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RESEARCH AND EVALUATION METHODS FOR MEASURING NONROUTINE MINE HEALTH AND SAFETY SKILLS: VOLUME I

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Thirty-six simulation exercises designed to teach and assess problem-solving skills for coping with mine emergencies were developed and field tested in annual refresher training classes in eight states. The exercises focus on first aid and self-rescue and escape situations. Previous research in the development of simulation problems for aviation, medical, and military personnel guided the development of the new exercises. The 4,000 miners in the field test samples averaged 37 years of age with 12 years experience. Only 2.1 percent of the sample was female. Miners and their instructors rate the exercises highly in terms of their authenticity, relevance, and utility. Analysis of performance data suggest the exercises are valid, discriminate between persons with basic and advanced levels of training, and challenge most miners. The exercises deal with critical skills that should be learned to high levels of mastery. Yet, fewer than 30 percent of the miners in the samples achieved mastery scores at or above the 90 percent level. The low levels of mastery suggest: 1) miners have little opportunity to practice judgment and decision-making skills in mine emergency situations because of the infrequent occurrence of these events, and 2) working the simulation exercises in annual refresher training classrooms may contribute to miners' preparedness [redacted] infrequently encountered mine emergencies.

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FOREWORD

This report was prepared by the Behavioral Research Aspects of Safety and Health Working Group (BRASH), Institute for Mining and Minerals Research (IMMR), University of Kentucky under USBM Contract number HO348040. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of the Pittsburgh Research Center with William J. Wiehagen acting as Technical Project Officer. Michael L. Nowicki was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period from October 1, 1984, to May 31, 1988. This report was submitted by the authors on July 11, 1988.

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Executive Summary

The U. S. Bureau of Mines contracted with the University of Kentucky to research, develop, and evaluate methods for teaching and assessing nonroutine health and safety skills needed by underground coal miners to cope with emergency situations. This final report describes that research. Two earlier technical reports provide detailed information about the initial field studies and reviews of research that directed the development of the materials described in this final report.

Two broad categories of nonroutine skills were identified. These included first aid for self and others, and self-rescue and escape from mine fires, gases, smoke, and other life-threatening situations. The types of events that require these skills are relatively infrequent occurrences in the lives of individual miners. For this reason the skills are said to be nonroutine. Maintaining proficiency in such infrequently used skills is difficult, as is demonstrated in previous military and medical emergency personnel preparedness research. The problem simulation materials developed under this contract were designed to help maintain preparedness in the information gathering, judgment, and decision making skills required for coping with these types of mine emergencies.

The focus and the content of the simulation exercises are based on 1) a series of field studies of miners needs for critical skill training, 2) extensive review of research about the development and use of critical skill simulations in other fields, and 3) review of hundreds of accident investigations in the mining industry. This information was used to develop 36 simulation exercises. These simulations fall into three general

types: paper and pencil simulation exercises, first aid role play simulations, and a self-contained self-rescuer (SCSR) donning procedure for the oxygen generating emergency breathing apparatus used by miners to escape from mine fires, smoke, and gases.

These three types of simulation exercises were field tested with approximately 4,000 miners in annual refresher training classes in eight coal producing states in the United States. Data are analyzed and research results presented for each of the three types of simulations. Chapters 2 through 4 describe the research, development, design characteristics, field evaluations, and effectiveness of each of these types of exercises.

Three types of field test data were collected and analyzed for each exercise. Summaries of these data include 1) the demographics for the sample of miners involved in the field tests, 2) the miners' and trainers' evaluation of the worth of the exercises, and 3) the miners' performance scores on the exercises.

Analysis of the demographic data reveal the average age of the miners in the sample was 37 years. The averaged mining work experience was 12 years. Only 2.1 percent of the sample was female. About half of the persons involved in the field tests were working miners, with the other half being nearly evenly split between mine supervisors and maintenance/technical personnel.

Analysis of the miners' and trainers' numerical ratings of the exercises shows all three types of exercises meet design criteria of perceived acceptability and usefulness for the intended audience. The simulations are perceived as authentic, useful for improving problem solving skills for coping with emergency situations, helping miners

to learn and remember important information, and as interesting and enjoyable classroom activities.

Analysis of the performance data reveals that many miners perform well below desirable high levels of mastery on critical skills of early problem recognition, information gathering, judgment, and decision making. These data suggest that miners need more opportunity to practice the skills required for prevention and control of mine emergencies.

Analyses of the performance data suggest that the exercises are valid instruments for teaching these types of skills, and for assessing miners' present skill capabilities. Most of the exercises significantly discriminate among levels of training and expertise. Although these differences in performance scores are generally small, experts outperform regular miners and novices. Supervisors often outperform regular miners, probably by virtue of the additional training and certification required for mine managers. Miners certified in mine technical areas and in advanced first aid procedures also tend to outperform miners who lack such advanced training.

The exercises are designed primarily as teaching devices, not as tests. Working the exercises reinforces wise choices and corrects errors in miners' thinking and actions. This reinforcement and remediation is provided immediately as miners work the exercises. This makes the exercises effective teaching devices, but compromises their value as skill assessment tests. The large amount of corrective feedback is designed to present information and ideas when miners are most receptive to this learning because of their active participation in the problem solving process. Thus, working an exercise tends to teach the miner as he or she completes the task.

The exercises could be modified to become tests, which when individually administered, could be used to certify miners' competence. However, it is better to use the exercises as teaching devices. In this role they are nonthreatening to miners and instructors. They foster cooperation rather than competition in the solving of problems. They help miners communicate and work together in coping with simulated emergency problems like those that may be encountered in the work place. The group problem solving and detailed analytical thinking promoted by the exercises may generalize to actual mine emergency events when miners must work together, gather information, communicate with one another, and make life and death decisions.

Seventeen of the 36 exercises have recently been released for national distribution through the National Mine Health and Safety Academy and the University of Kentucky Institute for Mining and Minerals Research. These exercises are currently in use throughout the United States mining industry with more than 20,000 miners in hundreds of annual refresher classes. The format and teaching methods employed by the exercises suggest new ways to conduct training. Trainers at a number of sites have begun to experiment with the exercises, adapting their design features and formats to other material taught in annual refresher training. A series of regional workshops and seminars is planned to help these groups learn more about the instructional design principles that underly the exercises. This effort may assist trainers at many sites to develop additional simulation exercises and similar materials long after the completion of this initial Bureau of Mines funded contract.

Chapter 1: Critical Skills in Mine Emergencies

Earlier studies have identified critical skills miners need to prevent and cope with emergency situations that develop in underground coal mines. These critical skills fall into two broad categories. For convenience, these two areas are referred to as "first aid" and "self-rescue and escape."

Two Broad Categories of Critical Skills

The first category concerns first aid skills needed by all miners for immediate treatment of self and co-workers who are victims of accidents or illnesses that occur in the isolated environment of mines. Typical first aid problems that miners must be prepared to cope with include heart attacks, allergic reactions to medication, insulin shock, hypothermia, heat exhaustion, crushing injuries, amputations, incisions, lacerations, puncture wounds, hemorrhage, fractures, electrical shock, traumatic shock, thermal and chemical burns, asphyxiation, dislocations, strains, sprains, bruises, and abrasions. (Cole, Berger, Vaught, Lacefield, Wasielewski, Haley, & Price, 1988a, Chapter 1; Katz & Oglesby, 1979; Pickar, 1977).

The second broad skill category deals with procedures to prevent, immediately recognize, minimize, and avoid property damage, injury, and death that can result from a mine emergency situation. Emergency situations of this type frequently include ventilation failures, fires, explosions, accumulations of dangerous levels of mine gases, sudden inundations of water or gas, malfunctioning equipment, or improper sequences of mining operations and procedures that create hazardous conditions. Critical skills for preventing and coping with such emergency situations include hazard recognition

and control, adherence to safe work practices (Cole, Berger, Garrity, Auvenshine, Szwilski, Hernandez, Blythe, & Lacefield, 1986; 1985; Garrity, Berger, Cole, & Auvenshine, 1986), good communication among miners both within and across sections and shifts (Committee on Underground Coal Mine Safety, 1982), and the ability to rapidly gather relevant information needed to make informed judgments and decisions in the face of a potential or ongoing major mine emergency situation (Bureau of Mines, 1982; National Research Council, 1981). Other critical skills include knowing mine evacuation routes and procedures, proficiency in using self-rescue breathing apparatus, planning and improvising alternative means and routes for escape, and when escape is not possible, barricading and improvising to maintain life until rescue teams can arrive (Berry et al., 1976; Boghani, 1978; National Research Council, 1981; Richmond, Price, Sapko, & Kawenski, 1983). Studies of self-rescue and escape behaviors from fire and smoke in large complex structures such as factories, hospitals, nursing homes, hotels, and dwellings (Bryan, 1977, 1978; Canter, 1980, Canter, Breaux, & Sime, 1980; Lerup, Conrath, & Liu, 1980; Marchant, 1980) can help to define the critical skills needed by miners to escape from underground fires and explosions (Cole, et al. 1988a).

Request for Research Concerning Critical Skills for Miners

In April 1984 the U. S. Bureau of Mines issued a request for proposals for "Research and Evaluation Methods for Measuring Nonroutine Mine Health and Safety Skills." The initial request for proposals had a number of intents. First, the request was designed to identify critical skills miners need to cope with infrequently occurring (nonroutine) mine emergencies in underground coal mines. First aid and self-rescue

and escape situations are infrequent events from the perspective of individual miners. Therefore, it is difficult to maintain miners' proficiency in the critical skills needed to cope with these emergency situations.

A second intent was to focus instruction on the skills needed by underground coal mining crews for coping with these types of emergencies. Development of other materials for training surface and mine management personnel in disaster preparedness and overall mine emergency management procedures was previously funded by the Bureau and prepared by West Virginia University as the Mine Emergency Preparedness Seminar. While the West Virginia materials are designed for mine managers, this current project was to focus on working miners. It was to develop methods by which to help teach and test coal miners on what they must know and do to prevent and cope with emergencies with only the resources available to them at their underground working sections.

A third intent was to apply recent developments in instructional design theory and human performance measurement methodology to produce effective methods for teaching and testing miners' proficiency in selected critical skills. Much of the earlier work in critical skills teaching and testing has occurred in the training of military personnel, medical personnel, and civil and military flight crews through the construction of well designed simulation problems. This work was to be reviewed, its theories and methods adapted to the design of training materials for underground coal miners, the new materials developed, field tested, and evaluated.

A New Research and Development Project

In October 1984, under a 38 month contract from the Bureau of Mines, a

multidisciplinary team of researchers from the University of Kentucky, Behavioral Research Aspects of Safety and Health (BRASH) working group began to identify, design, and evaluate methods for teaching and testing critical skills needed by miners for coping with first aid and self-rescue and escape situations. In addition to identifying and reviewing the earlier research in critical self-rescue and escape skills in mining and in related settings, the researchers also undertook a series of field interviews and studies that helped further identify the specific skills miners need to cope with underground mine emergencies.

Both the earlier research and the newer studies suggested that miners, as well as other persons in similar situations, often get into difficulty as emergency situations develop because they fail to recognize impending problem situations and delay action. People also have difficulty with the information gathering, decision making, and judgment tasks required for the "front end" coping with infrequently experienced emergency problems. In addition, observation and review of existing training materials and practices suggested that the critical information gathering and decision making skills required for early problem recognition and subsequent problem solving are often not included in the instruction miners receive in annual refresher classes. Instruction is typically focused upon the teaching of specific information and techniques such as naming the locations of pressure points, splinting and bandaging of fractures, learning the specifications for and use of fire fighting equipment, discussing the federal requirements for maintaining mine ventilation, reviewing the mine roof control plan, and descriptions of the mine evacuation and escape procedures. This type of factual information and procedural knowledge is appropriate for annual refresher training, but

it is not sufficient to assist miners in practicing the broader array of skills required to identify and solve complex underground mine emergency problems from their inception to their conclusion.

Subsequently, a series of training materials that both teach and test miners' proficiency in coping with underground mine emergencies were developed. The design of the training materials was assisted by the large amount of research concerning the use of simulation exercises in teaching problem recognition and problem solving skills to military, aviation, and medical personnel. The content of the new materials was based on interviews with hundreds of miners, mine rescue personnel, and emergency medical technicians who had experienced, observed, or investigated mine emergency situations. Case material from hundreds of state and Mine Safety and Health Administration accident investigations was also reviewed. Subsequently, this information was used to develop three types of simulation training exercises. Much of this research is reported in two earlier technical reports (Cole, et al. 1988a: Cole, Berger, Vaught, Haley, Lacefield, Wasielewski, & Mallett, 1988b).

The researchers' conceptualization of mine emergency preparedness for working miners was influenced by an earlier National Research Council (1981) study titled Underground mine disaster survival and rescue: An evaluation of research accomplishments and needs. This earlier study, also supported by the Bureau, called attention to the the activities needed to prevent and control mine disasters. It outlined six stages for responding to an underground mine disaster. The recommended prevention and control activities are listed in Table 1.1 and the six stages of disaster response are summarized in Table 1.2.

Table 1.1: Activities for preventing and controlling mine disasters*

stage	activity
1	Eliminate as many hazards as possible.
2	Reduce chances of occurrence if hazard(s) cannot be eliminated.
3	Localize the effects of accidents to prevent or limit a disaster.
4	Enhance prospects for evacuation, escape, and survival in the face of a disaster.

Table 1.2: Six stages of disaster response*

stage	action	definition/example
1	hazard control	Recognizing potential problems and preventing their occurrence. Example: reducing methane face ignitions in gassy mines by maintaining good ventilation, sharp cutter bits, and good water sprays on the continuous mining machine, and by providing equipment and training for prompt firefighting.
2	evacuation	Orderly assembly of mine crews and exit by a previously planned route and means when in danger from extensive smoke, fire, gases, explosion, inundation, and other uncontrolled hazards.
3	escape	Exit to safety by individuals and groups of miners when the normal assembly points and evacuation routes cannot be used. Examples: use of the personal filter self-rescuer (FSR) and self-contained self-rescuer (SCSR) emergency breathing apparatus. Knowing secondary escapeways and originating, improvising, and carrying out a plan for escape when the usual escapeways are impassable.
4	survival	Determining when all means of escape are cut off and barricading and improvising to sustain life until rescue.
5	rescue	Coordinated effort by trained persons from outside the mine directed toward locating, communicating with, reaching, and removing trapped miners.
6	recovery	Removal of bodies and restoration of the mine to normal operations.

* Adapted from National Research Council (1981), Underground mine disaster survival and rescue: An evaluation of research accomplishments and needs.

Overview of the Research

The remainder of this report describes the development, properties, and field test results for three types of training materials designed to teach and test miners' proficiency in critical skills for emergency first aid and self-rescue and escape situations. All three types of training materials are simulation exercises.

Chapter 2 describes paper and pencil simulation exercises designed to teach and test problem recognition, information gathering, judgment, and decision making skills that miners need to deal with emergencies. Thirty one of these paper and pencil simulation exercises have been developed to date. Each exercise is based upon case materials. The exercises are designed to vicariously place miners in situations that simulate the information gathering and decision making skills needed to cope with actual mine emergencies. These exercises teach the prevention and control of mine emergencies and disasters by focusing on the four activities outlined in Table 1.1. The exercises are directed toward the first four stages of the six stage disaster response described in Table 1.2. The first four stages define the things that working miners can do to prevent, reverse, limit, or escape a developing mine emergency situation. Chapter 2 describes both the design characteristics of these exercises, and summarizes data from miners' and trainers' evaluations of the materials.

Chapter 3 presents a summary of the psychometric (mental measurement) properties of the paper and pencil exercises. The reliability, validity, and difficulty of the exercises are examined as determined from analyses of field test data. The miners performance scores across the exercises are also presented, interpreted, and discussed.

Chapter 4 describes another type of simulation exercise, a new hands-on self-contained self-rescuer (SCSR) donning procedure. The new procedure was developed and field tested during 1985 and 1987. In 1987 it was released by the Bureau of Mines to the National Mine Health and Safety Academy for national distribution. The new training procedure is currently used throughout the United States coal mining industry. Hands-on training with SCSRs for all underground coal miners is now required by federal law and the new "3 + 3" method developed under this project contract is recommended (Spicer, 1988). The procedure uses a variety of instructional methods including simple, easy to remember verbal directions and line diagrams of donning positions and sequences, short videotape demonstrations, observation and objective performance evaluation of others donning the apparatus, individual hands-on donning practice without prompting, and objective performance evaluation and corrective feedback for each miner until mastery of the SCSR donning task is demonstrated. The new procedures result in fast and proficient SCSR donning.

Chapter 5 describes four additional exercises that simulate first aid emergencies through role play situations. The method is based upon earlier studies concerned with teaching first aid problem solving skills and procedures. The simulations are demanding, interesting to miners and instructors, and test the range of first aid skills needed from the beginning of an accident event until the injured miner has been delivered into the care of emergency medical system personnel.

Chapter 6 discusses the impact the simulation exercises are having on annual refresher training classes in the mining industry. As noted earlier, the "3 + 3" SCSR donning method is being used nationwide. Approximately 17 of the paper and pencil

exercises have recently been duplicated for national distribution by the National Mine Health and Safety Academy, and the University of Kentucky Institute for Mining and Minerals Research. The remaining exercises will soon be duplicated for distribution. Those exercises that have been released are currently in use with more than 20,000 miners in annual refresher training classes throughout the country. Groups of mine health and safety trainers have begun to adapt existing exercises to create new simulation problems for work settings other than underground coal mines. This activity and its potential for improving annual refresher instruction in other areas is examined.

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Chapter 2: Field Evaluations of Paper and Pencil Simulation Exercises[1]

When an emergency situation develops in the isolated environment of an underground coal mine, the well-being of the miners depends upon the early recognition of the problem and prompt responses to prevent, limit, or escape from the emergency. Civil and military aircraft flight crews face similar problems during inflight emergencies. Research suggests that paper and pencil and/or computer presented simulations of inflight emergencies can better prepare air crews to recognize and cope with actual nonroutine critical events (Brecke, 1982; Flathers, Giffin, & Rockwell, 1982; Giffin & Rockwell, 1984; Jensen, 1982). Similar research suggests that training physicians and other medical personnel in medical diagnostic judgment and decision making can be facilitated by simulation exercises (Babbott & Halter, 1983; Berner, 1984; Dugdale, Chandler & Best, 1982; Elstein, Shulman, & Sprafka, 1981; Gilbert, 1975; Jones & Keith, 1983; McGuire, 1984; McGuire & Babbott, 1967; McGuire, Solomon, & Bashook, 1976; Rimoldi, 1961). These types of simulations have come to be used extensively in the training of many kinds of military personnel in a wide range of problem solving tasks (Halff, Hollan, & Hutchins, 1986). Simulation exercises are sometimes constructed using latent image (invisible) ink and paper and pencil tests. When the person makes a choice in a simulated diagnostic procedure, a special pen is used to mark in a space on the paper. A message appears and tells the test taker the results of his decision or action. Computers, role playing, physical models (e.g. Resusci-Annie),

[1]Some of the work in this chapter is reported in earlier documents (Cole, Wasielewski, Lineberry, Wala, Mallett, Haley, Lacefield, & Berger, 1988; and Cole, Vaught, Wasielewski, & Wiehagen, 1986).

and case reviews are also used to teach and assess proficiency in medical diagnostic and decision making skills. The research literature about these simulations provides much information about how to teach and assess proficiency in fields where critical judgment and decision making are required for health and safety.

Simulation Exercises for Coal Miners

Simulations that require miners to recognize and cope with developing emergency events in underground mines were developed and evaluated. Problem scenarios were constructed based upon actual mine emergencies involving fires, explosions, water and gas inundations, roof falls, equipment failures, serious injuries, and sudden illnesses. The scenarios are authentic with respect to both the language and context of mining. As a problem unfolds, miners must first gather information. Then they must make judgments and decisions about what additional information they need, how to obtain the information, and ultimately what actions to take and in what order.

Proficient performance results in problem solutions that prevent or minimize the accident or emergency. Errors in information gathering, interpretation, judgment, and decision making lead to actions that worsen the situation. Thus, in the safety of a training room, miners experience vicariously the consequences of good and bad judgments and decisions. It is not uncommon for a miner to end up "dead" or in deep trouble. When this happens, the miner is attentive to the information and procedures that are included in the remediation portion of the exercise. The remediation is intended to correct errors miners make in responding to the simulation problem. The intention is to improve the ability of miners to cope with the judgment and decision making aspects of actual mine emergencies that may be encountered in the

workplace.

Active versus Inert Knowledge

For the past several years, members of the research project have attended annual refresher training classes at many sites in several states, both as observers and as participants. Other studies of annual refresher training were also reviewed (Digman & Grasso, 1982). Studies of the effectiveness of various types of instruction for teaching problem solving skills were also reviewed (Cole, Vaught, Wasielewski, & Wiehagen, 1986).

The primary focus in annual refresher classes tends to be the transmission of large amounts of information to trainees by instructors through traditional methods of lecture, demonstration of tasks, showing films, and conducting group discussions. The content is generally relevant and appropriate. The instructors are usually competent in the technical content of the material being taught, and they are usually respected by the trainees. This approach to instruction is common in all types of classrooms in secondary, higher, technical, and professional education. It is dictated by the perceived need to teach large amounts of material in short periods of time, and by the limited time instructors have available to develop more sophisticated approaches.

This type of traditional instruction tends to produce learning that is largely "inert" (Bransford, Sherwood, Vye, & Rieser, 1986; Cole, 1971; Halpern, 1984). Learners tend to remember the factual details of the material presented for a relatively short time, and to have difficulty using this information to solve problems in their lives and work. Learners also often find this type of instruction to be boring (Bransford, Sherwood, Vye, & Rieser, 1986; Chipman, Segal, & Glaser, 1985; Cole, 1971; Mayer, 1983; Segal,

Chipman, & Glaser, 1985; Resnick, 1987).

Studies have shown that instruction focused upon problem solving like that required for coping with real world tasks is superior to instruction focused on teaching factual information. Instruction can be arranged to present realistic, complex problems that require learners to gather and organize information, to recall and apply relevant facts, and to use skills that are necessary to solve actual problems. When instruction is organized in this manner it tends to produce active knowledge. That is, learners are able to apply what they have learned in the classroom to their lives and work. Learners also tend to be highly motivated by problem oriented instruction (Bransford, Sherwood, Vye, & Rieser, 1986; Chipman, Segal, & Glaser, 1985; Cole, 1971; Halpern, 1984; Mayer, 1983; Segal, Chipman, & Glaser, 1985; Resnick, 1987). The preparation of these types of problem solving exercises is more time consuming and difficult than the presentation of factual information lectures and discussions (Anglin & Cole, 1983; Cole, 1971). Such problem solving exercises also require more instructional time to cover fewer facts and concepts. Traditional approaches to instruction can present more material much more rapidly, but generally leave the learner unable to remember and apply much of the material to his or her work and life.

The simulation exercises described in this report are problem solving tasks. They are designed to assist miners in using their past experience, knowledge, and skills to solve realistic problems. They are designed to be interesting experiences that will be seen as authentic and worthwhile activities. They are one means for miners and their instructors to connect the large amount of factual material encountered in the training room to events encountered in the workplace. Well designed simulation exercises are

known to be effective in helping learners see instruction as relevant and in helping what is learned in the training room to become active knowledge (Jones, 1987).

Developing Simulation Exercises About Mine Emergencies

Using accident reports and the help of experienced mine safety personnel, 36 simulation exercises have been developed. Thirty one of these are paper and pencil simulations. Twenty nine of these 31 paper and pencil simulations use the latent image format. All the exercises require problem solving similar to that which miners need in actual mine emergencies.

