positive transfer of skills when a particular task is actually attempted (Schmidt, 1988). With these findings as a guideline, Bureau personnel constructed a 3-D Viewmaster[1] reel depicting a miner performing the 3+3 sequence while donning an SR-100. It was hypothesized that once an individual had learned those discrete actions involved in putting on an SR-100, he or she would benefit from reviewing the steps by using a Viewmaster. In this way a person, once trained, could prepare mentally for his or her next performance by running through the sequence periodically.

Ten state mine inspectors, to whom the SR-100 was issued by their department, were trained to criterion using the 3+3 donning method. Each of the participants was then given a Viewmaster and reel showing the sequence of steps he had just learned. The inspector was asked to use his viewer and mentally practice the donning procedure at a regular time during every workday. Approximately 90 days after training, eight of the 10 participants were evaluated.

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[1]Reference to specific products does not imply endorsement by the Bureau of Mines.

In order to establish a baseline for assessing whether there might have been a performance gain due to daily mental practice, the seven mine sample discussed earlier was partitioned into "elites" (trainers, inspectors, and rescue team members) and others. A computer-generated sub-sample of eight individuals was drawn from the elite category for purposes of comparison. Figure 3 illustrates how the two groupings fared in terms of proficiency (Perfect or Adequate) and non-proficiency (Marginal, Poor, or Fail).

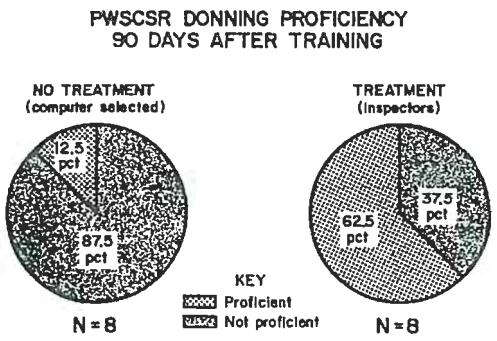

Figure 3.--Ninety-day donning proficiency for trainees using the Viewmaster.

Such a marked difference suggests mental practice holds much promise as a practical and simple mechanism for maintaining an acceptable level of SCSR donning skills between actual performance opportunities. Further research is needed to explore this possibility.

In short, the key to achieving and maintaining SCSR donning proficiency can be summed up in one sentence: Train well initially, and be prepared to offer thorough, consistent, practice periodically.

IMPACT ON MINER TRAINING

The simulation exercises that have been developed were designed to work well across a variety of settings. The pens, answer sheets and problem booklets required are inexpensive and can be obtained at cost from the National Mine Health and Safety Academy in Beckley, West Virginia. The SCSR donning exercise requires evaluation forms, and training apparatus which can be purchased from the various manufacturers or built from discarded units using plans that are also available from the Academy. In essence, everything discussed in this paper that might be needed to help enhance miners' proficiency in nonroutine situations is inexpensive, readily available, and easy to use. This fact is evidenced by the widespread distribution of more than a quarter million simulation answer sheets and the general adoption of the 3+3 SCSR donning method by the coal industry.

The impact of widespread use does not stop with specific exercise content, however. Many instructors use their experience with the materials to develop ideas and insights for other classroom activities. The paper and pencil simulations demonstrate new ways to approach discussion of hazard recognition and correction, accident prevention, and emergency response procedures, for instance. The SCSR exercise demonstrates simple means by which to conduct performance oriented task training because the methods can be generalized to other tasks that require manipulation of equipment and knowledge of procedure. In sum, the results of all field tests suggest that the materials developed from the research effort reviewed here have tremendous potential for improving mine safety training.

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U.S. Department of Labor

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Bureau of Mines
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Michael Karmis
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

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