Problem scenarios, complete with accompanying maps and illustrations, are developed from reviews of actual mine emergencies reported in accident investigations. Sometimes scenarios are developed from the experience of miners, mine rescue team members, and mine inspectors. As a scenario unfolds there are predicaments. At some stages in the problem it is often unclear what series of correct actions is necessary to avoid or lessen the impact of an ongoing or impending accident. Each exercise presents a problem that unfolds over time. Just as in real life, the miner knows something of what has happened in the past, but cannot know what the future holds. However, just as in life, wise miners can anticipate what actions, choices, (and failures to act) will likely alter future events, for better or worse.

Once they are developed the exercise scenarios are then discussed in small groups of experienced miners and experts in mine safety and mine emergency procedures. As the discussion progresses, good and bad options for coping with the problem at each of several stages emerge. This information is recorded and later used to construct individual questions as well as correct and incorrect answers to these

questions for each scenario. Once developed, these prototype exercises are authenticated with small groups of other experts. The exercises are then revised, produced, and field tested with miners in annual refresher training classes. All the exercises concern either first aid, self-rescue and escape, hazard recognition, accident prevention, or a combination of such situations.

The exercises are written as if the problem were developing and unfolding for the person who completes the exercise. Exhibit 2A shows the beginning of one first aid exercise. The basic background and problem information is presented succinctly in simple language. Simple line drawing illustrations appear in the printed exercise booklet and help to further describe the problem. Exhibit 2B shows part of another exercise concerned with an underground mine fire. Appendix A provides a brief description of each of the exercises developed to date.

After studying the problem situation and illustrations, miners work the problems by reading a series of multiple choice questions that appear in a problem book, with one question per page. As noted earlier, 29 exercises use the latent image format. These exercises have an accompanying answer sheet. Brackets on the answer sheet enclose each latent (invisible) image message for each course of action listed as an alternative for each question. When the miner makes a decision and selects a particular alternative, he or she marks between the brackets on the answer sheet with a special pen. Immediately, the invisible ink message becomes visible and informs the miner of the correctness or incorrectness of the response. Often additional information that would normally result from that action is also presented. Thus, miners soon learn the consequence of their choice, and the inadequacy or the value of a particular

response. In this manner, the exercise takes the miner through from 6 to 15 key steps in the problem where information must be gathered, decisions made, or action taken. The exercises are designed to teach as they simultaneously assess miners' proficiency in dealing with the problems presented.

Exhibit 2B illustrates part of another exercise, this one dealing with escape from smoke and gases originating from an unknown source in a mine. It too presents a complex problem in simple language. The problem narrative and a sequence of mine section maps provide information needed to make decisions about fire fighting, rescue of a trapped miner, and choice of escape routes.

Twenty nine of the 31 paper and pencil simulation exercises developed to date use the latent image format. However, once an exercise is developed it can be prepared in any format: open ended essay, discussion, latent image, short written or objective answer, or computer administered format. Appendix C includes BASIC programs for four of the exercises that were converted from latent image format to a computer administered format. Some exercises, especially in the first aid area, also lend themselves to a role playing simulation format with miners acting out the role of victim and first aiders. These role play simulation exercises are described in Chapter 5.

Results of Field Testing

In 1986 and 1987, a total of 28 exercise versions were field tested, revised, and field tested again in 239 annual refresher training classes at 100 sites in 6 states involving approximately 3,650 underground coal miners. The remainder of this chapter analyzes the miners' and trainers' evaluations of these 28 exercise versions. The

results reported in this chapter are summarized across these 28 exercise versions. The versions are representative of the exercises developed throughout the project.

Since this chapter was written, several new latent image exercises have been developed and field tested, and others are currently being field tested. Summary data from these new exercises are not included in this chapter, but will be included in the instructor's manual for each new exercise.

The results reported in this chapter are based upon a large and representative sample of the mining workforce. The sample included miners working at large and small mines, union and nonunion companies, high and low coal seam mining conditions, and various mining methods and techniques. The basic demographic characteristics of this sample of miners is presented in Table 2.1. The distribution of age, gender, and job classification in this sample closely matches the observed distribution of these characteristics in other national samples of miners (Rockefeller, 1980). Generally the classes were small, averaging about 16 miners. (See Table 2.2.)

The field test data show that the exercises were rated highly by miners. In addition to completing an exercise answer sheet, each of the 3,658 miners in the sample rated the worth of the activity on ten characteristics on a standard form. These characteristics are shown in the first column of Table 2.3. They include such things as whether the miners felt the exercises were realistic, enjoyable, easy to read, and would assist them in remembering important things. As can be seen from inspection of Table 2.3, the exercises were rated highly on all categories, except for clarity of scoring procedures.

Subsequent exercise revisions included improvements in directions to miners for

Table 2.1: Demographic characteristics of underground coal miners from 8 states, 100 sites[2], and 239 annual refresher training classes held in 1986 and 1987 (n = 3,658)*

	age and experience (years)				gender distribution (percent)		
	n	mode	mean	s.d.		n	frequency %
age	3,404	35	37.2	9.0	male	3,334	97.9
experience	3,148	10	11.9	7.2	female	72	2.1

job classification**	n	frequency %
miner	1,521	48.1
maintenance/technical	761	24.1
supervisory/management	761	24.1
other	119	3.8

*The total numbers in the specific parts of the table are smaller than 3,658 because of instances of missing data cases on specific variables.

**The category miners includes all persons in regular and direct coal production jobs underground. The maintenance/technical category includes mechanics, electricians, masons, carpenters, belt setup crews, surveyors, inspectors, engineers, geologists, and others who work underground but not directly in production. The supervisory/management category includes all managers from the section foreman up through general mine foreman, superintendent, and top company management. The other category includes clerical and office personnel, preparation plant and surface mine workers, accountants, laboratory workers, and others who generally work on the surface, but who sometimes participate in annual refresher training.

[2]The 100 sites were located at facilities associated with 29 company, state, and vocational/technical school mine health and safety training regional centers distributed across the coal fields of Kentucky, West Virginia, Pennsylvania, Virginia, Tennessee, Illinois, Utah, and Ohio.

Table 2.2: Typical number of miners per class

mode	median	mean	standard deviation
5	14.0	15.3	10.9

Table 2.3: Miners' rating of the validity, relevance, quality, and utility of 28 exercises in annual refresher training in 239 classes, at 100 sites, in 8 states (n = 3,658)

miner judgment category	n	yes (%)	no (%)
exercise content is authentic	3,451	97.6	2.4
working exercise will help me to remember important things	3,433	95.0	5.0
learned something new from working the exercise	3,414	84.8	15.2
the exercise was too long	3,382	15.4	84.6
liked working the exercise	3,381	91.5	8.5
instructor directions clear	3,393	96.1	3.9
written directions in the exercise are clear	3,396	90.3	9.7
graphics in the exercise are easy to understand	3,393	94.2	5.8
the procedures for scoring my performance are easy to understand	3,204	86.0	14.0
the exercise is easy to read	3,102	94.6	5.4

scoring their performance, thus overcoming this early problem. These field scoring procedures are used simply to provide immediate feedback to miners concerning how well they performed on the exercise. Early versions of the exercises omitted these field scoring procedures. Trainers complained because immediately following completion of an exercise, miners wanted to know how well they had performed. The field scoring procedures were developed for this purpose. These are a simple set of instructions that tell miners how to count and sum the correct answers they have selected to obtain their total score for the exercise.

The actual scoring of the miners' performance for the psychometric and performance analyses reported in Chapter 3 are not based on the field score. Rather, a precise scoring algorithm is prepared for each exercise. This algorithm is used to

score each miner's performance based on the raw data. Therefore, miners problems in understanding the field scoring procedures have no relevance for the validity of the scoring procedures used to carry out performance analyses.

For each class administration, the instructor also completed a questionnaire that solicited information about 1) how the exercise was introduced and administered, 2) if the instructor modified the exercise in any way, 3) the observed frequency of reading problems among miners in the class as they worked the exercise, and 4) the instructor's judgment about key aspects of the exercise. The judgment categories included the degree to which miners were able to understand the instructor's directions, the clarity of written directions and graphics in the exercise, and the scoring procedures. The instructor also was asked to judge the appropriateness of the performance objectives, the relevance of the exercise for the annual refresher training class, and whether more exercises like these should be used in the future in other classes. Instructors also were asked to make comments to improve the exercise, and many did so.

The summary data for the instructor's questionnaire are presented in Tables 2.4 through 2.9. Most instructors administered the exercise individually (see Table 2.4), in large part because they were asked do so to enable the correlation of miner's performance scores with their questionnaire data. Given their own choice, the majority of instructors report they prefer to administer the exercises in small groups of from three to five miners per group. There are three reasons for this. First, the latent image answer sheets, which are consumable, last longer this way and more classes of miners can be taught with fewer of these materials. Second, most class members prefer to

Table 2.4: Frequency of instructor administration format (n = 164 classes)

reported administration format	percent
administered individually, one exercise booklet per miner	74.4
presented exercise on transparencies while each miner responded individually	2.4
presented exercise on transparencies while class members responded as a group	0.0
used one exercise per small group in several groups per class	20.1
used computer aided instruction format	0.0
used another format	3.0

Table 2.5: Frequency of instructors' explanations and directions to miners concerning how to work the exercise (n = 178 classes)

explanation or direction provided	percent
explained how to work the exercise and use the latent image pen	92.7
made general comments about the exercise problem prior to miners working the exercise	65.7
answered some miners questions as they worked the exercise	42.7
led the miners through the exercise questions, page by page	12.9
provided other types of explanations and direction for working the exercise	1.7

Table 2.6: Frequency with which instructors modified the exercise and used the instructor discussion notes provided

instructor action	percent
instructor did not modify the exercise (n=174 classes)	98.3
instructor did use the discussion notes after the miners finished working the exercise (n = 169 classes)	76.9

Table 2.7: Frequency of miners who had difficulty in reading the exercises as reported by instructors (n = 124 classes)

number of miners with reading problems	number of classes	% of classes
0	64	51.6
1	25	20.2
2	18	14.5
3	7	5.6
4	3	2.4
5	3	2.4
>6	4	3.2

Table 2.8: Instructors' rating of exercise clarity, quality, objectives, and relevance

		percent responding					
		strongly agree			strongly disagree		
rating category	n of classes responding	4	3	2	1	mean	s.d.
miners understood instructor directions	182	61.5	35.2	2.2	1.1	3.57	0.60
miners understood written directions in exercise	181	51.4	42.5	6.1	0.0	3.45	0.61
miners understood graphics in exercise	181	65.2	28.7	6.1	0.0	3.59	0.60
miners understood scoring procedures	180	26.1	42.2	21.1	10.6	2.84	.94
performance objectives are appropriate	182	73.6	23.1	2.2	1.1	3.69	0.57
exercise fitted well with annual refresher training	177	85.9	10.7	1.7	1.7	3.81	0.54
more exercises like these should be used in the future	172	94.8	4.1	0.6	0.6	3.93	0.34

Table 2.9: Amount of time in minutes needed by the slowest class member to complete the exercise, as reported by instructors

number of classes	mode	median	mean	s.d
179	30	35	39.0	20.0

work the exercises cooperatively in small groups rather than individually. Once miners have worked an exercise as part of a small group, they usually resist attempts to have them work a second exercise individually. Miners enjoy and learn from the active debate and dialog that occurs as each small group decides on the best sequence of actions as the problem unfolds. Third, in actual mine emergencies, and in routine mine work, miners are generally required to work together. Working the simulation exercises in small groups may actually be more valid for teaching and assessing miners' judgment and decision making skills than having them work independently. As in real life, the opportunity exists for group decisions at critical points to be informed or misinformed by members of the group with special status, authority, and expertise.

As can be determined from Table 2.5, before administering the exercise about 93 percent of instructors explained the mechanics of working the exercise, and 66 percent commented on the problem. In about 43 percent of the classes, instructors reported answering some questions by miners as they worked the problem. Observation of field site classes suggest most of these questions by miners concerned matters of procedure and clarification of the meaning of specific words and phrases to be consistent with local conventions, e.g. "Is a belt control line the same as our Air Alert system?" or "Is the expression 'dinner hole' what we call the kitchen?" Only about 13 percent of the classes had an instructor who led the miners through the exercise in a

lock step fashion, a method that is generally distracting and annoying to trainees. About 98 percent of the instructors reported making no modifications to the exercise, and 77 percent reported using the instructor discussion notes provided with the exercise. (See Table 2.6.) These data and many field observations suggest instructors administered the exercises as intended.

Instructors' observations also verified that miners have few problems in reading the exercises. Table 2.7 shows how instructors from 124 classes reported on this topic. In 52 percent of classes instructors reported no one experienced difficulty reading the exercises. In about 20 percent of the classes, one miner experienced reading difficulty. Classes in which two miners experienced reading difficulty constituted 15 percent of the 124 classes. Fewer than six percent of the classes reported three miners who experienced reading problems. In only eight percent of the classes reporting did four or more miners have difficulty reading the exercises.

Inspection of Table 2.8 reveals that instructor judgments of the relevance, quality, and clarity of exercise content parallel those of the miners. With the exception of clarity of scoring procedures, all other aspects of the exercises received consistent high ratings.

When developing the exercises a major criterion was that they be easily used by instructors and acceptable to both miners and instructors (Cole, Berger, Vaught, Lacefield, Wasielewski, Haley, & Price, 1988a). When instructional materials fail to meet these criteria, they are not disseminated and used. These exercises appear to meet these utility and acceptability criteria. Inspection of the last row in Table 2.8 reveals that 99 percent of the instructors involved in the field tests of exercises agreed

that more exercises like these should be developed and used in future annual refresher training classes. Field observations of many classes, and direct interaction with instructors while arranging for additional field tests, independently confirm the data in Table 2.8. Instructors consistently requested more exercises for use in their classes. They reported that the simulation exercises were relevant and effective instructional tools that helped them do a better job of teaching.

When developing the exercises, another major criterion was to keep them short (Cole et al., 1988a). Most similar simulation exercises used in other fields tend to be much longer and often require as much as two to three hours to complete. In annual refresher training classes the available yearly time for instruction is only eight hours. Materials are not likely to be used unless they are well organized, brief, and time efficient. The exercises meet this criterion. Instructors reported the time required for the slowest member of their classes to complete the exercise. The average time of 39 minutes reported in Table 2.9 is actually longer than the time needed by the typical miner. The standard deviation for this variable is large for two reasons. First, exercise length varies quite a bit. Some exercises are long and others are short, as can be seen from inspection of Appendix A. Second, there is wide variation in the reading speed and comprehension of any group of adults, including coal miners.

Why the Exercises are Easy to Read

Still another important design criterion for the exercises was that they be easy to read (Cole et al., 1988a). From the beginning, the exercises were designed to minimize demands upon reading speed and comprehension. Exercise design was also influenced by the large amount of recent research in the area of story grammar and

reading comprehension. This research has established that the structure and organization of written passages is more critical to a person's motivation to read the material and the ability to comprehend it than are the particular words used in the passage. Well organized prose materials that have a story line or plot, that deal with interesting emotive laden content, that present dilemmas and predicaments, and that are cast within contexts and life roles that are common to the reader's own experience are compelling reading and result in good comprehension (Anderson, 1985; Bower, 1978; Mayer, 1983). All exercises developed were designed to meet these criteria for the writing of good prose material.

Other information also explains why the exercises are easy to read. First, although the problem content is often complex, the exercises are written in simple and direct language. Specialists in the design of instructional materials rewrote and simplified exercise wording after these were initially outlined by technical personnel such as engineers, emergency medical personnel, and experienced mine rescue specialists. The rewriting of initial drafts of exercises to conform to standards of good narrative structure, clarity, and simplicity of language and directions must not alter or detract from the technical content and purpose of the exercise. A team effort and a willingness to cooperate in exercise construction is essential.

An analysis of the readability level of three early, but representative exercises was carried out using the University of Kentucky Composite Readability Analysis Program. This program carries out seven independent estimates of the completed school grade level equivalent required to comprehend the samples of text material analyzed. The three representative exercises were found to have reading difficulties at

the upper elementary and junior high school level. The results are presented in Table 2.10. It should be noted that all samples were corrected for the specialized mining jargon words that appear in both the simulation exercises and in other materials used for miner training. The easy reading levels of the simulation exercises is not related to the absence or presence of special technical words, but to the simplicity, directness, and clarity with which complex ideas are expressed.

Table 2.10: Estimated reading difficulties in grade level equivalence of representative exercises

estimation formula	HRL	WLP	VMI
Spache	4	4	4
Dale-Chall	10	7	7
Raygor	7	4	4
Fry	4	5	7
Flesch	*	*	*
Gunning-Fog	*	*	*
SMOG	7	7	8

legend

HRL= Harry Harlan (first aid exercise)
WLP = Water Line Repair Problem (self and other rescue and escape exercise)
VMI= Vulcan Mine Ignition (methane ignition, rescue, escape, and first aid exercise)

*Material is below formula range and an estimate cannot be calculated.

Table 2.11 lists the number of words per exercise by exercise components. The data in the table provide additional evidence that helps explain why the exercises are easy to read. The number of words per exercise is small. Little reading is required to work completely through an exercise. This is accomplished by precise use of simple and direct language, and by the use of appropriately placed graphics throughout the exercise as the problem unfolds. Furthermore, the majority of the entire exercise parts are not read by the miner in the annual refresher training class. Rather, the trainee reads only the problem booklet questions (PB), the answers (AS) from which to select, and only those latent image (LIA) messages from the answers selected. The alternative choices to a question, as well as the invisible latent image feedback on the answer sheet, is terse and to the point.

Field Observations of the Exercise in Use

Throughout the field testing, the researchers visited and observed many classes where the exercises were being administered. A detailed account of these observed effects of the exercises on miner and instructor interactions and behavior is presented in an earlier technical report (Cole, Berger, Vaught, Haley, Lacefield, Wasielewski, & Mallett, 1988b). These frequent observations of miners in more than 30 refresher training classes independently confirm the summary data presented in Tables 2.2 through 2.7.

Trainees and instructors were observed to engage in lively debate and discussion about the problems. The level of dialogue stimulated by the exercises tended to be sophisticated and technical. Yet, it was also emotional as miners and trainers debated what should or should not be done, under various circumstances, and why or why not. The exercises appear to stimulate detailed thought and discussion

Table 2.11: Exercise components word count

Abbreviation	HT	OBJ	PB*	MAS	DN	AS*	LIA*
ADA	306	217	938	496	1068	203	300
AVB	1218	267	728	471	1098	185	294
BHL2	300	147	1134	570	918	244	333
BJF	308	169	665	407	798	181	230
BUB	295	234	1786	1372	1850	226	1172
CCP2	300	164	1906	1179	1644	289	897
CCPS^{S}	953	353	NA	NA	1844	NA	NA
CEC2	278	228	1766	1114	2393	248	872
COP	300	136	1267	568	900	212	363
CVA2	312	408	2140	1225	2951	473	807
DMC2^{E}	1424	262	1974	NA	3121	500	NA
DOT	278	142	950	506	915	219	294
DWY2	294	264	1208	840	932	176	671
EMA	1043	267	962	426	1077	189	243
FXT	309	287	668	612	1108	114	507
HHS2	295	160	1115	566	1232	223	353
HRL2	299	163	985	447	1150	199	254
HRLS2^{S}	1015	453	NA	NA	1840	NA	NA
HSC	308	141	1151	929	1206	228	708
JJJ	309	200	1159	663	1219	140	530
JJS	300	201	1227	790	1365	243	555
LCF3	315	271	1699	1312	1843	306	1097
MRL2	309	316	1829	971	2002	167	810
MRLS2^{S}	1248	595	NA	NA	1903	NA	NA
PME2	300	148	966	497	685	199	305

Table 2.11: (continued)

Exercise	HT	OBJ	PB*	MAS	DN	AS*	LIA*
PPC	300	143	1598	740	1267	247	500
RFE	308	160	1706	793	1122	267	533
SSR^{S}	3586	125	NA	NA	NA	NA	NA
TAA^{S}	1027	386	NA	NA	1347	NA	NA
THA	309	320	2553	1474	2247	193	1288
THI	316	194	1383	827	1085	234	1288
VMI3	308	258	2308	1279	1755	158	1128
VMR2	1295	323	2395	1449	3638	199	1257
WLP2	309	408	1538	894	962	138	763

*The problem book (PB), answer sheet (AS), and latent image answers (LIA) are the only parts of exercises that trainees read. All other materials are for the instructor.

Legend

HT = How To Use This Exercise (directions for the instructor)
OBJ = Performance Objectives (for planning by the instructor)
PB = Problem Booklet (read by the trainee)
MAS = Master Answer Sheet (for use by the instructor)
DN = Discussion Notes (for the instructors' use)
AS = Answer Sheet (read by the trainee)
LIA = Latent Image Answers (those that are selected are read by the trainee)

^{E}Exercise has an essay format

^{S}Exercise has a role play simulation format

All other exercises have a latent image format

about ways to cope with and prevent mine emergencies like the ones presented in the exercises. Miners and instructors were observed to relate and generalize the content and predicaments presented in the exercise problems to their own mines and experiences. As noted earlier, classroom instruction that stimulates the active interest

and involvement of learners in problem solving activity makes what is learned more likely to be remembered and applied to relevant aspects of the person's work and life (Bransford, Sherwood, Vye, & Rieser, 1986; Halpern, 1984).

Two broad generalizations can be drawn from these direct observations and the field test data. First, the exercises are time efficient. An entire problem from introduction to class discussion can be completed in approximately one hour. Second, exercises are motivating to the miners who work them. At each site, regardless of physical conditions or competing concerns, the part of the program devoted to exercise administration was characterized by concentrated effort and a high level of interest on the part of both trainers and trainees. There are three possible reasons for these findings.

First, the technique used in presenting the problems is intriguing. Although latent image technology has been in existence for several decades, few individuals have been exposed to it as an instructional technique. Therefore, it is novel and perhaps appealing to miners. However, the novelty soon wears thin if that is all the exercise offers. The latent image technique can be considered an attention getter, but it is <u>not</u> the reason miners are willing to spend an hour or more intently working and debating a problem. The major appeal of the exercises derives from the selection of interesting and realistic problems for miners to work, and the effective presentation of the learning materials through good instructional design principles. Experience during the authentication and initial field testing of exercises confirmed that poorly designed simulation problems are rejected by miners and trainers, whether or not they are presented in a latent image format. Errors in technical accuracy, authenticity of the

problem and the roles of persons in the problem, confusing directions for completing the exercise, difficult wording and language, and the selection of trivial problems anger and frustrate miners. Only a few of these errors are needed to prevent an exercise from functioning.

A second factor in the appeal of the exercises is the opportunity they provide for miners to work together in the solving of problems. In order to complete an exercise, class members must become involved. They must gather information, draw upon their past experience, make judgments and decisions, and resolve predicaments. While they work an exercise, miners usually speak to one another as if they were personally involved in the simulated problem. They tend to adopt the roles of the persons in the problem. The exercises are designed to foster this type of involvement. This feature helps the trainees to "own" the problem. As in the workplace, the exercises allow the participants to exchange ideas and debate courses of action, both before or after the fact. The entire mode, therefore, evokes some of the same intensity of behavior that occurs in real life situations where miners seek to anticipate, cope with, or reflect upon an emergency situation.

The above point underscores a third aspect of the exercises being field tested. They reflect authentic situations -- the same kinds of predicaments miners talk about in the workplace and in other settings where they get together. Miners enjoy speculating on the things that went wrong when actual accidents or disasters occur. They also enjoy discussion of the simulated problems in the exercises. However, discussion of the simulation problems is usually accompanied by more information than is informal discussion of actual mine accidents or emergencies. This is because each exercise is

carefully designed to illustrate key points. Specific performance objectives for each exercise identify the key learning outcomes for miners. Each exercise is designed to provide opportunity for miners to practice and learn the skills stated in the exercise objectives. Detailed corrective feedback is provided as miners work through the exercise. Experts assist in the development of the exercises, the objectives, the feedback, and the ancillary material presented in the discussion notes. Consequently, the exercises teach specific knowledge and skills and a wealth of background information. Informal discussions of actual accidents are often based on incomplete or erroneous information. Discussions of the problems and predicaments presented in the simulation exercises tend to be much better informed because the relevant information is highlighted and reinforced for the trainees as the exercise is completed.

Conclusion

The data presented in this chapter were collected to answer questions about how well the exercises met specific instructional design criteria. These criteria were established early in the project before any exercises had been developed. They are based upon a large amount of prior research in instructional design of technical materials for adult learners. The criteria and their selection are described in the first project technical report (Cole et al., 1988a). The trainee and instructor questionnaires completed by the miners and the trainers who field tested the exercises were carefully designed to provide data about how the exercises were perceived and used. If only performance data had been collected, little would be known about how well the exercises achieved many of the desired design features. If they were to be used the materials must be perceived as realistic, authentic, easy to use, interesting, worthwhile, and helping

miners to remember and integrate classroom knowledge with real world problem solving. They also had to be easy to read, short and time efficient, and capable of being used with a minimum of special equipment or elaborate preparation by instructors. The data resulting from the field tests suggest that these design criteria have been met to a large degree. This is an important finding, for if the exercises failed to meet these criteria, they would not be used, no matter how sound and worthwhile their technical content.

Another design criterion was that the exercises present complex and challenging problems for miners to solve. Analysis of this feature of the exercises must be based on performance data, not miners' and trainers' perceptions and ratings of the exercises. The next two chapters summarize the performance data from the field tests of 36 simulation exercises. Twenty nine of these are latent image format exercises. Two are paper and pencil simulation problems. The others are four role play simulation exercises.

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UK/USBM HO348040 Draft MRL2 7/16/86

Marvin R. Letcher

Background

Driving 8 entries in 42 inch coal
Eleven miners at work on Section 001
Portal 4,000 feet outby the face
Time is just after lunch (Marvin ate a big meal)
EMT normally on this section is absent today
You are trained in basic first aid but not as an EMT
Top in this section is generally drummy and poor
Roof bolter has an ATRS

Problem

You are the pinner operator. You are bolting the roof in the #2 entry at the face. Your helper, Marvin R. Letcher, has gone out ahead of the bolter to mark the roof. You yell at him to get back. He almost gets back to supported roof when a piece of draw slate falls trapping both his legs. (See Figures 1 & 2 on page 3.) Marvin is lying face down screaming. The roof is dribbling across the whole entry just past the last row of bolts. Now, turn to page 4 and answer the first question.

Exhibit 2A: Portion of a first aid and roof control exercise

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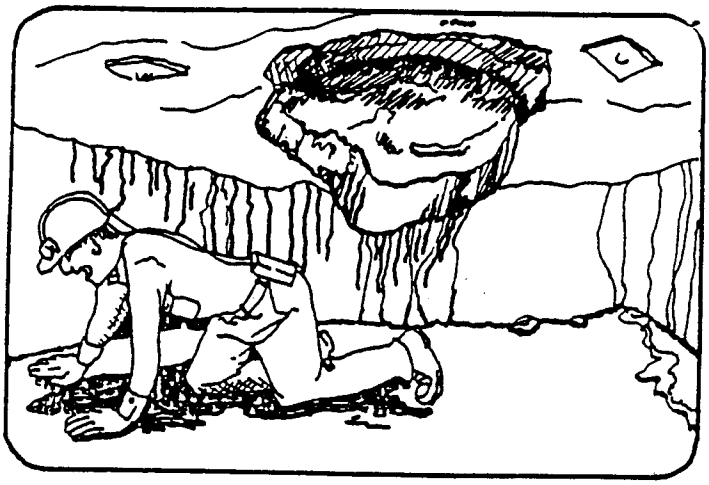

Figure 1: Draw slate falls from roof

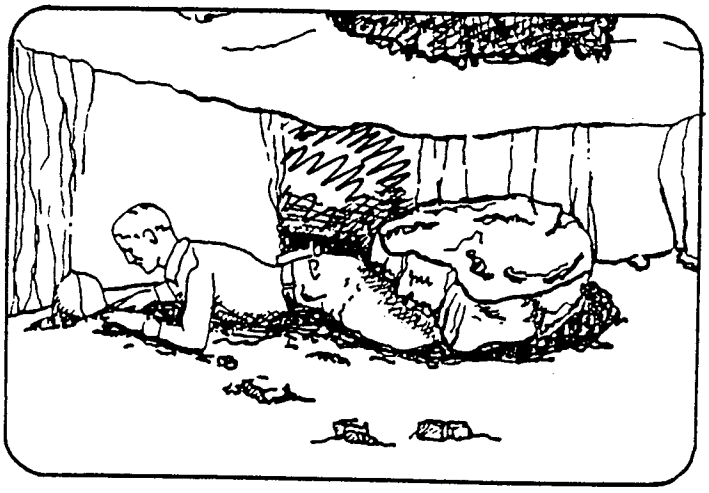

Figure 2: Draw slate hits Marvin's legs

Exhibit 2A: (continued)

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Question A

You yell for help. Three other miners come quickly. Marvin's legs are under the slate. His head is near the left rib. The roof bolter is outby his position about six feet. The ATRS is in place. (See Figure 3 on page 5.) The top continues to work. What would you do now? (Choose only ONE unless told to "Try again!")

1. Grab a couple of slate bars. Have the other three miners help you pry the rock off Marvin's legs.

2. Get the head of the roof bolter under the corner of the rock and lift it gently off Marvin's legs.

3. Move close to Marvin to check his injuries and begin first aid immediately.

4. Leave the bolter and the ATRS where they are. Set roof jacks and timbers from the ATRS toward and around Marvin.

5. Lower the ATRS on the bolter. Tram the bolter ahead and then raise the ATRS over Marvin.

6. Tram the roof bolter out of the entry. Then tram a scoop in so you can lift the rock off Marvin with the scoop bucket.

Question A Answers (Color in only ONE unless told to "Try again!")

1. [Risky! This may hurt you, the others, and Marvin. Try again!]

2. [Good idea, but the head is too big to fit under the rock. If you try to lift the rock this way it may slide, slip, or fall and hurt Marvin more. Try again!]

3 [This action places you and Marvin in danger. Try again!]

4 [Correct! With the roof supported, you can now help Marvin. Do next question!]

5 [When you start to lower the ATRS, more slate falls. This action places you and Marvin in danger. Try again!]

6 [When you lower the ATRS and begin to tram the bolter outby, more slate falls. Now Marvin is in more trouble and you can't get to him. Try again!]

Exhibit 2A: (continued)

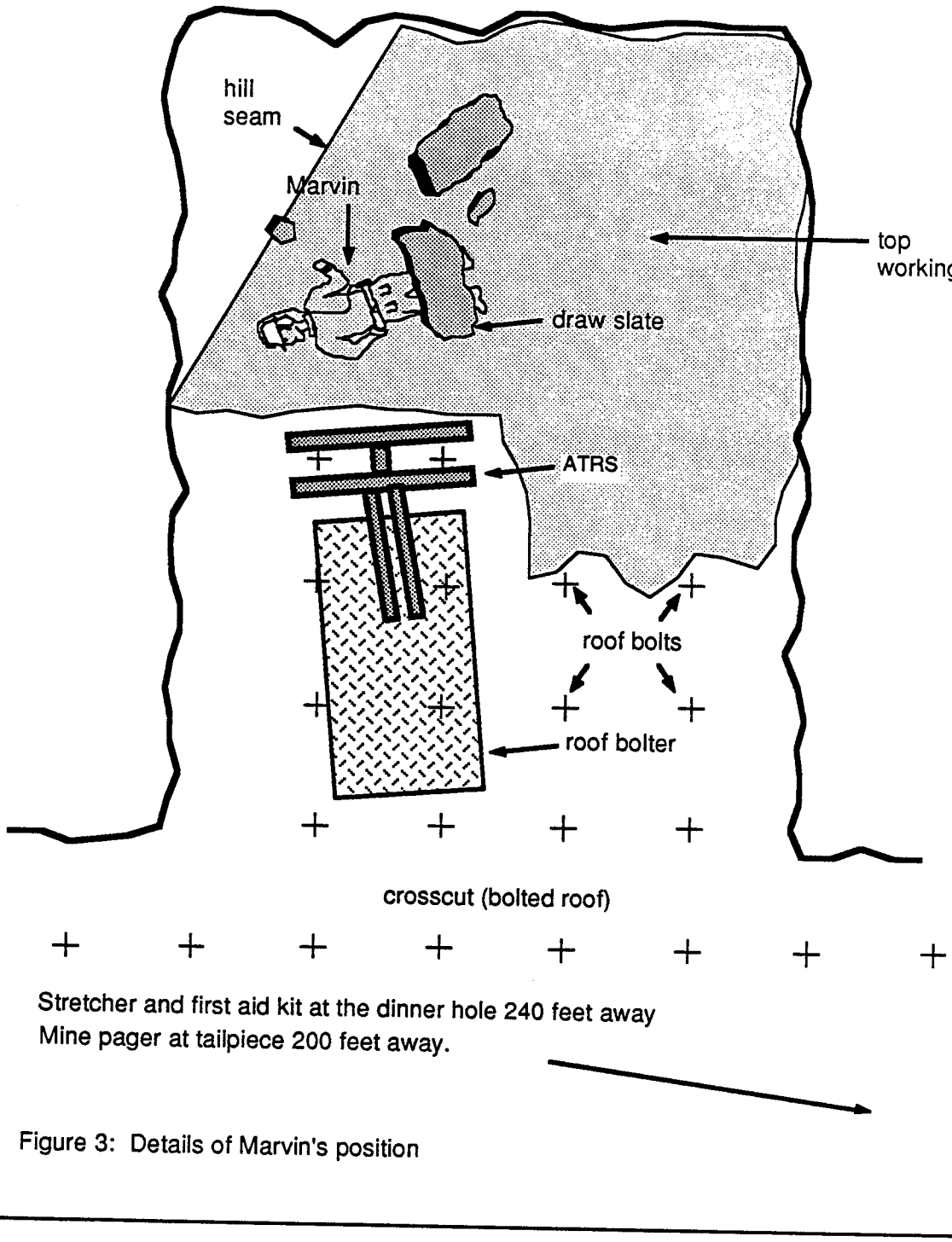

Figure 3: Details of Marvin's position

Exhibit 2A: (continued)

UK/USBM HO348040 Draft MRL2 7/16/86

Question 8

You have now supported the roof with two jacks and three posts. Using slate bars and a jack, the three of you have lifted the slate just enough to free Marvin's legs. The top continues to dribble across the whole entry. What should you do now? (Choose only ONE unless told to "Try again!")

7. Have your buddies grab Marvin by his belt and shirt while you grab his pants leg above and below his left knee. Pull together and slide him out from under the rock sideways on his stomach.

8. Get a board or some other object to serve as a splint. Put the board between his legs. Then gently tie his legs together before moving him.

9. Reach under the slate. Grab him by his boots and jerk him out sideways by his feet.

10. Leave Marvin under the rock. Give him first aid in this position until he has been fully immobilized and can be moved without further injury.

Question 8 Answers (Color in only ONE unless directed to "Try again!")

7. [Correct! This procedure would be the fastest and least harmful way to move him. Do next question.]

8. [This would endanger him and you. Try again!]

9. [This method of moving Marvin could cause further injury. Try again!]

10 [Risky and impossible. You can't work on him under the rock. This action also places you and him in danger. Try again!]

Exhibit 2A: (continued)

UK/USBM HO348040 CEC2 02/11/87

Cecil Exercise

Background

Wet mine, above the water table, 52 inch seam

8 entry supersection, 2 continuous miners, 2 shuttle cars

You (Cecil) are a continuous miner operator on the West Mains Section

You are slim, strong, and in good shape, 5' 10" and 145 lbs.

Big Tim, your helper, is overweight and in poor physical condition, 6' 2" and 275 lbs.

The shuttle car roadway is littered with a large accumulation of loose coal and coal dust

Problem

You and Big Tim have just trammed the continuous miner to the face of the #1 entry. Your boss comes by and tells you that one shuttle car with a damaged cable, is stalled between #3 and #4 in the last open crosscut, and the other is stuck near the feeder. You and Big Tim decide to replace a few worn bits while waiting. While pulling the bits, you smell something burning. Tim tells you the smell is probably just from heat shrinking the boot over the splice on the shuttle car cable. After installing the bits, you go to the mouth of the #1 entry to establish face ventilation. Your eyes begin to burn and water. You look down #1 and across to #2 and see a cloud of thick, black smoke. The smoke is going by the mouth of #1 and out the return. You do not know the size, or location of the fire, or the quality of the air elsewhere on the section. You immediately yell to Tim and tell him about the smoke.

After studying the map on page 3, turn the page and answer the first question.

Exhibit 2B: Portion of a mine fire exercise

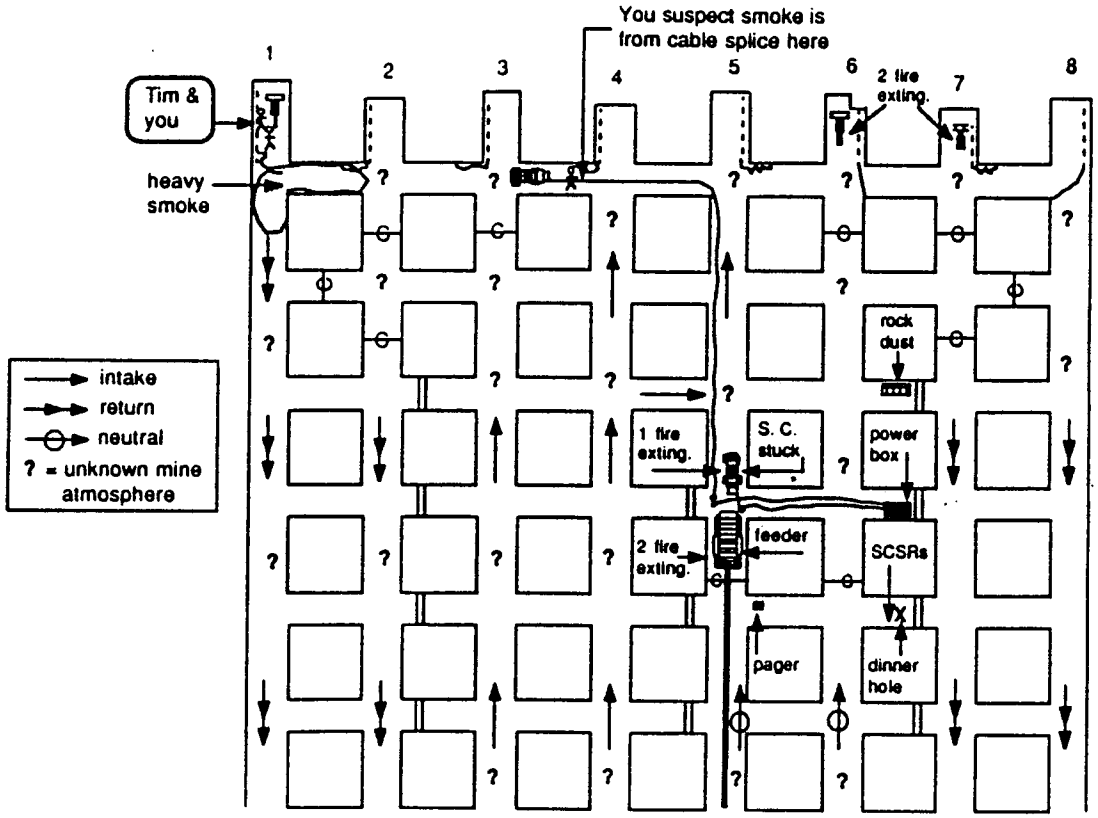

Figure 1: Your and Tim's position on the section, with the smoke cloud you can see and the possible locations of smoke marked with question marks

Exhibit 2B: (continued)

UK/USBM HO348040 CEC2 02/11/87

Question A

After telling Tim about the smoke, what should you do first? (Choose only ONE unless directed to "Try again!")

1. Take your filter self-rescuer off your belt and have it ready in case you need it.
2. Sit down and wait for instructions from your face boss.
3. Put on your filter self-rescuer and tell Tim to do the same.
4. Take a deep breath and head for intake air quickly.

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

1. [You shouldn't do this unless you plan to put it on now. Try again!]
2. [He's probably down at the feeder. You need to act now. Try again!]
3. [Correct! Carbon monoxide may be present. Do next question.]
4. [This is very dangerous! You and Big Tim may die. Try again!]

Exhibit 2B: (continued)

UK/USBM HO346040 CEC2 02/11/87

Question B

As you are putting on your filter self-rescuer (FSR), Big Tim tells you that he has left his FSR on the other miner, which is broken down in the #6 entry. What would you do now? (Choose only ONE unless directed to "Try again!")

5. Finish putting on your FSR, but stop and think before taking further action.

6. Share your FSR with Tim by taking turns breathing through it, and dash through the smoke.

7. Tell Tim to stay put. Finish putting on your FSR and go across the section to get Tim's FSR.

8. Leave your FSR off and wait for help with Tim.

9. Offer your FSR to Big Tim and have him go for help.

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

5. [Correct! A "snap" decision could prove fatal to both of you. You are not yet in smoke. Do next question.]

6. [This would be difficult to do, and you would likely become separated in the smoke. Try again!]

7. [There is a more critical first step. Try again!]

8. [Although "misery loves company," it is important that at least one of you is protected from carbon monoxide. Try again!]

9. [Should it be necessary for someone to get through the smoke quickly, it should be you rather than Tim. Try again!]

Exhibit 2B: (continued)

Chapter 3: Miner Performance Data for Paper and Pencil Exercises

The previous chapter described the design characteristics and miner and trainer evaluations of the paper and pencil simulation exercises. To date, thirty six simulation exercises have been developed. Thirty one of these exercises are paper and pencil simulations. Twenty nine of the paper and pencil simulations use the latent image technique. The other five exercises are role play simulations and an emergency breathing apparatus donning exercise. Forty seven versions of the 31 paper and pencil simulation exercises have been field tested with approximately 4,000 miners in more than 250 classes at many sites in eight states. Most exercises were field tested in multiple versions. Data from the first field test were used to modify and improve later versions of the same exercise.

Chapter 2 provides detailed information about the size and geographic distribution of the field test samples and the demographic characteristics of the miners involved. It also provides data about how well the exercises met specific design criteria. The present chapter summarizes the performance data for the miners who completed the 47 versions of the 31 paper and pencil simulation exercises. Basic psychometric (mental measurement) properties of each exercise throughout each of its versions are also described. Descriptions of exercise content and exercise names and abbreviations are found in Appendix A. Detailed psychometric analyses for each exercise are provided in Appendix B.

Simulation formats other than paper and pencil were developed. These include the performance demonstration self-contained self-rescue (SCSR) donning exercise

described in Chapter 4, and the first aid role play simulation exercises described in Chapter 5. Miners' performance data and the psychometric properties of these additional exercises, along with information about their design characteristics, field testing, and miner and trainer evaluations, are provided in each of these respective chapters.

Chapter Organization

This chapter consists of four main parts. The first part presents summary data for each exercise version that was field tested. The unit of analysis is the individual exercise version. This summary begins with the total score statistics for each exercise. Then, data that describe the discrimination capability of individual questions with respect to exercise total score for each exercise are presented. The capability of individual exercises to discriminate between basic and advanced levels of training represented in the field test samples is next summarized. The final part of this first section is a summary of the capability of individual exercise versions to discriminate among job categories included in the field test samples. The performance score data for these analyses are all based upon a zero to 100 scaled score for each exercise. The intention of these analyses is mainly descriptive. The summary tables reveal the basic psychometric properties for each exercise and its multiple versions.

The second section pools selected individual exercise versions' performance scores across three major types of exercise content: those having to do with mine technical training (MTT), those having to do with first aid training (FAT), and those that contain a mixture of both mine technical training and first aid training (MIX). For these analyses the unit of analysis is the exercise content type. Individual exercise

performance data were pooled by exercise type to form the three categories. Only those exercises that were field tested with at least 80 persons and with appropriately diverse samples with respect to levels of training and job categories were included in these analyses. Inclusion of data from smaller and less varied samples would have invalidated the analysis. For these analyses, performance scores for persons in the samples were transformed to standard T scores with a mean of 50 and a standard deviation of 10. The standard score transformation equates performance data across many different exercises with varying levels of difficulty, and with nonrandom field test samples with varying levels of ability. The purpose of these analyses is to further assess the capability of the three types of exercises to significantly discriminate among levels of training and job categories represented in the sample in general, without respect to specific exercises.

The third section examines the typical levels of mastery of exercise content by groups of miners who completed each exercise version. These data are reported on the same zero to 100 common score that are used in the first set of analyses. As in the first case, the unit of analysis is the individual exercise version. The intention is to provide information about the typical levels and degrees to which miners in the exercise samples exhibited mastery of the critical skills and performance objectives for the exercises.

The fourth and final section is a discussion of the exercises as teaching and as testing devices. They have strengths and limitations in both roles, and their design and use can be directed more toward one or the other role. The discussion in this final section explores this characteristic of the exercises and its implications.

Individual Exercise Summary Psychometric Data

Table 3.1 summarizes the total score statistics for each of 31 exercises and 47 exercise versions. The exercise name abbreviation is listed in alphabetic order in the first column of the table. Appendix A provides the complete name of the exercise, information about its performance objectives, content, number of questions, level of

Table 3.1: Summary performance statistics for exercise versions

Exercise[¥]	n	minimum score*	maximum score*	median	mean	s.d.	skewness	alpha
ADA1	35	55.2	89.8	78.4	76.8	8.87	-0.59	0.51
AVB1	44	50.7	87.9	70.5	70.0	8.58	-0.20	0.24
BHL2	58	67.5	100.0	89.4	89.2	7.82	-0.90	0.55
BJF1	69	76.4	100.0	94.3	93.0	5.58	-0.98	0.36
BTR1	50	41.9	91.5	70.3	69.5	12.86	-0.14	0.81
BUB1	34	32.6	88.1	75.3	73.3	10.78	-2.01	0.57
CCP2	51	63.9	98.2	87.2	85.7	7.49	-0.89	0.06
CEC1	63	42.9	86.1	73.6	71.8	9.62	-0.56	0.43
CEC2	145	24.9	97.8	80.8	80.1	10.27	-1.48	0.65
COP1	28	62.9	96.4	81.1	82.2	9.74	-0.38	0.45
CVA1	22	64.0	87.3	75.2	75.9	6.38	0.02	0.06
CVA2[G]	29	78.6	98.2	90.5	91.5	4.59	-0.43	0.24
CVA2	19	87.7	96.4	92.3	92.3	2.43	-0.66	0.02
CVA2[I/G]	48	82.3	98.2	92.3	92.3	3.40	-0.28	0.08
DMC1[G]	28	42.9	100.0	80.4	75.9	15.23	-0.78	0.82
DMC2[G]	15	53.0	83.0	69.0	70.4	10.64	-0.43	0.49
DOT1	47	63.3	97.6	89.3	86.5	9.23	-0.84	0.50
DWY1	87	14.8	81.9	63.3	57.4	16.94	-0.70	0.67
DWY2	51	29.8	95.5	55.7	58.6	19.8	0.41	0.52
DWY3	41	54.5	96.2	88.8	85.2	10.39	-1.16	0.66
FXT1	80	0.0	100.0	84.7	81.9	17.04	-2.56	0.76
HHS2[G]	25	67.8	100.0	86.7	87.4	7.58	-0.71	0.54
HRL1	66	55.6	96.7	81.7	80.5	9.64	-0.72	0.32

Table 3.1: (continued)

Exercise[¥]	n	minimum score*	maximum score*	median	mean	s.d.	skewness	alpha
HRL2	39	57.0	96.7	83.0	81.5	10.86	-0.68	0.57
HSC1	133	65.4	100.0	91.4	89.3	7.05	-1.10	0.42
JJJ1[I/G]	44	59.2	98.4	84.9	84.1	9.36	-0.54	0.49
JJJ1	32	59.2	98.4	83.6	83.1	9.22	-0.51	0.44
JJP1	16	66.7	95.3	88.1	84.9	9.39	-0.73	0.68
JJS1	62	50.5	100.0	84.5	82.9	10.10	-1.01	0.64
LCF1	99	27.1	100.0	79.7	79.1	16.25	-0.65	0.71
LCF2	84	36.9	87.5	75.0	73.6	9.28	-1.28	0.57
LCF3	25	66.5	97.5	86.3	82.9	9.34	-0.32	0.47
MRL1	132	34.6	100.0	82.9	81.4	11.75	-0.80	0.69
MRL2	61	68.2	100.0	89.2	87.4	8.00	-0.81	0.54
PME2	33	47.9	90.4	80.0	79.5	8.95	-1.44	0.28
PPC1	38	77.8	95.3	88.0	87.1	4.67	-0.17	0.27
RFE1	68	27.5	100.0	93.8	91.7	9.71	-4.58	0.78
THA1	60	71.7	100.0	88.3	89.7	8.08	-0.52	0.69
THI1	52	54.3	94.3	86.0	83.3	9.42	-1.06	0.51
TTR1	35	43.5	100.0	66.7	67.8	14.19	0.67	0.45
VMI1	121	58.7	100.0	83.0	81.5	8.91	-0.61	0.55
VMI2	115	33.9	90.6	77.4	76.2	9.03	-1.29	0.62
VMI3	79	17.7	100.0	83.3	81.1	10.96	-2.71	0.56
VMR1	20	45.8	96.1	78.8	77.5	11.1	-1.02	0.81
VMR2	73	49.5	94.3	81.1	79.8	8.70	-1.24	0.71
WLP1	169	0.0	100.0	80.0	76.4	14.99	-0.78	0.64
WLP2	102	46.7	100.0	83.3	82.0	13.05	-0.56	0.62

¥ See Appendix A for the complete exercise name and description. The number following the exercise abbreviation refers to the exercise version.

* The values reported are the minimum and maximum scores observed, for this sample. The lowest possible score = 0.0, and the highest possible score = 100.

G Group data (Persons collaborated in small groups of 2 to 5 persons while working these exercises.)

I/G Individual and Group data combined

All others are Individual data (Persons worked the exercise individually with no collaboration with others.)

difficulty, and intended audience. This descriptive information about each exercise is too long to be included in the text of this chapter.

The basic data provided in Table 3.1 include the number of persons who completed each exercise version in each formal field test; the minimum, maximum, median, and mean exercise scores observed in the sample; the standard deviation and skewness of the total exercise score, and the estimated reliability of the test based upon the Cronbach alpha internal consistency estimate. Additional individual exercise psychometric analyses for each question on each exercise, as well as the total score statistics, are found in Appendix B, where exercises are also listed alphabetically by name. This detailed item analysis of individual exercise versions is too massive to be included in this summary chapter.

Inspection of Table 3.1 reveals a number of important points. The discussion that follows details each of these points and their significance.

Versions of Exercises

Some exercises were field tested in only one version. When the number "1" follows the exercise name it means that this was the first version of the exercise. Likewise, a "2" or a "3" after the exercise name indicates a second or third version of the exercise. Even exercises that list only one version actually underwent two rounds of field testing. All exercises underwent a round of authentication and revision prior to the first formal field test. The authentication process was actually a small field test that produced too little data for meaningful statistical analysis, but many suggestions and ideas for the revision and improvement of the exercise. Authentication of exercises and their subsequent revisions often led to the development of an exercise that needed little

revision following the first formal field test. Other exercises went through as many as three rounds of formal field testing, following their initial authentication. Exercise versions always deal with the same general problem and content, but the structure, questions, and answers may change a great deal from version to version depending upon the results of the field testing.

Sample Sizes

The number of persons included in the field test sample for each exercise version is listed in the second column in Table 3.1. These sample sizes are highly variable, and they are smaller than the sample sizes listed in Chapter 3 where the miners' and trainers' evaluations of the exercises are reported. Although every miner who completed an exercise also filled out a trainee's questionnaire, not all miners completed individual answer sheets. The smaller sample sizes reported in Table 3.1 resulted from many instructors administering the exercises in small group formats, where two to five miners collaborated in answering the questions to one test, and produced one answer sheet for the group. As noted in the previous chapter, both miners and trainers prefer small group exercise administration, feeling that this method is more realistic and informative than the individual working of exercises by miners. However, group administration prevents carrying out the psychometric studies concerned with the relationships between individuals' levels of training and job categories and their performance scores. For these reasons the psychometric analyses were carried out on the data from individual administrations of exercises. Table 3.1 includes group administered data from only the CVA, DMC, HHS2, and JJJ exercises. The summary data for these group administered exercises are accurate, but

their data cannot be used in the discrimination analyses discussed later. Because instructors and miners favor the group administration method over the individual method, more than half of all the data collected from field tests for many exercise versions were group data and could not be included in the analyses in this chapter.

Common Performance Score Scale

The performance score data for each exercise version are reported on a zero to 100 scale, where zero is the minimum possible score and 100 is the maximum possible score. This common scaling of all exercise version scores was accomplished by weighting each question score on each exercise such that a perfect score on each question sums to 100 for the exercise total score. This procedure allows 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 and easily interpreted convention for reporting test results.

Exercise Difficulty Level

The total mean scores reported in Table 3.1 tend to be negatively skewed toward the upper end of the scale. The minimum, maximum, median, and mean scores also tend to be moderately high. The exercises vary greatly in difficulty and complexity. This variation in exercise difficulty is only partially apparent in the variation in exercise version mean scores shown in Table 3.1. The reason for this is that the samples of miners also varied widely in terms of the numbers and levels of job categories and levels of basic and advanced training represented. Generally, simple exercises were field tested with samples of miners without advanced levels of technical training. Likewise, complex technical exercises were field tested with persons with advanced

levels of technical training and appropriate experience. These arrangements were necessary to maintain the ethical constraints involved in annual refresher training. The training material should match the needs, capabilities, and interests of the miners in training. Otherwise, the training may be less useful or counterproductive. Trainers are generally aware of this responsibility and the project staff were sensitive to and supportive of the need to match exercise content and difficulty to the needs and ability levels of miners enrolled in annual refresher training classes.

The peculiarities of each exercise version field test sample may be determined from Appendix B, Tables 1 through 4 for each exercise. Examination of these tables reveals that field test samples frequently were biased toward advanced levels of technical training and supervisory and technical personnel as opposed to regular miners. Examination of the summary demographic data presented in Chapter 2 confirms this point. Thus, differences in the average scores of miners on the exercises versions are caused by a combination of variations in individual exercise difficulty level, and variations in the skill levels represented among miners in the various samples.

Even with these limitations in the sampling of miners in the field tests, an interesting generalization can be inferred from the data in Table 3.1. Although the field test samples tend to be biased toward miners with more knowledge, experience, and skill than a random sample of miners, and although many of the exercises deal with basic knowledge and skills, the overall performance scores are far from perfect. The simple average performance score across the total scores of all 47 exercise versions is 81.1 with a standard deviation of 8.04. This value, inspection of the individual exercise

statistical analyses included in Appendix B, and direct observations of field test participants and instructors, and their written comments, all suggest that many miners in the samples performed inadequately on the critical skills represented in the exercises. The exercises deal with the types of skills that miners should exhibit at mastery levels near perfection. However, the exercises were also designed to focus on infrequently practiced but critical judgment and decision making skills required for nonroutine emergency situations. It appears that the exercises generally assess proficiency in these critical skill areas, a point independently supported by miners' and trainers' evaluations of the exercises, as noted in Chapter 2. The corrective feedback included throughout each exercise, as well as the large amount of corrective information that occurs in the discussion that follows the exercise, helps ensure that the exercises also teach and improve miners' proficiency in the critical skills required to prevent and to cope with mine emergency events.

Reliability

The reliability estimates for each exercise version are the Cronbach alpha coefficients listed in the last column of Table 3.1. The coefficients range from high to low values, with most exercises having moderate values. Reliability coefficients may vary from 0 to 1. The coefficient is an estimate of the internal consistency of the test, e.g. the degree to which each question on the test correlates with each other question. If the correlations among questions on a test are high, the alpha coefficient is high and the test is said to be reliable. A perfectly reliable test produces an alpha coefficient of +1. A completely unreliable test has a alpha value of 0.

The internal consistency Cronbach alpha method is an alternative to the more

desirable test and retest method by which to determine the stability of the measurement characteristics of a test. The test/retest method administers the same test to the same group of persons with some elapsed time between administrations, but with no intervening training or practice in the content of the test. If the correlation between the persons' first and second scores is high, the reliability of the test is said to be high. High reliability estimates, by whatever method, imply that the test consistently and accurately measures some common trait or skill.

The reliability data for these paper and pencil exercises must be interpreted cautiously. These exercises are not like the tests for which reliability estimation procedures are designed. The usual psychometric assumption for tests is that a person's score on any one question on the test will not influence their score on any other question on the test. When this condition prevails the test is said to have local question independence. Therefore, any empirically determined correlation between test question scores is assumed to be caused by similarity in the content of the questions, not the influence of one question's score on a question encountered later in the test. The paper and pencil simulation exercises deliberately violate this assumption. Large amounts of immediate feedback are provided to the test taker as he or she completes each question and its answers. This feature is a sound instructional design principle (Cole, Moss, Gohs, Lacefield, Bares, & Blythe, 1984; Lacefield & Cole, 1986). It helps persons to identify and correct errors in their performance as they work the exercise. The intention is to correct errors immediately, and to help persons perform better in the future when they encounter a similar situation in their own lives and work. A typical test without this immediate corrective feedback is less capable of

helping persons to identify and remediate errors, and far less instructive. These paper and pencil simulation exercises are designed such that individuals' errors on the initial questions are corrected. Performance on later items is influenced by this corrective feedback for the earlier items. Because of this property of the exercises, neither the Cronbach alpha reliability estimate, nor the test/retest method of reliability determination, nor any other existing method is adequate for their reliability determination. The reliability estimates in Table 3.1 are presented for general descriptive information purposes, and because it is conventional to do so.

Discrimination Capability of Exercise Questions

Table 3.2 reports the percentage of answers (options) to questions that discriminated properly between persons with high total scores on the test and those persons with low total scores for each exercise. Tests that have multiple choice answers to questions must include some incorrect and some correct answers. The persons who take the test must choose among correct and incorrect answers (distractors) to each question. Persons who get a high total score on the test are assumed to 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 of the test and those who know little. However, when persons who get high scores on the total

Table 3.2: Exercise question discrimination capabilities across exercise versions

exercise	number of questions	percent positive discrimination	percent negative discrimination	percent no relationship
ADA1	35	57.1	2.9	40.0
AVB1	42	52.4	0.0	47.6
BHL2	37	73.0	0.0	27.0
BJF1	23	65.1	0.0	34.9
BTR1	59	74.6	0.0	25.4
BUB1*	43	-.-	-.-	-.-
CCP2	60	60.0	0.0	40.0
CEC1	50	62.0	0.0	38.0
CEC2	52	86.5	0.0	13.5
COP1	29	31.0	0.0	69.0
CVA1	61	39.3	1.6	60.7
CVA2^{G}	53	26.4	0.0	73.6
CVA2	53	15.1	0.0	84.9
CVA2$^{I/G}$	53	30.2	0.0	69.8
DMC1^{G}	21	61.9	0.0	38.1
DMC2^{G}	25	36.0	0.0	64.0
DOT1	32	65.6	0.0	34.4
DWY1*	47	-.-	-.-	-.-
DWY2*	47	-.-	-.-	-.-
DWY3*	41	-.-	-.-	-.-
FXT	26	96.7	0.0	3.8
HHS1^{G}	39	36.0	0.0	38.0
HHS1	39	78.6	0.0	21.4
HHS2^{G}	39	36.0	0.0	38.0
HRL1	31	77.4	3.2	19.4
HRL2	33	66.7	0.0	33.0
HSC1	42	78.6	0.0	21.4
JJJ1$^{I/G}$	39	53.8	0.0	46.2
JJJ1	39	43.6	0.0	56.4
JJP1	40	37.5	5.0	57.5
JJS1	40	72.5	0.0	27.5

Table 3.2: (continued)

exercise	number questions	percent positive discrimination	percent negative discrimination	percent no relationship
LCF1	34	94.1	0.0	5.9
LCF2	35	68.6	5.7	25.7
LCF3	37	54.1	0.0	45.9
MRL1	40	90.0	2.5	7.5
MRL2	45	62.2	2.2	35.6
PME2	30	50.0	0.0	50.0
PPC1	66	36.4	3.0	60.6
RFE1	35	74.3	0.0	25.7
THA1	60	73.3	0.0	26.7
THI1	39	79.5	0.0	20.5
TTR1	61	29.5	0.0	57.5
VMI1	49	91.8	0.0	8.2
VMI2	54	88.9	0.0	11.1
VMI3	53	73.6	0.0	24.5
VMR1	83	39.8	0.0	60.2
VMR2	84	67.0	1.0	32.0
WLP1	40	97.5	0.0	2.5
WLP2	40	87.5	0.0	12.5
n		43	43	43
mean		61.9	0.63	37.2
s.d.		21.53	1.40	21.15

* Significance level $p < .10$
** The branching structure of these exercises prevented the completion of discrimination analyses.
G Group data
I/G Individual and Group data combined

test tend to select 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 select 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 of test questions are determined in field tests. These empirical data are used to identify and correct problems in the answers to questions for each exercise. To be valid, the method requires an adequate sample of persons who exhibit a wide range of variability in their total test scores.

Table 3.2 reports the frequency with which answers to questions for each exercise version behaved in this desirable way. The table lists 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. The positive and negative discrimination columns reflect only that proportion of answers that were statistically significantly correlated with the total test score for the alpha level $p < 0.10$.

Inspection of Table 3.2 reveals a number of important findings. First, very few of the questions across exercises negatively discriminated with respect to total score performance. The mean percentage of negatively discriminating questions across the exercise versions is 0.63 with a standard deviation of 1.40. Second, the majority of exercise question scores discriminated positively with respect to total score. The mean value for positively discriminating questions across exercises is 61.9 percent with a standard deviation of 21.53. Third, an average of 37.2 percent of the questions scores were not significantly related to the total exercise scores.

The actual discrimination indices of the exercises are probably higher than the values reported in Table 3.2. There are two reasons for this. First, as mentioned

earlier, trainers and project staff generally attempted to match the exercise difficulty level to the ability levels of the persons who were to work the exercise. While this procedure is sound from the standpoint of ethical and instructional considerations underlying annual refresher training classes, it tends to produce a restricted range of ability levels in the field test samples. This in turn tends to lower the variance in performance scores and lower the observed discrimination indices of the question scores for exercises. Second, those exercises with the lowest percentage of positive discriminating items tend to be the ones that were administered to small samples, or to samples containing mainly experts with high levels of technical training. The AVB, COP, CVA1, CVA2, and VMR1 exercises are good examples of this point. Each was administered to groups of persons with high levels of expertise and little variation in levels of skill and training. Inspection of the sample sizes for exercise administration in Table 3.1, and inspection of the demographic characteristics of the miners involved in each exercise field test, as revealed in Tables 1 through 4 for each exercise in Appendix B, tends to confirm this point. It is likely that if the exercises were administered to more heterogeneous samples of miners with respect to experience and skill level, the percentage of positively discriminating questions would be higher.

Even though the field test samples tend to be biased toward persons with more advanced levels of training, and even though exercises tended to be matched to ability levels when arranging field testing, the exercise questions generally properly discriminated among persons with respect to observed total scores. This is one indication the exercises are valid.

Exercise Discrimination Between Training Levels and Job Categories

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 3.3 reports which exercise total scores discriminated between persons in the sample with different levels of self-reported mine technical training (MTT) and first aid technical training (FAT). Miners indicated on the trainee's questionnaire whether they had basic or advanced levels of training for the MTT or FAT areas. Miners' individual performance scores were analyzed with respect to these two categories. A one way analysis of variance (ANOVA) was carried out for each exercise to determine if a significant difference in mean performance scores existed for miners with basic or advanced levels of training. Psychometric tables for each exercise are included in Appendix B. Analysis of variance tables are provided for each exercise version. These tables show whether or not the exercise significantly discriminated between the self-reported levels of training. In addition, all exercise questions that did significantly discriminate between the two levels are identified in these tables. Readers with an interest in the details of these analyses should examine Appendix B.

Another discrimination analysis by individuals' total exercise scores was carried out among the four major job categories represented in the sample. One of the questions on the trainee questionnaire asked the person to list their current job category. These different job listings were categorized into four groups. The category "miners" 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

Table 3.3: ANOVA significance test p values across exercises by training levels and and job categories

exercise	adequate sample*	training level MTT¥	training level FAT¥	job categories
ADA1	No. (68% with adv FAT)		0.360	0.150
AVB1	No. (84% were EMTs)		-.-**	0.665
BHL2	Yes. (mainly working miners)		0.079	0.253
BJF1	No. (mostly supervisors with adv FAT)	0.740		0.380
BTR1	No (job categories not properly specified)		0.184	0.148
BUB1	Yes. (large, representative sample)	0.810	0.340	0.620
CCP2	No. (no regular miners in sample)	0.000	0.977	0.117
CEC1	Yes. (representative sample)	0.099		0.117
CEC2	Yes. (large representative sample)	0.005		0.062
COP1	No. (sample too small)		0.720	0.550
CVA1	No. (sample too small)	0.271		0.969
CVA2^{G}	No. (sample mainly experts)	0.319		0.358
CVA2	No. (sample mainly experts)	0.052		0.775
CVA2$^{I/G}$	No. (sample mainly experts)	0.072		0.314
DMC1^{G}	No. (worked in groups)	-.-		-.-
DMC2^{G}	No. (worked in groups)	-.-		-.-
DOT1	Yes. (representative sample)		0.402	0.118
DWY1	Yes. (representative sample)	0.656		0.858
DWY2	Yes. (representative sample)	0.006		0.623
DWY3	No. (miners familiar with scenario)	0.216		0.575
FXT1	No. (78% were maintenance)	0.531		0.300
HHS2^{G**}	No. (worked in groups)		-.-	-.-
HRL1	No. (only 6.3% regular miners)		0.033	0.498
HRL2	Yes. (representative sample)		0.006	0.001
HSC1	Yes. (representative sample)	0.000	0.630	0.021
JJJ1$^{I/G}$	No. (worked in groups)	-.-	-.-	-.-
JJJ1	Yes. (small but representative sample)		0.430	0.890
JJP1	Yes. (small but representative sample)		0.018	0.017
JJS1	No. (only 18% regular miners)		0.715	0.160
LCF1	Yes. (representative sample)	0.124		0.000
LCF2	Yes. (large proportion MTT)	0.047		0.517
LCF3	Yes. (representative but small sample)	0.020		0.710

Table 3.3: (continued)

exercise	adequate sample	training level MTT¥	training level FAT¥	job categories
MRL1	Yes. (representative sample)		0.000	0.006
MRL2	Yes. (representative sample)		0.500	0.420
PME2	No. (small sample, 72% supervisors)		0.534	0.953
PPC1	No. (small sample, 0% supervisors)	0.256	0.553	0.356
RFE1	No. (only 18% regular miners)	0.490		0.360
THA1	Yes. (representative sample)	0.340	0.400	0.180
THI1	Yes. (representative sample)	0.637	0.487	0.512
TTR1	No. (all supervisors and instructors)	0.213		0.333
VMI1	Yes. (representative sample)	0.197		0.034
VMI2	Yes. (representative sample)	0.249	0.943	0.573
VMI3	Yes. (representative sample)	0.075	0.675	0.649
VMR1**	No. (sample all experts)	-.-		-.-
VMR2	Yes. (representative sample)	0.004		0.000
WLP1	Yes. (representative sample)	0.003		0.505
WLP2	Yes. (representative sample)	0.500	0.050	0.350

* Size and composition of the sample adequate for discrimination analyses.
¥ MTT = Mine technical training exercise content
¥ FAT = First aid technical training exercise content
G* Pooled answer sheet from small group administration (group data) prevented analyses.
I/G Individual and Group data combined
** No variation in training levels in the sample.

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 preparation plant workers, surface workers at underground mines, office personnel, and others who are not miners but who sometimes participate in annual refresher training classes. The rationale for this analysis is that supervisory,

maintenance, and technical personnel who work in mines usually have greater levels of mine technical training (and often advanced first aid training as well) compared to regular working miners. Many mining companies make promotion to these management and technical positions contingent upon the acquisition of such extra training and skill. In addition, many of these mining job positions require special certification.

A one way analysis of variance was also performed on these job category data sets for each exercise version. These results are also included in Appendix B. Table 3.3 presents the ANOVA alpha values for the job category analyses that were completed for each exercise version, as well as the alpha values for analyses completed by level of training. Inspection of the values in the table reveals which exercises versions discriminated significantly by levels of training and job categories for various alpha levels (although the level selected apriori was $p < 0.10$).

The first column in Table 3.3 lists the exercise version abbreviated name. The second column comments on the adequacy of the sample for the discrimination analyses. As was mentioned earlier, not all the exercise field test samples were sufficiently large and varied with respect to levels of training and job categories. The most common bias is that samples consisted of too many persons with advanced levels of training and too many persons in supervisory or technical/maintenance job categories.

Inspection of Table 3.3 and the additional levels of training and job category discrimination analyses in Appendix B reveal two major points. First, about 24 of the exercise versions field test samples were inadequate with respect to sample size and

distribution of training levels and job categories. With larger and more adequate samples many of these exercises may be found to discriminate in both areas.

Second, of the 25 exercise versions that had adequate field test samples, 8 significantly discriminated among job categories, while 19 significantly discriminated between the two levels of training for the appropriate area, MTT or FAT. Generally the exercises were more sensitive to differences in self reported levels of training than to differences in major job categories.

In addition to the limitations of the field test samples previously discussed, there are other reasons why these two discrimination analyses are not particularly robust. The self-reporting of advanced or basic levels of training in the MTT and FAT area is not a precise procedure. There is much room for individual interpretation in this matter. It was not uncommon to encounter highly skilled miners, such as ventilation engineers or fire fighting team members, who would indicate they had no advanced levels of training. When questioned, these persons often responded that they were not more highly trained than others in their own specialty area or technical group. Another statement on the trainee questionnaire asked the person to list their current mining job. Sometimes it was possible to use this information, and to properly code the performance data for the person to indicate that a ventilation engineer did indeed have advanced technical training that would certainly be related to the content of mine fire and mine gases problems. However, sometimes the categorization was unclear and the coding undoubtedly in error.

Another problem with the job categorization analyses concerns the large number of regular working miners who have advanced training and certification in a large

range of technical and supervisory jobs. Many miners continue to study and learn, often in preparation for job advancement. Therefore, present job category is perhaps not as strongly related to level of special training and knowledge as it might first appear.

A third problem involves the "other" category. This category included persons who did not fit into the other categories. In reality this category, which represented only 3.8 percent of the total sample (see Table 2.1 in Chapter 2), included persons with very little mine technical and first aid knowledge and persons who were expert in one or both areas. This is because coal company guards, pilots, accountants, and secretaries, as well as experts in blasting, ventilation, geology, rock mechanics, and mining methods and techniques, and other technical specialists were included in this "other" category. Thus, the aggregated performance data from these persons with diverse levels of skill and knowledge are difficult to interpret and relatively meaningless.

Because of these limitations, the self-reported levels of training and job category discrimination analyses are less robust than the question discrimination analyses based on individuals' total exercise scores reported in Table 3.2. Yet, many of the exercises were found to discriminate between levels of training and job categories, especially when the sample size and composition were adequate for this task. These data suggest many of the exercises are valid with respect to their content and ability to discriminate among levels of expertise. However, a more rigorous analysis of the effects of level of training and job category on individuals' performance scores was desired. These additional analyses were needed to provide more information about

the validity of the exercises.

Standard Score Analysis of Training Level and Job Category by Exercise Type

A subsequent analysis was conducted for persons' standardized scores on exercise types rather than on individual exercises. The intention was to determine to what degree training level and job category are related to differential performance on the three types of exercises in general. The unit of analysis was exercise type rather than individual exercise. All of the exercises and exercise versions can be categorized into one of three basic types. These include exercises concerned with mine technical training (MTT), those concerned with first aid technical training (FAT), and those that contain content from both the first aid and the mine technical training areas (MIX).

Criteria for Exercise Inclusion

It was important that the exercises included in this analysis had sufficiently large and varied field test samples. Otherwise this second analysis by training levels and job categories would have the same limitations that are noted for the raw score analyses by individual exercises in the previous section. Therefore, three initial criteria were used for the selection of exercises for the pooled analysis. These included 1) a field test sample size of at least 80 persons, 2) an appropriate range of diversity among the job categories of miner, maintenance/technical, and supervisory/management, and 3) an appropriate distribution of persons who were certified or not certified in the FAT and/or MTT areas. Only exercises or exercise versions that met these criteria were included in this second analysis.

Calculation of T Scores

Once an exercise version was selected for inclusion in the analysis, it was necessary

to convert each person's raw score into a standard score. The standard score metric is desirable in this situation because individual exercises vary greatly in difficulty level, and field test samples also vary greatly in skill or ability levels. In other words, some exercises are easy while others are difficult. Some field test samples were mainly from experts and others were mainly from persons with basic levels of training. An analysis based on standard scores allows a more rigorous determination of the effect of training level and job category on performance level by type of exercise. In this manner some of the limitations that confounded the training level and job category analyses of the exercise simple scaled scores might be overcome.

After an exercise was selected for inclusion in this subsequent analysis, each person's score for that exercise was converted to a standard z score. This was done by the usual procedure (Glass & Stanley, 1970). The mean raw score for the exercise was subtracted from each person's individual raw score and this quantity was divided by the standard deviation for the sample. This produces a deviation score. Each person's deviation score was than multiplied by 10 and the numerical value of 50 was added to this product. This produces a T score. T scores are standardized scores where the mean of a distribution of scores is 50 and the standard deviation is 10. They are widely used and appropriate to the pooled analysis of interest here. The algorithms for calculating the standard z and T score are:

$$z = (X_i - X)/s.d. \quad \text{and} \quad T = 10z + 50;$$

where: z = each person's deviation score for the sample,
X_i = each individual's raw score,
X = the mean raw score for the sample,
s.d. = the sample standard deviation in raw score units,
T = the standardized T score for each person.

Characteristics of the Pooled Samples

Table 3.4 shows the numbers and characteristics of miners included in the standardized T score analyses of the effect of training level and job category on performance by exercise type. Inspection of Table 3.4 reveals there were large numbers of persons in each of the three exercise content areas or types. The distribution of persons with and without special training and certification, and across the three major job categories is also shown to be adequate for the analyses. The "other" job category persons were not included in this analysis for the reasons discussed in the previous section, e.g. this sample constituted less than four percent of the total sample and it consisted of a mixture of experts and novices with the identification of novice or expert often not being possible.

Table 3.4: Number and characteristics of miners involved in the analyses of training level and job category on performance by exercise type

	exercise t type			
	FAT	MTT	MIX	
total number of miners	593	1057	596	
number with special certification*	182	461	110	(199)
regular miners	209	479	277	
maintenance/technical	117	217	175	
supervisory/management	112	208	59	
mean age (years)	36.7	35.8	36.8	
mean experience (years)	10.6	10.8	12.4	

*Miners who were certified and/or who regularly performed in each area of expertise were included in this category. Column three under MIX includes the number of miners with dual certification in both the FAT and MTT areas while the figure in parentheses shows the number certified in only one or the other areas.

Table 3.5 describes the distribution of standardized performance scores for these specially selected samples for each exercise type or category pooled across training levels and job categories. Inspection of the table reveals that the standardized score procedures did produce a mean score of 50 for each of the three types of exercises, and a standard deviation of approximately 10. The range, minimum, and maximum score values give some indication of the variability in performance scores of persons in the pooled samples for each of the three exercise types.

Discrimination Analyses by Job Categories and Training Levels

Once the exercises that included sufficiently large and varied field test samples were identified, and once the T scores had been calculated for each person in these samples, one way analyses of variance (ANOVAs) could be carried out to determine the effects of training level and job category on performance scores for each of the three exercise types. These results are summarized in Tables 3.6 and 3.7. The exercise versions included in the sample are footnoted in the tables. Table 3.6 provides the analyses for job categories by exercise types, while table 3.7 provides the results of the analyses for training level by exercise type.

Inspection of the tables reveals small to moderate but highly statistically significant differences in the performance scores of persons related to their job categories and training levels. Figure 3.1 plots the mean performance differences by job category and exercise type that are listed in Table 3.6. Figure 3.2 plots the performance differentials for training levels by mine technical training (MTT) and first aid (FAT) exercise types.

Table 3.5: Standard T score distributional characteristics for samples for each type of exercise

	exercise type		
statistic	FAT	MTT	MIX
mean	50.0	50.0	50.0
standard deviation	9.92	9.95	9.93
median score	51.4	51.4	51.5
score range	48.9	55.0	52.6
minimum score	18.1	14.1	18.2
maximum score	67.0	69.1	70.8

Table 3.6 : Mean standard score performance differentials between three job categories for three exercise types

			means & standard deviations					
exercise content	number of versions	number of miners	miner mean (s.d.)	technical mean (s.d.)		supervisor mean (s.d.)		F ratio	p value
*MTT	11	882	**49.3**(9.89)	**51.1**	(10.14)	**52.0**	(8.82)	6.48	.0016
*FAT	10	446	**49.2**(9.65)	**52.2**	(8.06)	**52.6**	(10.12)	6.50	.0017
*MIX	9	511	**49.1**(9.68)	**51.1**	(9.31)	**53.0**	(9.17)	5.15	.0061

*MTT exercise versions include CEC1, CEC2, DWY1, DWY2, HSC, LCF1, LCF2, RFE1, VMR2, WLP1, WLP2 (7 exercises, 11 versions)

*FAT exercise versions include ADA1, BHL2, CCP2, HRL1, HRL2, JJJ1, JJS1, MRL1, MRL2, THI1 (9 exercises, 10 versions)

*MIX exercise versions include BUB1, COP1, DOT1, FXT1, PPC1, THA1, VMI1, VMI2, VMI3 (7 exercises, 9 versions)

Inspection of these tables and figures reveals a number of interesting findings. From Figure 3.1 it is apparent that supervisors generally do better on all three types of exercises than regular miners or mine maintenance/technical personnel. This finding

Table 3.7: Mean standard score performance differentials between noncertified and certified miners by two exercise types

exercise content	number of versions	number of miners	means & standard deviations: not certified mean (s.d.)	certified mean (s.d.)	F ratio	p value
*MTT	11	988	**48.9** (10.11)	**52.6** (8.92)	31.09	.0000
*FAT	10	550	**49.3** (9.79)	**52.7** (9.70)	11.00	.0010

*MTT exercise versions include CEC1, CEC2, DWY1, DWY2, HSC, LCF1, LCF2, RFE1, VMR2, WLP1, WLP2 (7 exercises, 11 versions)

*FAT exercise versions include ADA1, BHL2, CCP2, HRL1, HRL2, JJJ1, JJS1, MRL1, MRL2, THI1 (9 exercises, 10 versions)

is undoubtedly related to the requirements of most mining companies and many states that mine foreman and managers be trained and certified in multiple technical areas as well as in advanced first aid procedures. While the differences in average performance of these three job categories are small, they are consistent and highly stable across the many exercise and exercise versions included in the sample. Regular miners' somewhat poorer performances on the exercises across all three types are almost certainly related to their generally lower levels of advanced training in technical and first aid areas. Persons in the maintenance/technical and the supervisory/management job categories usually have greater levels of advanced training in both first aid and mine technical areas.

Effect of Reading Ability and General Educational Level

Matters of general educational level and reading ability are not likely related to these observed performance differences. As was pointed out in Chapter 2, empirical data reveal that the exercises are easy to read and comprehend, even though their technical content is often complex. Differences in reading ability and levels of formal

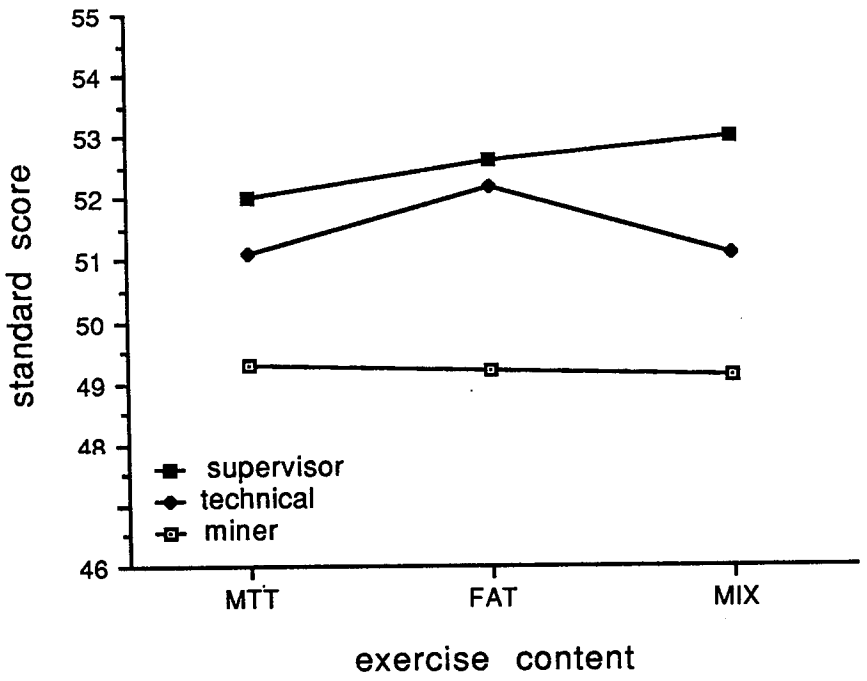

Figure 3.1: Mean standard scores by exercise type and job category

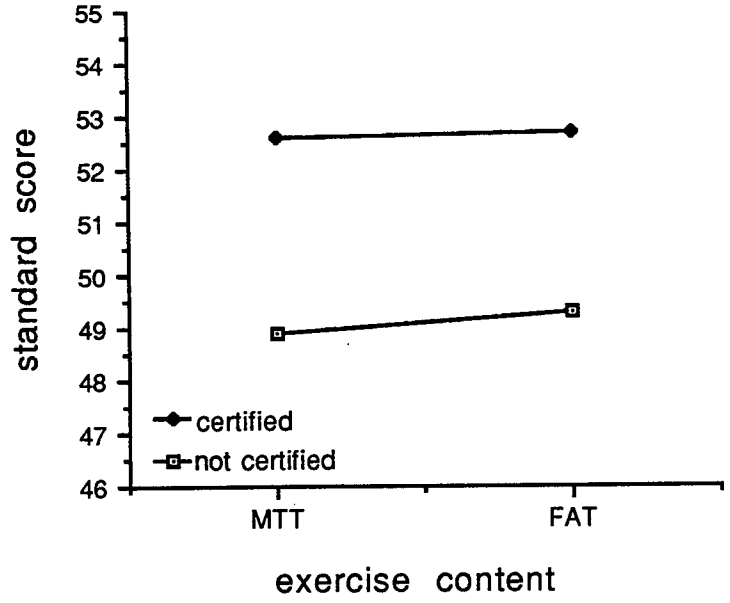

Figure 3.2: Mean standard scores by exercise type and certification

education are likely to have little influence upon performance scores on these exercises. This conclusion is also supported by the data presented in Table 3.7 and Figure 3.2. In these analyses the differential performance of persons with basic and advanced levels of training were examined, without reference to their job categories. Inspection of Figure 3.2 and Table 3.7 reveals a small but statistically significant effect of training level on performance scores for both the first aid and mine technical content exercises. Furthermore, the effect size is about the same magnitude as that observed for the job category differential.

Summary of Evidence for Exercise Validity

The more robust analytical procedures described in this section suggest that the exercises do significantly and consistently discriminate between persons with basic and advanced levels of training in both first aid and mine technical areas. The exercises also discriminate among the three broad levels of job categories: regular miner, maintenance/technical, and supervisory/management. However, most of this latter discrimination is probably caused by the greater levels of technical and first aid training required for most mine supervisory and management personnel.

Both the levels of training and the job categorization classification measures were determined from self-reported data by individuals on the trainee's questionnaire. Although the procedure is basically sound, both of these categorizations are crude and both certainly lend themselves to improper categorization on occasion. In addition, as can be seen from Table 3.3, many of the field test samples contained an inadequate sample of miners. Many samples were both too small and too homogeneous with respect to the levels of training and job categories represented. Data from exercises

tested with larger samples with more balanced representation of job categories generally discriminated by training level and job category. It is likely that most of the exercises would have behaved in this manner if the field test sample had been larger and more diverse. However, even with the crude discrimination measures used in this study, the consistent ability of the exercises to significantly discriminate among job categories and training levels suggests that the exercises are valid.

One exercise underwent a stronger validity study than was possible for most of the other exercises. The results of this study illustrate the capability of a technical exercise to discriminate between levels of expertise. The CVA exercise concerns mine ventilation arrangements during the connection of two previously separately ventilated sections of a mine. The exercise is designed for mine examiners, mine foreman, and mine engineers. It was administered to a representative group of 22 mine foreman and supervisors, and to a group of 48 experts in mine ventilation arrangements (Cole, Wala, Haley, & Vaught, 1987; Wala & Cole, 1987). The mean raw scores for each group on each question are plotted in Figure 3.3. The average total scores and standard deviation for these two groups are shown as the horizontal lines on the graph. The numerical values of these statistics are provided at the end of each line. Both individual questions and the total exercise score clearly and significantly discriminated between the two groups (Cole et al., 1987).

The exercise discrimination validity data presented in the previous sections of this chapter confirm the independent judgments of the thousands of miners and hundreds of instructors who have used the exercises. The data reported in Chapter 2 show that both miners and trainers judge the exercise to be authentic, helpful to their

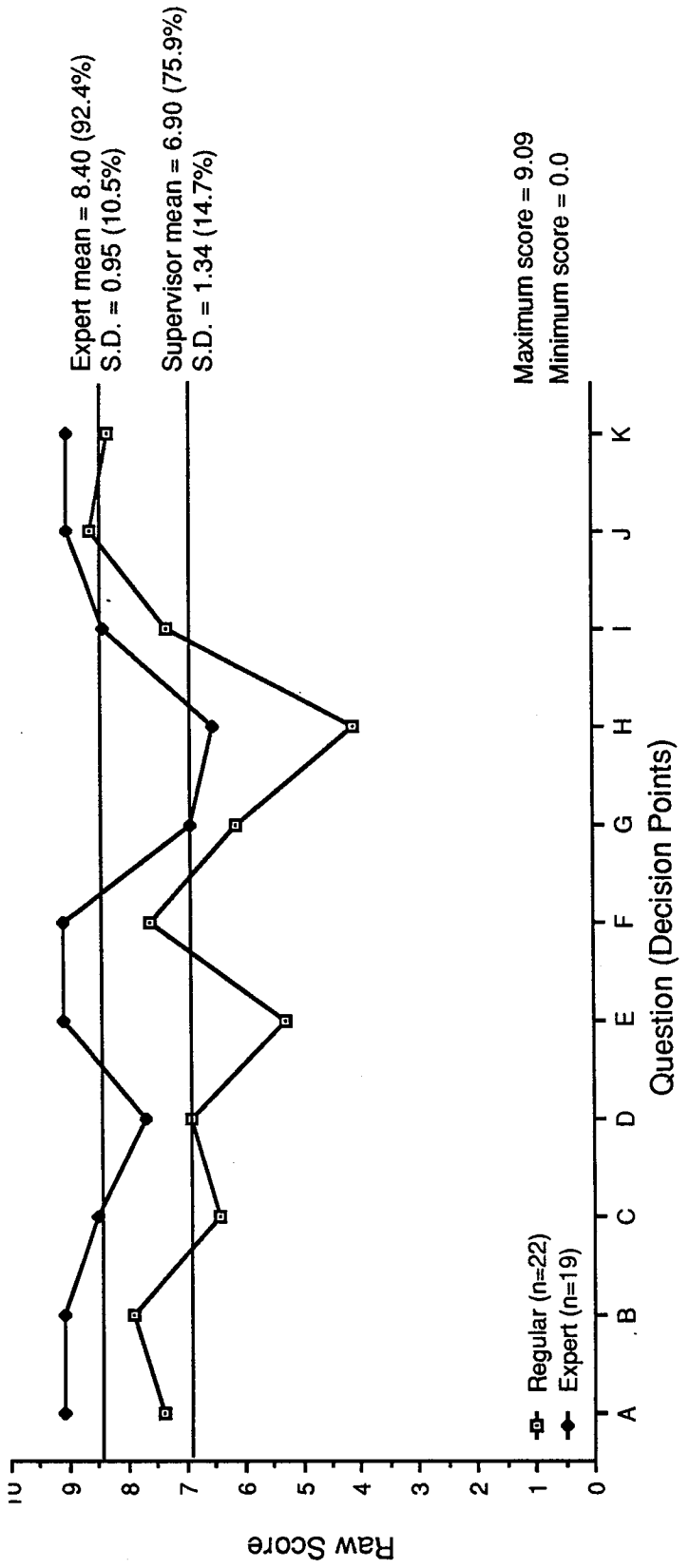

Figure 3.3: Performance differences for supervisors and experts on the CVA exercise

learning, enjoyable, relevant, and valid.

The validity of the exercises is not surprising when one considers the attention given to their design and development, which is described in detail in Chapter 2 and in other publications (Cole, Berger, Vaught, Lacefield, Wasielewski, Haley, & Price 1988a; Cole, Berger, Vaught, Haley, Lacefield, Wasielewski, & Mallett, 1988b; Cole, et al., 1987; Cole, Mallet, & Vaught, 1987; Lacefield & Cole, 1986). Each exercise is grounded in actual accident case materials. The development and authentication processes seek to further assure that exercise content, structure, language, problems and predicaments, and options for miners are all realistic and based upon real world events and probabilities. Care is taken to select exercise content that is significant and nontrivial in terms of what miners need to know and understand if they are to better cope with nonroutine emergency events. Good instructional design principles are used to ensure the reading level and mechanics of the exercise itself are simple and basic, and do not interfere with miners' ability to comprehend and focus on the problem content.

Evidence has been presented that suggests the exercises are reasonably valid. Now it is appropriate to examine the degree to which miners' performance indicates mastery of the critical skills and knowledge contained in the exercises.

Mastery Levels of Miners' Performance on the Exercises

This section examines the degree to which miners in the field test sample exhibited mastery of the mine emergency judgment and decision making skills assessed by the exercises. The unit of analysis is again the individual exercise and exercise version. The metric used in the analysis is the common zero to 100 scaled score for each

exercise. Before examining and interpreting the data for this analysis, the nature and purpose of mastery tests, differences between mastery and norm referenced tests, and some of the methods for the selection of content and critical skill performance levels for mastery tests are briefly described. Relationships of these theoretical matters to the design of the paper and pencil exercises are noted. Then, the typical mastery levels of miners involved in the field tests of the 29 exercises and 42 exercise versions are presented and interpreted.

Mastery versus Norm Referenced Tests

Mastery level performance tests are often used in areas of critical skills assessment (Cole et al., 1984). The mastery level is determined by considerations of the criticality of the skill or content the test is to measure. For example, commercial airline pilots are expected to exhibit near perfect levels of mastery in landing their airplanes. Low levels of mastery cannot be tolerated because the cost in damaged equipment, injured passengers and crew members, bad public relations, and lost profits are too high.

Unlike the norm referenced test, with which persons are most familiar, mastery tests do not compare the performance of persons to the typical score of others in a normative or reference group. Rather, mastery tests are criterion or performance referenced measures. The standard for judgment of adequacy of performance is not the average score of the group, but the adequacy of the score judged against some external performance criterion that is deemed appropriate. This level is often correct performance of 90 to 95 percent of the test material or task by the performer, and often by all of the members of a particular group, or at least by 95 percent of the group (Cole, et al., 1984). Mastery levels of 100 percent correct performance are not usually stated,

even for very critical skills. Research has shown that even the most highly skilled technical and professional persons make some errors and fail to exhibit 100 percent levels of mastery over many performances (Cole et al., 1984; Lacefield, 1981). However, these same studies suggest that a mastery level of 95 percent is usually attainable by experts on a regular basis for most performances, and that a 95 percent level of mastery is a reasonable and functional goal in the training of professionals in complex technical tasks (Cole et al., 1984; Lacefield, 1981).

Mastery Nature of the Exercises

The exercises described in this chapter, and elsewhere in this report, are designed as mastery tests. Their limitations because of the lack of question independence have been previously noted. The structure of the exercises makes them teaching devices as well as tests. Therefore, persons may be expected to score somewhat more highly on these tests than they would on more conventional tests that do not include corrective feedback. The corrective feedback included within the exercise teaches the person as he or she completes the test. Consequently, the total score for the exercise and the resulting mastery level should be higher for these exercises than for tests that do not include corrective feedback.

Critical Skill Focus of the Exercises

The exercises developed under this contract focus on critical skills required for preventing and coping with a wide variety of underground mine emergencies. More than a year was spent in the identification and selection of the skill and performance domains that define the focus of the exercises. The performance objectives and the content of the exercises are based upon reviews of a large amount of empirical

research concerning the selection, assessment and teaching of critical but nonroutine (infrequently utilized) skills for solving problems in a variety of technical fields. Interviews with hundreds of persons in the mining industry, and study of hundreds of mining accident investigation reports also contributed to the selection of critical skills and content for the exercises. These efforts were further supported by a series of field studies of miners. The studies gathered detailed information about which skills and knowledge are most needed to cope with a variety of infrequently experienced self-rescue and escape and first aid emergency situations. This research is reported in two earlier project technical reports (Cole et al., 1988a; Cole et al., 1988b).

Earlier research, review of accident investigations, and the field studies suggested miners often get into difficulty because they make errors in the types of emergency situations included in the exercises. Thus, the exercises were deliberately targeted toward problems where miners are believed to make errors, errors that sometimes lead to serious injuries or death. The problem content was also selected to assess those critical skills that miners should exhibit and maintain at high levels of mastery. It was known that miners are likely to have difficulty maintaining high levels of proficiency in these types of skills, because the emergency events for which they are required are relatively infrequent (nonroutine) in the lives of individuals. Thus, through lack of opportunity for practice, performance decrements may be expected to occur, just as they do in other workers who have little opportunity to practice critical skills on a regular basis. Working the exercises is intended to help miners maintain higher levels of preparedness.

Levels of Mastery Observed in the Exercise Field Test Samples

The analyses presented earlier indicate that the exercises are reasonably valid. Assuming 1) that the exercises are valid measures of miners' critical judgment and decision making skills for certain types of mine emergencies, and 2) that exercise content and skills represent areas of critical performance for miners in emergency situations, what can be inferred about the miners' level of mastery of these skills from the field test data?

Examination of Table 3.8 reveals that few of the miners in the field tests of exercises performed at levels of 90 percent or above. The average percentage of miners scoring at or above the 90 percent level of mastery was calculated for the 44 exercise versions for which data are presently available. The values in the last two columns in Table 3.8 were summed for each exercise to produce the percent of persons scoring at or above 90 percent mastery including the percentage with perfect 100 percent scores. The mean percentage of miners scoring at or above 90 percent mastery on the exercises is 28.7 with a standard deviation of 24.34.

Tables 3.9 through 3.11 group the exercises into each of the three types, e.g. FAT, MTT, and MIX. The proportion of miners scoring at or above each of the designated levels of mastery is listed for each exercise. The last column in the table is the percentage of miners who scored at or above the 90 percent mastery level including those with perfect scores. The mean percentage of persons at or above the 90 percent mastery level was calculated for the exercises in each group of exercises. These values are listed in the tables under the "at 90 or above" column. The mean percentage of miners scoring at or above the 90 percent mastery level for FAT

Table 3.8: Cumulative percent of miners scoring at or above specified levels of mastery across exercises

			cumulative percent at or above specified level					
Exercise	n	content	50	60	70	80	90	100
ADA1	35	FAT	100.0	94.3	77.2	42.9	0.0	0.0
AVB1	44	FAT	100.0	90.2	51.2	12.2	0.0	0.0
BHL2	58	FAT	100.0	100.0	98.2	89.6	46.5	3.4
BJF1	69	FAT	100.0	100.0	100.0	95.7	75.4	14.5
BTR1	50	FAT	94.0	72.0	50.0	26.0	4.0	0.0
BUB1	34	MIX	100.0	93.1	72.4	24.1	0.0	0.0
CCP2	51	FAT	100.0	100.0	95.9	81.6	30.6	0.0
CEC1	63	MTT	98.4	85.5	62.9	22.6	0.0	0.0
CEC2	145	MTT	99.2	97.1	85.0	54.3	14.3	0.0
COP1	28	MX	100.0	100.0	89.2	57.1	32.1	0.0
CVA1	22	MTT	100.0	100.0	81.8	27.3	0.0	0.0
CVA2^{G*}	29	MTT	100.0	100.0	100.0	99.9	81.4	0.0
CVA2*	19	MTT	100.0	100.0	100.0	100.0	84.2	0.0
DMC1^{G*}	28	MTT	91.6	83.3	75.0	50.0	8.3	8.3
DMC2^{G}	15	MTT	100.0	85.7	42.8	28.5	0.0	0.0
DOT1	47	FAT	100.0	100.0	91.5	78.7	48.9	0.6
DWY1	87	MTT	64.8	55.4	33.0	1.2	0.0	0.0
DWY2	51	MTT	60.0	38.0	34.0	16.0	12.0	0.0
DWY3	41	MTT	100.0	97.6	92.7	73.2	41.0	0.0
FXT1	80	MIX	95.0	91.3	88.8	65.0	33.7	8.7
HHS2^{G}	25	FAT	100.0	100.0	95.8	91.7	25.0	8.3
HRL1	66	FAT	100.0	93.9	84.8	57.5	13.6	0.0
HRL2	39	FAT	100.0	94.9	84.6	64.1	26.2	0.0
HSC1	133	MIX	99.2	99.2	96.2	89.4	55.6	1.5

Table 3.8: (continued)

			cumulative percent at or above specified level					
Exercise	n	content	50	60	70	80	90	100
JJJ1	32	FAT	100.0	97.0	93.9	62.6	18.8	0.0
JJP1	16	FAT	100.0	100.0	87.5	68.8	37.5	0.0
JJS1	62	FAT	100.0	95.1	90.3	64.5	21.0	1.6
LCF1	99	MTT	93.2	87.3	71.6	51.0	26.5	10.8
LCF2	84	MTT	97.6	91.6	75.9	26.5	0.0	0.0
LCF3	25	MTT	100.0	100.0	88.0	68.0	24.0	0.0
MRL1	132	FAT	99.1	95.3	85.5	56.0	21.9	4.5
MRL2	61	FAT	100.0	100.0	95.0	81.9	47.5	1.6
PME2	33	FAT	100.0	97.1	88.0	51.6	15.2	0.0
PPC1	38	MIX	100.0	100.0	100.0	94.8	31.6	0.0
RFE1	68	MTT	100.0	100.0	98.6	92.7	66.2	1.5
THA1	60	MIX	100.0	100.0	100.0	89.0	49.0	14.5
THI1	52	MIX	100.0	98.2	91.2	77.7	29.8	0.0
TTR1	35	MTT	97.0	69.7	39.4	21.2	12.1	3.0
VMI1	121	MIX	100.0	98.3	88.3	60.0	40.8	0.8
VMI2	115	MIX	99.2	93.9	80.6	37.2	2.7	0.0
VMI3	79	MIX	98.7	97.4	89.8	62.0	17.7	0.0
VMR1*	20	MTT	100.0	95.5	95.5	85.0	40.0	15.0
VMR2	73	MTT	98.5	97.1	88.1	56.5	8.7	0.0
WLP1	169	MTT	94.6	89.2	70.5	51.2	26.5	1.8
WLP2	102	MTT	99.0	97.0	91.9	69.5	41.9	13.3

$n = 44$
$\bar{X} = 28.7$
s.d. = 24.34

Table 3.8: (continued)

* These groups consisted mainly of experts
G Group data (Persons collaborated in small groups of 2 to 5 persons while working these exercises.) All others are individual data (Persons worked the exercise individually with no collaboration with others.)

Table 3.9: Cumulative percent of miners scoring at or above specified levels of mastery for FAT exercises

	cumulative percent at or above specified level				
Exercise	50	60	70	80	90
ADA1	100.0	94.3	77.2	42.9	0.0
AVB1	100.0	90.2	51.2	12.2	0.0
BHL2	100.0	100.0	98.2	89.6	49.9
BJF1	100.0	100.0	100.0	95.7	89.9
BTR1	94.0	72.0	50.0	26.0	4.0
CCP2	100.0	100.0	95.9	81.6	30.6
DOT1	100.0	100.0	91.5	78.7	49.5
HHS2	100.0	100.0	95.8	91.7	33.3
HRL1	100.0	93.9	84.8	57.5	13.6
HRL2	100.0	94.9	84.6	64.1	26.2
JJJ1	100.0	97.0	93.9	62.6	18.8
JJP1	100.0	100.0	87.5	68.8	37.5
JJS1	100.0	95.1	90.3	64.5	22.6
MRL1	99.1	95.3	85.5	56.0	25.4
MRL2	100.0	100.0	95.0	81.9	49.1
PME2	100.0	97.1	88.0	51.6	15.2

n = 16
$\bar{X}$ = 29.1
s.d. = 23.04

exercises is 29.1 with a standard deviation of 23.04. For the MTT exercises the mean is 16.9 with a standard deviation of 19.92. For the MIX exercises the mean is 33.5 with a standard deviation of 20.09.

Figures 3.4, 3.6, and 3.8 plot the percentage of miners who scored at or above the 90 percent level of mastery across each exercise, for each of the three types of exercises. The mean score across exercises for each type of exercise is plotted as a

Table 3.10: Cumulative percent of miners scoring at or above specified levels of mastery for MTT exercises*

	cumulative percent at or above specified level				
Exercise	50	60	70	80	90
CEC1	98.4	85.5	62.9	22.6	0.0
CEC2	99.2	97.1	85.0	54.3	14.3
CVA1	100.0	100.0	81.8	27.3	0.0
DMC1	91.6	83.3	75.0	50.0	16.6
DMC2	100.0	85.7	42.8	28.5	0.0
DWY1	64.8	55.4	33.0	1.2	0.0
DWY2	60.0	38.0	34.0	16.0	12.0
DWY3	100.0	97.6	92.7	73.2	41.0
LCF1	93.2	87.3	71.6	51.0	37.3
LCF2	97.6	91.6	75.9	26.5	0.0
LCF3	100.0	100.0	88.0	68.0	24.0
RFE1	100.0	100.0	98.6	92.7	67.7
TTR1	97.0	69.7	39.4	21.2	15.1
VMR2	98.5	97.1	88.1	56.5	8.7

n = 14
$\bar{X}$ = 16.9
s.d. = 19.92

*CVA2 and VMR1 exercises are not included because these groups were mainly experts

Table 3.11: Cumulative percent of miners scoring at or above specified levels of mastery for MIX exercises

	cumulative percent at or above specified level				
Exercise	50	60	70	80	90
BUB1	100.0	93.1	72.4	24.1	0.0
COP1	100.0	100.0	89.2	57.1	32.1
FXT1	95.0	91.3	88.8	65.0	43.4
HSC1	99.2	99.2	96.4	89.4	57.1
PPC1	100.0	100.0	100.0	94.8	31.6
THA1	100.0	100.0	100.0	89.0	63.5
THI1	100.0	98.2	91.2	77.7	29.8
VMI1	100.0	98.3	88.3	60.0	41.6
VMI2	99.2	93.9	80.6	37.2	2.7
VMI3	98.7	97.4	89.8	62.0	17.7
WLP1	94.6	89.2	70.5	51.2	28.3
WLP2	99.0	97.0	91.9	69.5	55.2

n = 12
$\bar{X}$ = 33.5
s.d. = 20.09

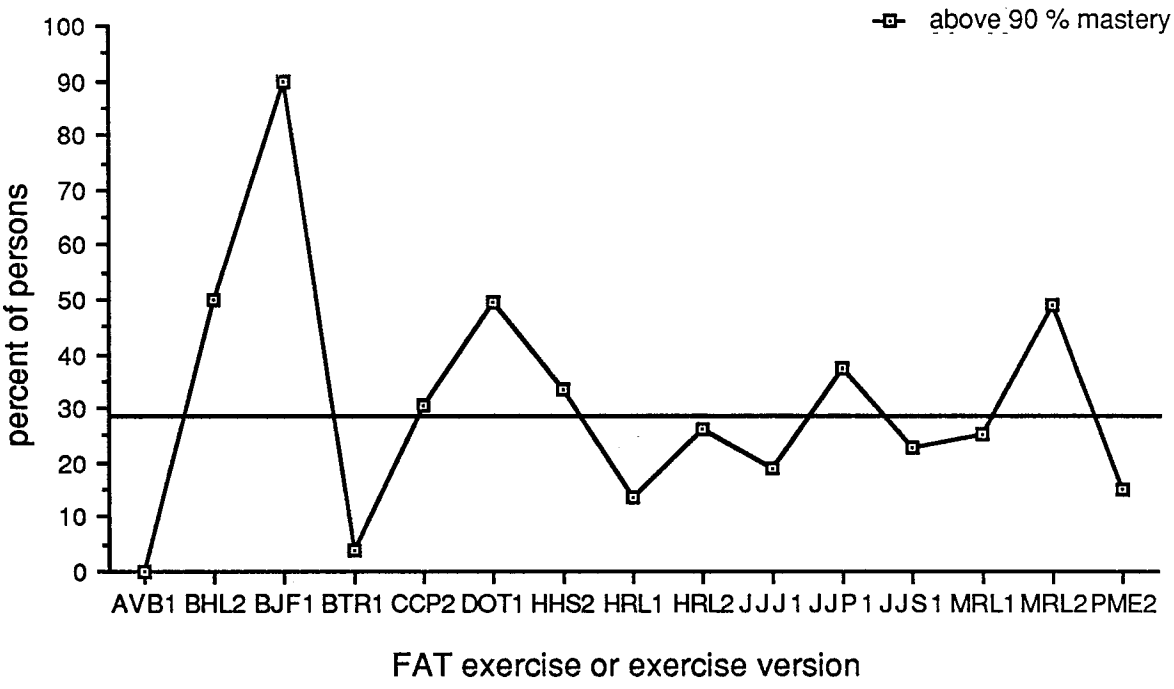

Figure 3.4: Percents of miners at or above 90 percent mastery on FAT exercises

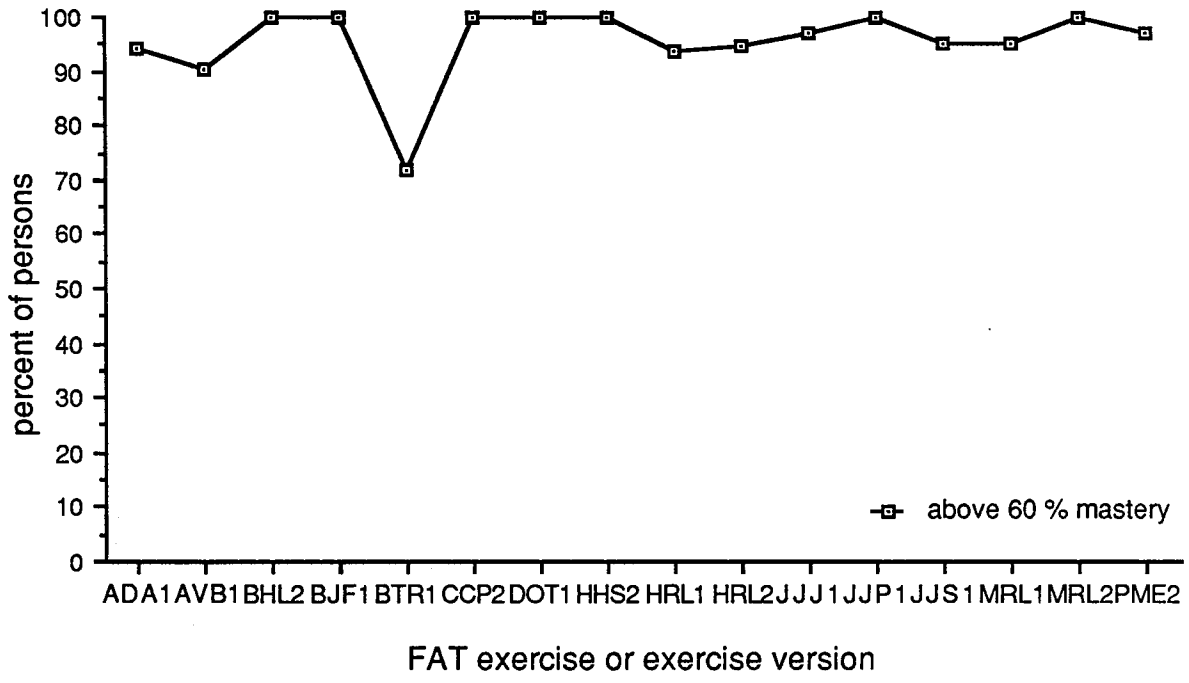

Figure 3.5: Percents of miners at or above 60 percent mastery on FAT exercises

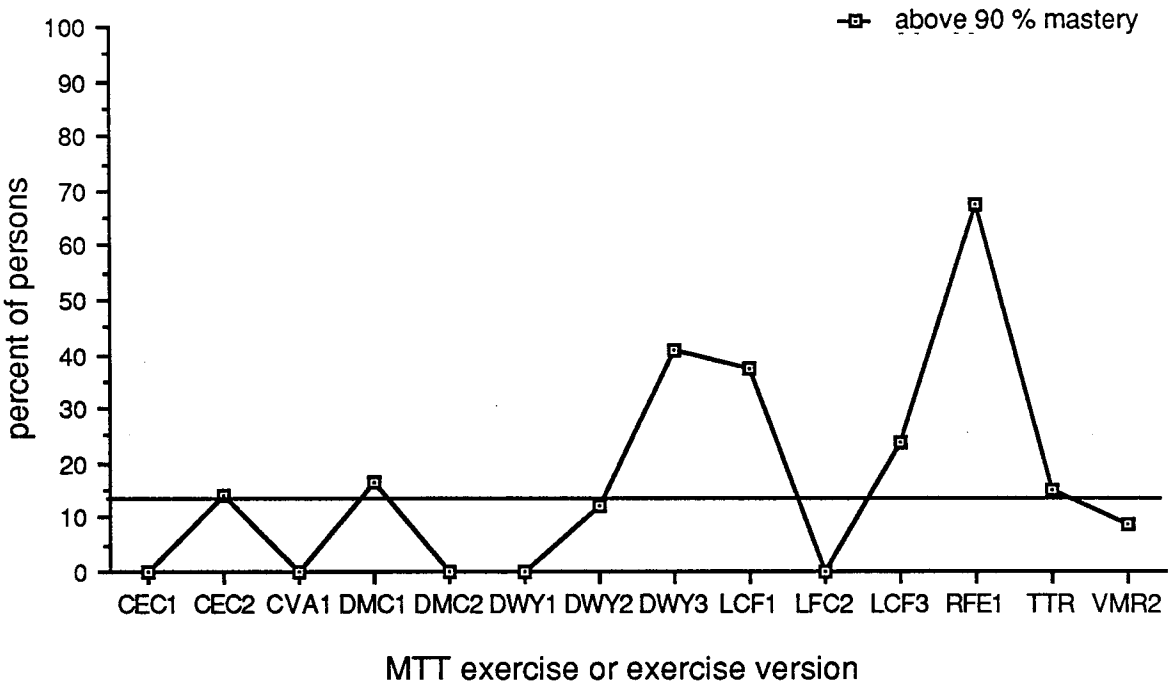

Figure 3.6: Percents of miners at or above 90 percent mastery on MTT exercises

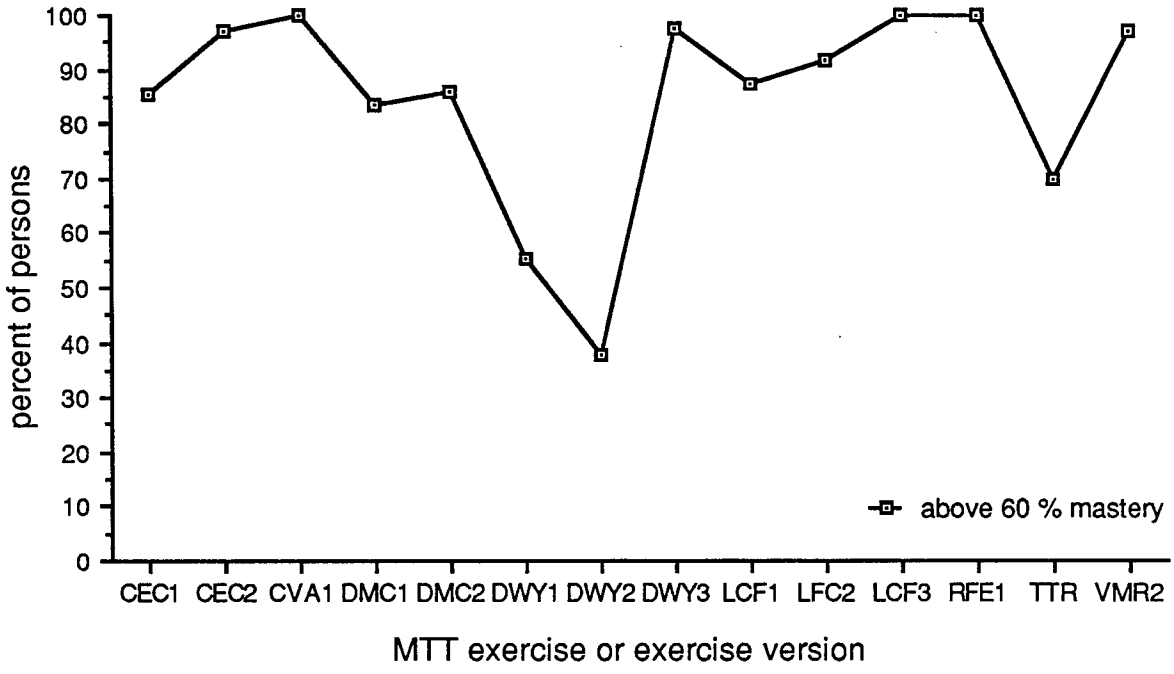

Figure 3.7: Percents of miners at or above 60 percent mastery on MTT exercises

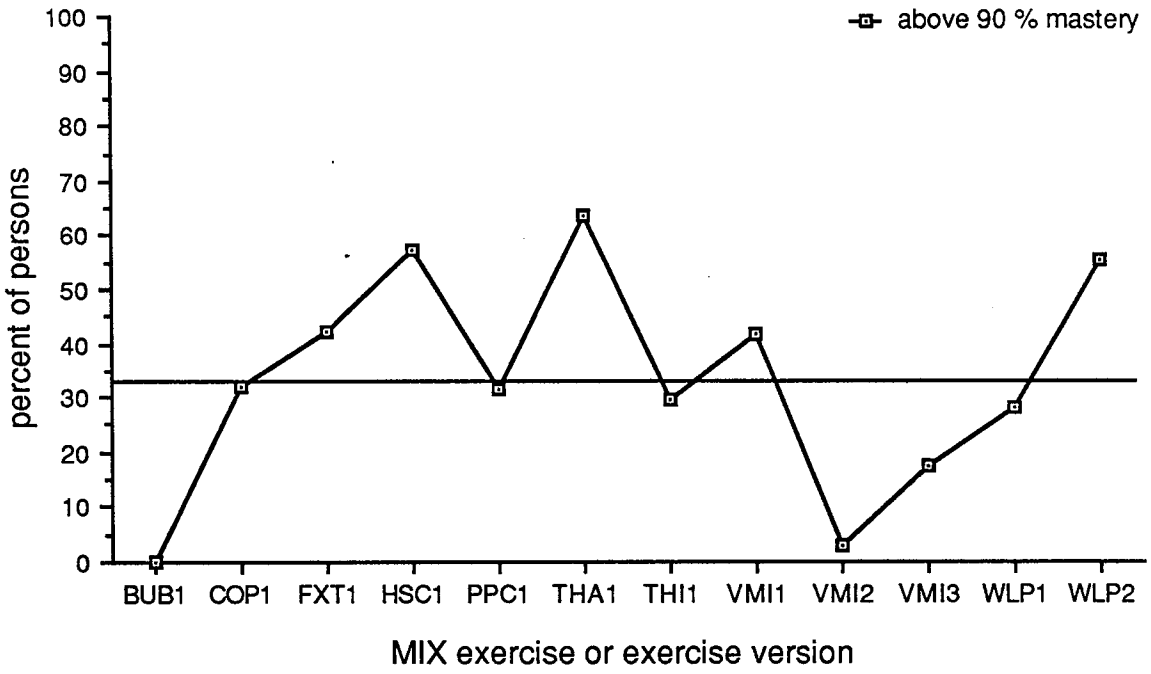

Figure 3.8: Percents of miners at or above 90 percent mastery on MIX exercises

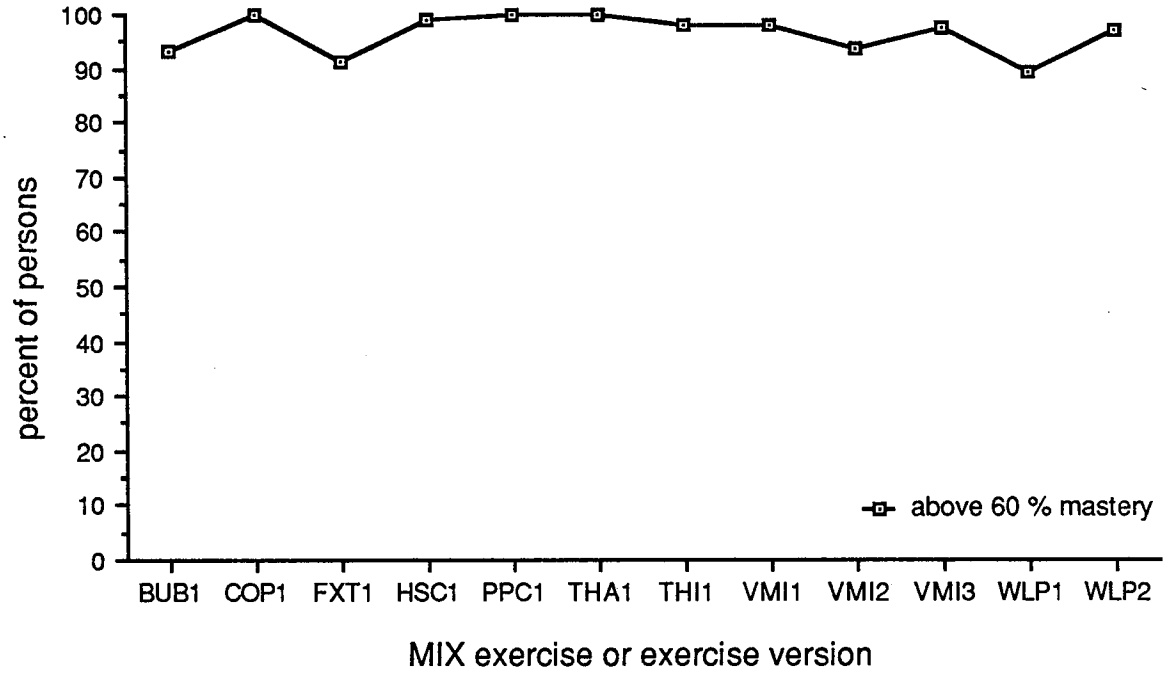

Figure 3.9: Percents of miners at or above 60 percent mastery on MIX exercises

straight line. These Figures quickly convey the typical proportion of miners who scored at or above the 90 percent mastery level on the exercises in that category.

Figures 3.5, 3.7, and 3.9 are similar to the plots in Figures 3.4, 3.6, and 3.8. The only difference is that the values plotted are the percent of miners who scored at or above 60 percent mastery levels. Each of these figures is paired with the appropriate 90 percent or above performance plot.

Inspection of Tables 3.9 through 3.11, and Figures 3.4 to 3.9 reveal a number of important points. First, the majority of miners on all exercises, and across all exercise types, do not perform at or above the 90 percent mastery level. Second, mastery levels are highest for the MIX and FAT exercises, and much lower for the MTT exercises. Third, the variance in proportion of miners achieving 90 percent mastery levels across exercises is large. Fourth, approximately 90 percent of the miners in the FAT and MIX samples performed at or above 60 percent mastery. For the MTT exercises the percent of miners who performed at or above 60 percent mastery is more variable across the exercises, and the average somewhat below 90 percent of the miners.

Interpretation of Observed Mastery Levels

As pointed out earlier, the exercises vary greatly in difficulty level, and the samples of miners in the field tests also varied in levels of expertise. In addition, the field test samples tended to be biased toward more advanced levels of training and more technical/maintenance and supervisory personnel than would be the case with more typically heterogeneous groups of miners. The higher proportion of persons with advanced levels of training should tend to raise the proportion of persons who achieved 90 percent or higher levels of mastery. Given these biases of the samples,

and the empirical data on mastery levels, an interesting conclusion can be drawn.

A criterion of 90 percent or higher mastery performance by 95 percent of the sample is a reasonable expectation for technically trained personnel in critical skill performance. However, far below 90 percent of the miners in these samples attain a 90 percent or higher mastery level. The level at which 90 to 95 percent of the sample of miners performs on the exercises is about 60 percent mastery. The reason for this lower than anticipated performance level by miners is likely related to their relatively infrequent practice of the types of information gathering, judgment, and decision making skills the exercises seek to assess and teach. The exercises were targeted to focus on little used, nonroutine skills that are thought to be critical to preventing and coping with mine emergency situations. If the exercises are valid, as they appear to be, these mastery level performance data suggest that exercise content has been appropriately targeted.

The effectiveness of the exercises for raising proficiency in critical judgment and decision making skills for emergency situations is not known. The miners who worked the exercises may have learned a great deal, and increased their proficiency. Both miners and trainers report this to be the case. However, no formal analyses capable of testing this hypothesis are possible with the data from the studies completed under this contract. Frequently working a series of related exercises that deal with critical skills in first aid or other mine emergencies may help to maintain levels of preparedness for coping with these nonroutine events.

Are the Exercises Teaching Devices or Tests?

The exercises have been developed primarily as teaching devices, not as tests. The

assessment purpose for which they excel is in the personal communication to the exercise taker, and to his or her colleagues and instructor, of serious errors in knowledge, judgment, and decision making in the context of authentic problem situations the miner may sometime encounter. The exercises are designed to make the presence of such errors salient to the individual miner, so that he or she is motivated to correct deficiencies and improve performance. The large amounts of immediate corrective feedback included in the exercises facilitate this tutorial approach. The exercises also focus on the positive aspects of miners' actions and judgments. As in real life problems, the majority of the miners' decisions made in the course of working an exercise are correct. Each time a miner responds with a correct action, inference, or judgment, the immediate feedback reinforces that response.

The authentic problems that are the core of each exercise motivate strong interest and persistence from miners, and they promote deeper thinking and reflection than usually results from annual refresher training. Working an exercise often helps miners and their supervisors to identify and clarify problematic technical and procedural points that are present in their own mines and work practices. The exercises also help teach that avoiding and coping with emergency situations is far more a matter of good planning and sound work practices than of chance factors. The exercises remind miners of what they already know, help identify areas of confusion and misunderstanding, and help to integrate and apply this large amount of practical knowledge and experience in the context of complex and authentic problems.

The Exercises as Tests

The exercises were not designed as measures by which to certify miners or mine

supervisory technical personnel. However, they could be used for this purpose, just as similar simulation exercises are currently used for the certification of medical personnel. However, if this task were to be undertaken, more studies should be done to specifically prepare the exercises for this role. There are a number of reasons for this.

First, to become better tests, and less oriented as teaching devices, the large amount of immediate corrective feedback should be eliminated from the exercises. The feedback, including information about the correctness or incorrectness of the each answer, is designed for instruction. The presence of this information teaches persons as they work the exercise, thus confounding the measurement of their knowledge and skill with what they have learned while completing the exercise. To be a better test, the only feedback presented should be the consequences and feedback that result from real life decisions as problems are experienced and choices and actions undertaken. One exercise that adopts this limited real world feedback mode is the Vulcan Mine Recovery problem. The structure of this exercise is patterned directly after the structure of medical simulation exercises used to certify physicians' competence in internal medicine diagnostic procedures. The references in the instructor's guide for the VMR exercise cite these sources and the technical documents that describe the development of such tests.

Second, to become good tests, the exercises would need to be administered to more carefully sampled and larger numbers of miners. The samples utilized should be more heterogeneous in composition, to avoid the sampling biases noted earlier. In addition, if the mastery performance orientation of the tests were to be maintained,

more attention would have to be given to the identification of expert samples. The exercises would have to be administered to these groups to adjust the difficulty level and to determine what the reasonable level of mastery should be.

Third, the exercises should be administered under more controlled conditions. Proctors should be present. All miners should work the exercises individually. In addition, the time allowed for exercise completion should be set at some appropriate limit during which all persons would have to finish. These procedures control and standardize test administration and remove variance in test performance scores that is unrelated to ability levels.

Fourth, once these procedures were accomplished, psychometric and validity studies, like those reported in this chapter, would need to be completed on these new data. The exercises would probably have to be revised to achieve the desired levels of sensitivity to classify and certify persons at various levels of competence.

Perhaps the largest and most difficult part of developing a series of tests is the specification of the skill and performance domains, the specification of specific performance objectives, and gathering, structuring, and arranging the problem materials for the tests and their questions. Much of this work has been completed under this contract. This effort, as well as the exercises themselves, could easily be adapted to the development of more rigorous psychometric instruments designed to sort, classify, and certify persons' levels of competence.

Disadvantages of the Exercises as Tests

Whether the exercises are used as teaching devices or as tests to certify competence of individuals depends on broader issues and goals. There are a number of

disadvantages in using exercises like these as certification tests.

Certification tests are designed to sort and screen persons. The intention is to limit the practice of certain jobs or tasks to those who can demonstrate their competence. Although such tests are widely used, they are fraught with problems. A basic problem is that there are always persons who can demonstrate high levels of mastery on the test, but who are not competent performers in the real world in which they are to work. No matter how well designed, a test is only a small sample of the individual's capability in the more robust real world performance. This is why the selection of persons for critical task performance is almost always based on multiple indicators, especially the individual's demonstrated proficiency in the performance of specific work procedures as judged by peers and supervisors on qualities of safety, productivity, accuracy, efficiency, etc. There is no better way to proceed in such matters. Too often in American culture, persons and agencies are inclined to substitute administration of a standardized or some other type of test for the more complete and thoughtful assessment of a person's abilities that is required (Cole et al.,1984).

Testing, especially when it is tied to obtaining jobs and job promotions, encourages competitive behaviors and secrecy. The exercises designed under this contract encourage cooperation and openness. Both are needed if miners are to work together to understand problems, plan to prevent emergencies, and cope with and limit emergency situations that do develop. It is clear from studies of mine accident investigations, and other research cited in this report, that the potential for accidents and disasters is much higher when miners do not communicate, collaborate, and work together. Procedures used to help assess and certify mining crews' competence in

nonroutine and emergency operations and procedures should facilitate the openness and cooperation that is required for informed and wise performance of these complex tasks.

Traditionally tests also fail to correct deficiencies, although they excel in identifying person's limitations. Information about an individual's strengths and limitations based upon his or her test performance is usually not provided for some time, and then provided in only the vaguest of terms, usually to administrators and supervisors and not the test taker. The individual who took the test often receives no information about his or her performance, other than it was good or bad, or at a certain percentage level, etc. The feedback received is not specific to particular concepts or skills encountered in the test content, and it comes long after it can be instructive and useful. Any opportunity to teach the individual things he or she needs to know to overcome deficiencies is lost. In short, tests as traditionally used, are designed to sort, screen, and certify persons, not to teach and improve their skills. Consequently most persons do not like tests, feel threatened by them, and would rather avoid them altogether if possible.

Advantages of the Exercises as Teaching Devices

The exercises developed under this project have a different set of goals and assumptions. First, they recognize the necessity of cooperation and openness among miners if they are to communicate well and to prevent and cope with mine emergencies. Second, the exercises focus on critical skills that are likely to be less than perfectly demonstrated, in large part because of infrequent utilization. Third, the exercises are carefully contrived to engage miners' active participation in and full

attention to the simulated problem, preferably in a group context. Fourth, the exercises are deliberately designed to provide immediate feedback that both reinforces correct performance and remediates incorrect performance. This tutorial is ongoing throughout the exercise. The reinforcement and correctives occur when the miners are affectively aroused by the content of the exercise and the decisions it demands. This method of presenting reinforcement and correctives during the "teachable moment" is known to help learners remember and generalize their learning to the real world. The research underlying this generalization has been reviewed and discussed elsewhere in this and earlier technical reports. Furthermore, the empirical results of the field tests reported in this and the previous chapter suggest the exercises function in this intended way. It would be wise to continue to use and develop additional exercises in these teaching and personal assessment roles. Miners and trainers enjoy working the exercises in their present role as teaching devices. This interest and good will would be sharply abated if the exercises were to be used as tests to certify competence for job performance or advancement.

Summary

The data presented in this chapter are supported by miners' and trainers' independent judgments of the worth of the exercises reported in Chapter 2. The exercises appear to be reasonably valid, as assessed by three means. The reliability of the exercises as measuring instruments remains unknown because the properties of the exercises violate assumptions for which reliability estimation procedures are designed. An analysis of miners' performance levels on the exercises reveals a lower level of mastery than might be deemed desirable for critical skills. This is probably a result of

the infrequency with which miners encounter these types of problems. It is likely that the exercises have been appropriately targeted to include critical but nonroutine skills miners need to both prevent and cope with emergency situations. Whether or not working the exercises increases miners' preparedness to cope with such emergency events remains unknown, although miners and trainers report they believe this to be the case.

The exercises can be converted to more rigorous testing devices for certification of miners' competence. The initial performance domains, objectives, and test item content needed for such an undertaking have been researched and developed. Slight modification of the exercises and more carefully controlled field testing and validity studies would be needed to convert the exercises to more conventional psychometric measures. However, exercises developed and used mainly as tests would likely be perceived less favorably, avoided, and prove far less useful for teaching and influencing miner behavior in positive ways.

The exercises are best used as teaching devices designed to help miners engage in a personal assessment of their strengths and limitations for coping with various mine emergency situations. Exercise structure immediately reinforces correct responses and remediates incorrect actions. The information gathering, judgment, and decision making skills required to cope with emergencies are emphasized. For these reasons it is wise to continue to use, and to develop new exercises, primarily as teaching devices, and not for the certification of miners' competence in critical skills. In their present teaching device form, the exercises are popular and likely to be frequently utilized. They will likely promote thinking and cooperation among miners concerned

with preventing and coping with mine emergencies.

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Chapter 4: A New SCSR Donning Procedure[1]

The ability of miners to don the self-contained self-rescuer (SCSR) emergency breathing apparatus rapidly and flawlessly during a mine fire, explosion, or gas inundation is a critical but seldom used skill. This chapter describes problems identified with earlier SCSR training materials and practices, the origins and development of the new SCSR training procedures, and the effectiveness of these new procedures based on field tests at multiple sites.

From June 1985 to March 1987, University of Kentucky researchers carried out a series of SCSR donning studies. The University team was assisted by technical staff and trainers from the Bureau of Mines, the Mine Safety and Health Administration (MSHA), the Kentucky Department of Mines and Minerals, Martin County Coal Corporation, Richland/Conrich Coal Company, and the University of Kentucky Institute for Mining and Minerals Research. These studies produced a new set of SCSR donning instructional procedures and materials for the CSE, Draeger, MSA, and Ocenco SCSRs. Later in 1987 the new materials were distributed nationally by the National Mine Health and Safety Academy (Mine Safety and Health Administration, 1987a, 1987b, 1987c, 1987d). Subsequently, MSHA required hands-on SCSR training for all underground coal miners in the United States, and recommended using

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the new instructional materials developed under this contract (Spicer,1988).

Researchers at the Bureau of Mines have continued a series of studies concerned with SCSR training and miner performance. These studies include the effectiveness of various instructional techniques for presenting the new donning method, decrements in miner donning proficiency over time, and the design of inexpensive, high fidelity SCSR simulators to maintain donning proficiency (Bureau of Mines, 1988; Kellner, 1988a, 1988b, 1988c; Vaught & Cole, 1987a, 1987b; Vaught, Brnich, & Kellner, 1988). This more recent research is not reviewed in this chapter.

Much of the research reported in this chapter has been presented in other earlier reports and papers. The project second technical report (Cole, Berger, Vaught, Haley, Lacefield, Wasielewski, & Mallett, 1988b) describes details of the initial field studies and experimental findings that led to the development of the new donning method. Other documents review this early experimental work, as well as the development and field testing of the new donning method (Cole & Vaught, 1987; Cole, Vaught, Kellner, & Chafin, 1986; Vaught & Cole, 1987a, Vaught & Cole, 1987b). Readers interested in the details of these studies, and in recent developments in ongoing Bureau of Mines SCSR research, should refer to the documents cited above.

Critical Nature of SCSR Donning

Immediately after an explosion in an underground coal mine the local atmosphere is oxygen deficient and frequently contains from five to eight percent carbon monoxide. Under such toxic conditions, nearby miners have approximately 45 to 60 seconds to isolate their lungs from the mine atmosphere (Green, Althouse, Frost, Wheeler, & Shores, 1986). Longer periods result in unconsciousness. Therefore, rapid and

flawless donning of an oxygen generating self-contained self-rescuer (SCSR) is imperative. Miners located at some distance from a fire or explosion may have more time to don an SCSR. However, the mine ventilation system can quickly sweep deadly levels of smoke and carbon monoxide into areas where miners are working. Thus, even in these cases proficiency in donning an SCSR is critical.

Absence of Prior Donning Studies

In 1985 a search for previous research concerned with SCSR donning was undertaken (Cole et al.,1988b). While many studies have evaluated SCSRs' durability, reliability, and duration of oxygen supply under various levels of physical exertion, only one earlier study that reports donning times was located. As part of a field evaluation of the Draeger OXY-SR 60B and the Mine Safety Appliance Model 464213 SCSRs, Peluso (1981) reported that donning times for 46 miners ranged from half a minute to 3.2 minutes with an average time of 1.5 minutes. However, the study reports only the overall donning time. No information about frequency and types of donning errors is reported. No times for completion of the many part tasks in the complex donning sequence are provided.

Problems With Existing SCSR Donning Procedures

Several coal company, MSHA, and other trainers who had conducted hands-on SCSR training were interviewed and training sessions were observed. It was noted that miners often fail to complete the donning sequence fully and proficiently without ongoing prompting by the trainer. Our own experience in donning SCSRs as part of hazard training showed that we too frequently made many serious errors. Both we and the miners we observed being trained seldom had an opportunity to realize how poorly

we had performed because the trainer almost always prompted, corrected errors, and frequently performed part of the task for us when we experienced difficulty in opening the case, locating and opening the oxygen valve, or positioning the apparatus and adjusting its straps. In a mine emergency situation no tutor will usually be available to prompt, correct errors, and complete omitted steps as a miner attempts to don an SCSR under conditions of great stress, poor visibility, and life and death consequences.

Even though we underwent frequent traditional training for donning SCSRs, we experienced much difficulty in remembering the more than a dozen required steps and the sequence in which they were to be completed. Our observations of miners showed they too had these same problems. Review of military research (Hagman & Rose, 1983) revealed that simpler tasks like donning a gas mask are also problematic, typically showing large and rapid drops in performance speed and proficiency after initial training. Discussions with many additional miners and mine safety trainers revealed that most coal miners had never received hands-on training in SCSR donning. Rather, the typical training session appeared to have been watching an instructor demonstrate the procedure, and/or viewing a training film, training slides, or the manufacturer's wall chart that depicts the donning steps and sequence.

Review of existing SCSR training materials also revealed problems. All of the training materials demonstrated donning the SCSR while standing up in a well lighted room. The SCSR was often placed on a table in front of the miner. Generally the miner was instructed to first inspect the seals and pressure gauge, hold the unit up to the chest, hang it around his or her neck, then adjust the neck straps, open the case,

activate the oxygen, extend the breathing hose, unfold the breathing bag, insert the mouthpiece, breathe the oxygen, put the nose clips on, tie and adjust the waist straps, put on the hard hat, and move out. The critical tasks needed to isolate the miner's lungs from the mine atmosphere were often delayed until after secondary steps (like adjusting straps) had been completed. Furthermore, it was not clear what the miner should do with the hard hat and lamp during the donning sequence. Some training materials showed the cap without a lamp and cord. When the cord was shown, it was often draped over the miner's shoulder so that the cap and lamp hung down the miner's back or side at or below knee level. This is clearly a nonfunctional position in a dark underground mine. Our own experience in donning SCSRs, observations of others doing so, and subsequent controlled studies of miners' performance showed these typical earlier training sequences to be problematic.

There are three main problems with the earlier training methods for donning SCSRs. First, the donning position was difficult and inefficient. Second, the donning sequence tended to place less critical tasks like adjusting straps before some of the tasks critical for survival. Third, the training materials presented no simplified, easy to remember overall procedural rules that could cue miners to recall and properly order the complex array of multiple tasks needed to don an SCSR.

It is difficult to stand up, hold an SCSR with one hand and work with the other hand to open and don the unit in a dark room or mine, all the while with the cap lamp cord hanging over one shoulder and the light shining down one's leg or to the rear. It is time consuming to hang the SCSR from the neck and adjust the straps until the unit is properly centered on the chest. The critical tasks required for isolating the miner's

lungs from a toxic atmosphere (activating the oxygen, inserting the mouthpiece, and putting on the nose clips) are delayed when less critical tasks are performed first. It is difficult to remember all the things one should do and the sequence in which these should be done when the donning instructions consist of 12 to 14 individual ordered steps that are to be followed.

An Experimental Study

Personnel from the University of Kentucky, the Bureau of Mines, and Martin County Coal collaborated in an SCSR donning study carried out as part of annual refresher training classes. A total of 50 people were involved in the study: 36 underground coal miners and 14 others. Table 4.1 shows the experimental groups. Group 1 consisted of persons from the preparation plant, surface mines, and company offices. These persons had no prior experience with SCSRs. Group 2 consisted of 20 underground coal miners and group 3 of 16 more. Approximately four years earlier all the miners in groups 2 and 3 had received hands-on training in donning the CSE SCSR. Each person in these two groups had donned and breathed from an SCSR. Thereafter, these miners had witnessed an annual SCSR donning demonstration by a company trainer, the last one about seven months prior to the experiment. The hands-on training and the prior annual demonstrations followed the manufacturer's instruction that used the standing position and typical donning sequence in use prior to 1985.

The purpose of the study was to compare the SCSR donning performance of the three groups. Differences in donning speed, proficiency, and errors could be related to no training (group 1), earlier hands-on training and annual demonstrations (group 2) and earlier hands on training, annual demonstrations, plus a recent demonstration

Table 4.1: Experimental groups and conditions

Groups	n	Condition
1 Baseline (no prior experience)	14	nonunderground miner no hands-on training and no annual demonstration no task demonstration immediately prior to performance assessment
2 Control (demonstration 7 months prior)	20	underground miner prior hands-on training plus four annual demonstrations no task demonstration immediately prior to performance assessment
3 Experimental (demonstration 2 - 4 hours prior)	16	underground miner prior hands-on training plus four annual demonstrations task demonstration two to four hours prior to performance assessment

(group 3). Group 1 was included to obtain information about how well untrained persons might perform. Equipment can sometimes cue correct procedural responses even among persons not familiar with the apparatus or task. It was important to determine to what degree this condition was present with the CSE SCSR, and by logical extrapolation for other SCSR units.

It was assumed that the recent task demonstration by the company trainer would be the same as the earlier training, e.g. the traditional standing position and donning sequence. However, during the week in which the experiment was conducted, the company trainer became aware of the new donning position advocated by a Bureau of Mines trainer. Subsequently, when the trainer demonstrated the procedure to group 3, he used the new kneeling position and he performed the task in the new sequence, doing critical tasks first and secondary tasks later. The simplified donning positions and sequence were not explicitly pointed out or verbally presented to the miners.

However, the instructor's physical demonstration followed these new procedures. This change in training of group 3 confounded the experiment. Observed differences in donning times, proficiency, and sequence could be caused both by recency of training and change in training procedure. Nevertheless, much was learned from the experiment.

Each member of each group was individually administered the performance task. An SCSR was placed on the floor about two feet in front of the person who was standing. The unit was turned the wrong way, so the person would have to rotate it to properly position it for donning. The person was instructed to put the SCSR on just as he or she would need to in a fire, and to signal when the donning was complete by raising their right hand. At a signal, the person began to don the unit and the full performance was observed and videotaped. When the person signaled that he or she was finished the taping stopped. After the performance the person was shown the videotape and donning errors were corrected in an individual tutorial session.

The videotape performance data were recorded on the form shown in Figure 4.1. The 14 tasks in the left column are those required to don the CSE SCSR. The order in which the steps are listed in Figure 4.1 is not important for recording observed data, but it is important for training. It represents a first attempt by the researchers to order critical tasks early in the sequence and to place secondary tasks later in the sequence.

Even with its confounded treatments the experiment provided data for five major areas of inquiry. For Example:

1) Data from group 1 provided information about how well totally untrained persons can don the CSE.

Performance Scoring Sheet

Observer_____ Date_____ Time_____

Task	Completed Sequence	Time	First Attempts	Time	Errors
1. CASE opened					
2. OXYGEN VALVE opened					
3. GOGGLES removed and saved					
4. BREATHING HOSE extended					
5. MOUTHPIECE PLUG pulled					
6. MOUTHPIECE inserted					
7. NOSE CLAMP put on					
8. HEAD STRAP put on					
9. GOGGLES put on					
10. BREATHING BAG opened					
11. NECK STRAP donned					
12. HARD HAT donned					
13. NECK STRAP adjusted					
14. WAIST STRAP tied					

TIME to signaled completion _____

Figure 4.1: Performance scoring sheet for CSE SCSR

2) Data from group 2 spoke to how well miners with one prior hands-on training experience perform seven months after an annual demonstration of the traditional donning position and sequence.

3) Data from group 3 provided information about how recency of demonstration and observation of the new donning position and sequence influenced performance.

4) Data from all groups provided information on the types and frequency of errors made by miners in the donning activity.

5) The experiment also provided data useful for improving instruction and for improving the design of equipment to make donning easier.

Figure 4.2 answers a number of these questions and presents the major findings for the study. It orders the persons in each group by their time of completion of the three critical tasks, e.g. activation of oxygen, inserting the mouthpiece, and putting on the nose clips. These are the three critical tasks that must be completed first if a miner is to survive a toxic atmosphere. In the experiment miners were allowed all the time they wanted to complete the donning. The performance stopped only when the person signaled that the donning was complete. When they signaled task completion, the persons in groups 1, 2, and 3 believed their lungs were isolated from the mine atmosphere, and that they were ready to move through heavy smoke. Inspection of Figure 4.2 reveals the majority of persons in all groups would likely have perished in an actual mine fire or explosion. And the miners in groups 2 and 3 were unique in that they, unlike most miners, had experienced hands-on SCSR training and annual demonstrations. Most miners interviewed in the earlier and later field studies had never donned an SCSR, and many only infrequently had witnessed a demonstration. In fact, as a later table will show, most trainers who taught SCSR donning had never actually donned and breathed from an SCSR.

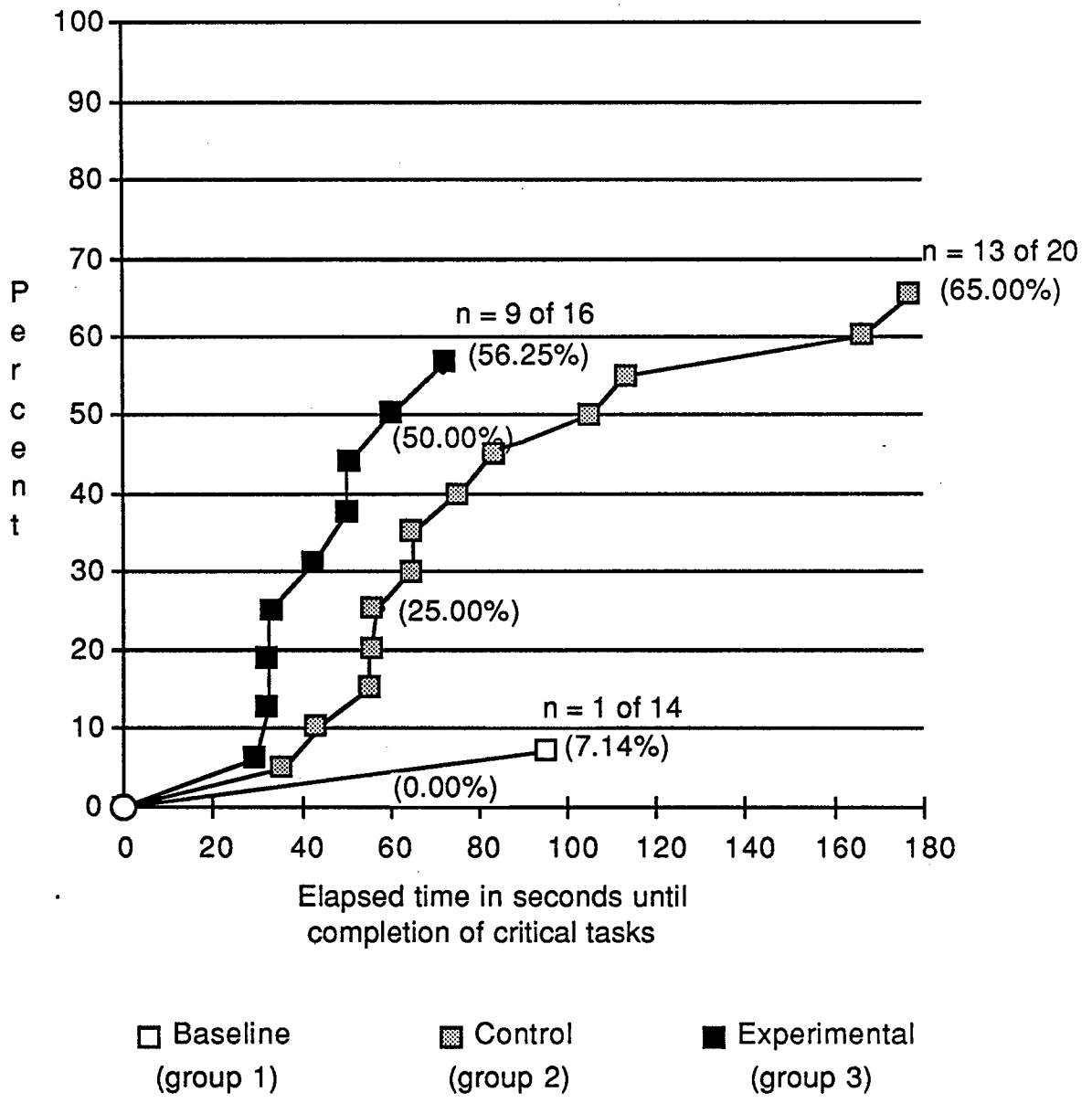


Figure 4.2: Persons in each group ordered by time of completion of critical tasks

Inspection of Figure 4.2 reveals that only one of the 14 persons (7.14%) in the untrained group might have survived. This person required approximately 95 seconds to complete the critical tasks, well beyond the 45 to 60 second limit suggested by the work of Green et al., (1986). Miners in group 2 performed better. Given all the time they needed, 13 of the 20 miners (65.00%) in this group would have survived. But, if they had to complete the three critical donning steps within a minute, only 5 of the 20 (25.00%) would have survived. The miners in group 3 had observed the new donning position and sequence two to four hours prior to their performance. They performed more proficiently. Eight of the 16 (50.00%) completed the three critical tasks within one minute. However, given more time, only one more miner completed the three critical tasks for a total of 56.25 percent "survivors".

The longer times required for miners in group 2 to complete the three critical steps are related to two factors which cannot be unconfounded in the study. First, the company trainer demonstrated the kneeling donning position and the new donning sequence for miners in group 3, although verbal and printed instructions that made the new donning procedure explicit were not presented. The more rapid completion of the three critical tasks by group 3 is probably caused by their doing these tasks first. Group 2 miners were trained in the standard sequence. Adjusting the unit neck strap precedes and delays the completion of the three critical steps. Likewise, working in a standing position also makes it more difficult to open the unit and complete the donning sequence. However, some of the increased speed with which group 3 performed the three critical tasks also may be related to their recent observation of a demonstration.

Some idea of the effect of recency of training on the performance of each subtask may be determined from inspection of Figure 4.3. Each of the 14 subtasks is listed on the horizontal axis of the graph. (The subtasks are specified in the same order as in Figure 4.1.) The vertical axis shows the average time in seconds each group needed to complete these tasks. Inspection of Figure 4.3 reveals that the untrained persons in group 1 required much longer than the trained miners to complete most tasks. In fact, many persons in group 1 never completed many of these tasks, and never attempted many more. The values in Figure 4.3 are based only on the persons who attempted and completed tasks.

Figure 4.3 also reveals that generally miners in group 3 carried out each subtask more quickly than miners in group 2. These observed average differences are likely related to recency of the demonstration. While the new demonstration emphasized a new and faster donning position and sequence to complete critical steps first, it did not change the way each subtask should be completed.

The group 3 miners who had recently witnessed the demonstration required longer than the group 2 miners to complete five subtasks. These are opening the case, getting the head strap on, putting the neck strap on, adjusting the neck strap, and then tying the waist strap. Inspection of the performance data on the videotapes explained these results.

First, in the new demonstration for group 3, miners were instructed to open the case on the floor and to complete the critical tasks before donning the SCSR neck strap. Miners in group 2 were taught by the conventional earlier method to first hang the SCSR around their neck. In the experiment, the SCSR was placed with the wrong

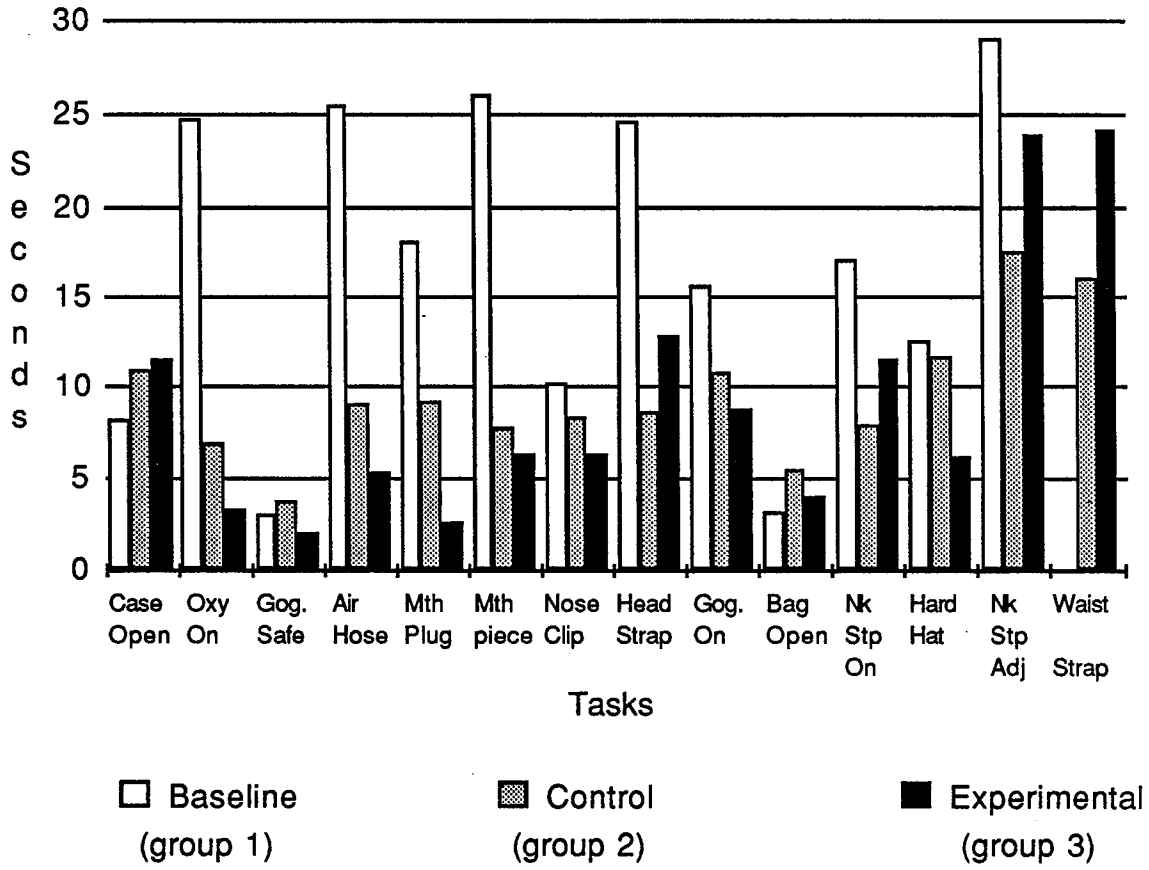


Figure 4.3: Average time in seconds required by those persons in each group who completed each task

end toward the miner. Hanging the SCSR strap around the neck as a first step orients the unit the correct way for donning and simplifies later donning tasks. Half the miners in group 3 opened the case from the wrong end without first orienting it properly. Then they proceeded to complete the three critical steps. Later, when they came to don and adjust the neck straps, they found this to be difficult because the unit was on backwards. Even if the unit was oriented correctly, the neck strap had to be brought down under and around the SCSR before being placed over the neck. Because of this training error more members of group 3 had difficulty in donning and adjusting both the neck and head straps. Many of the miners removed the head strap, mouthpiece, and nose clips in an attempt to straighten and untangle straps. This error in the training design in the initial experiment illustrated how important it is for miners to orient the SCSR case in the proper direction when donning the apparatus. Hanging the SCSR neck strap around the neck before doing anything else in the sequence properly orients the apparatus. This proper orientation of the unit prevents a number of subsequent costly and potentially fatal errors that usually result from an improperly positioned SCSR. This finding was later incorporated into the training design for the new donning sequence.

Figure 4.4 plots the number of persons in each of the three groups who completed individual donning tasks. Examination of these data reveal that few untrained persons in group 1 completed most donning tasks, that many more of the recently trained persons in group 3 completed most of the donning tasks, and that the performance of the prior trained group 2 persons fell in between. Recent training appears to remind persons to attempt and complete more donning tasks in the total

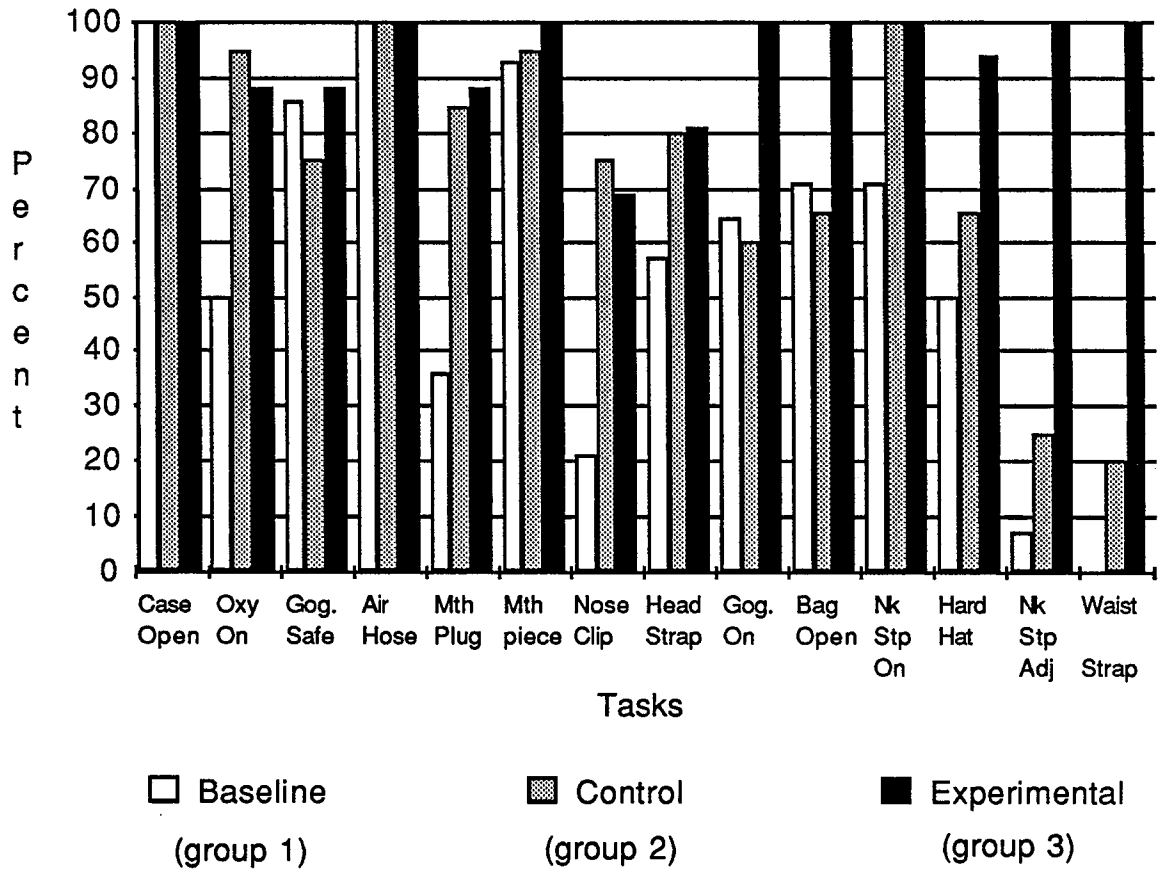


Figure 4.4: Percent of each group completing each task

sequence.

The miners in group 3 who recently viewed the demonstration were conscientious about attempting to don the head strap, to adjust the neck strap, and to tie the waist straps. Nearly all the untrained persons in group 1, and many of the miners in group 2, quickly gave up or did not attempt to don the head strap, adjust the neck strap, or tie the waist straps. Rather, a typical response was to lift the SCSR up with one arm (and usually crush the breathing bag and exhaust oxygen) and carry the unit with straps unadjusted and untied, a possibly fatal error in an actual mine fire or explosion. The reason that group 3 miners took longer on these tasks is that far more of them completed the tasks. Inspection of Figure 4.4 confirms this point.

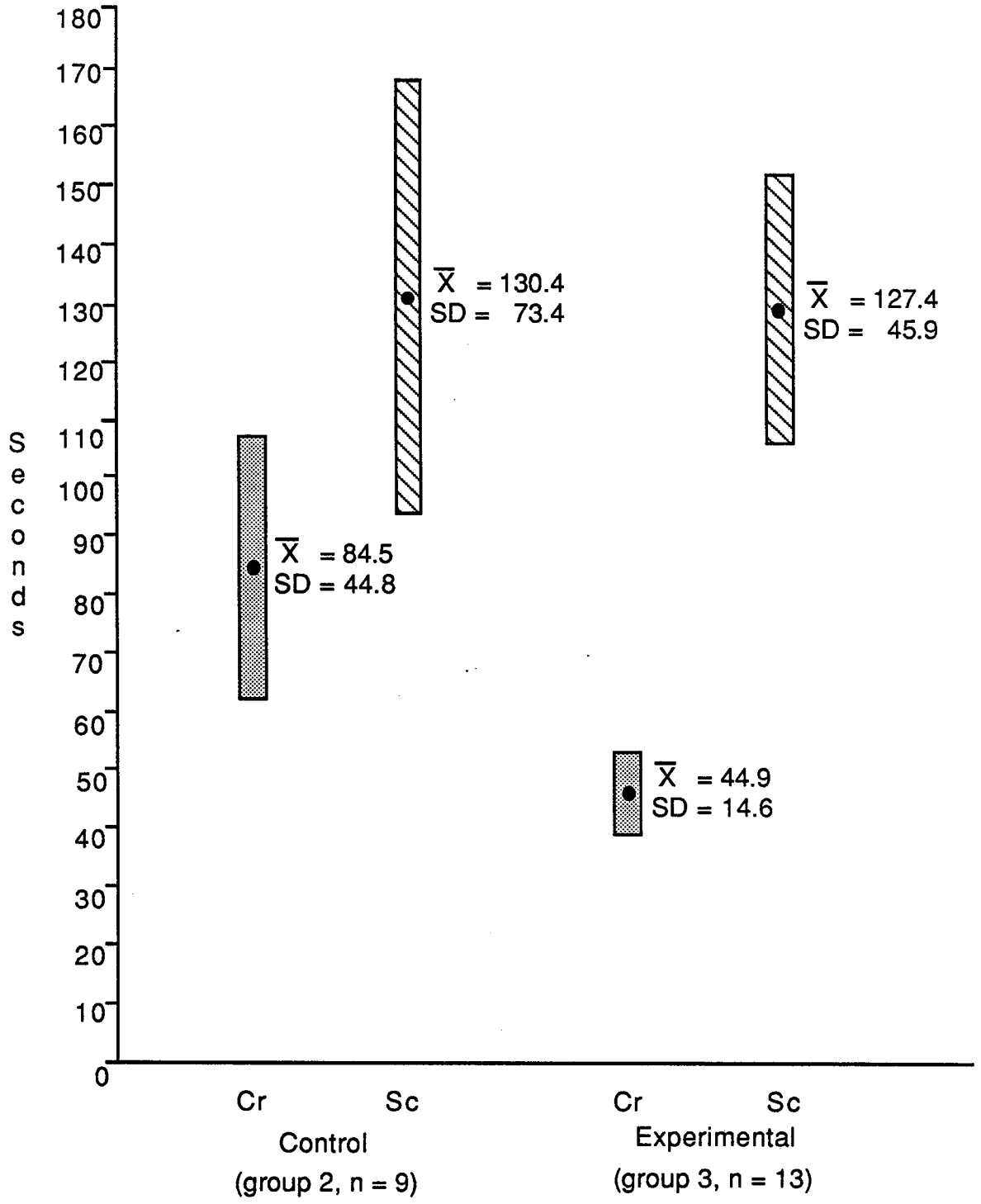
In summary, the experiment revealed that untrained persons could not don the CSE SCSR proficiently, that initial hands-on training and annual demonstrations did not produce high levels of proficiency, that the existing training sequences could be significantly improved by simplifying and better organizing what miners needed to remember, by reordering the donning task sequence to place critical tasks early in the sequence, and by changing the donning position from standing to kneeling. It was also learned that neither the traditional training procedures, nor the new one then under development, produced high levels of donning proficiency for the CSE SCSR. Although no formal studies with other models of SCSRs were carried out, the researchers did practice donning Ocenco, MSA, and Draeger SCSRs. Many miners were observed donning these other models. The similarity of the donning task for the CSE and the other three major types of SCSRs suggested the problems identified in the formal study of the CSE were common to all the units.

It was also apparent that the miners in groups 2 and 3 had received far more training in donning SCSRs than was the case for most miners. Yet about 44 percent of the miners in group 3 failed to complete the three critical tasks, and 35 percent of the miners in group two failed to do so, even when miners in both groups took as much time as they wanted. In addition, miners in both groups generally exhibited a lack of proficiency, often making errors and interrupting tasks. Both groups required relatively long times to complete the critical and secondary donning tasks (see Figure 4.5), although the mean time for group 3 was significantly faster than for group 2 on the critical tasks ($t = 2.54$, $df = 21$, $p < .01$). Again, this difference is caused by both the more recent donning demonstration and the changed instructional sequence received by group 3. It was clear the SCSR donning procedures needed to be improved, and that frequent hands-on experience is required to build and maintain proficiency. Consequently, a revised set of training materials were developed and field tested. What resulted is the new "3 + 3" donning procedure.

A New SCSR Donning Procedure

The new donning position and sequence was developed from the observations and empirical studies described in the previous section. The basic donning position is described in Table 4.2 and illustrated in Figure 4.6.

This new donning position has a number of advantages. First, in many mines it is not possible to stand erect. The crouched donning position works well in low or high seam coal. Second, crouching keeps the miner's face nearer to the mine floor where during a fire or explosion the air and the visibility are generally better. A crouched position places the miner's face directly over the SCSR. It is easier to see the unit and



Cr = critical steps (part time) Sc = critical steps + secondary steps (whole time)

Figure 4.5 Means and standard deviations for critical and secondary CSE SCSR donning times

Table 4.2: An efficient SCSR donning position

1. Place the SCSR on the mine floor directly in front of your feet (or knees).
2. Crouch on your knees so your face is just above the SCSR.
3. Lay your cap on the mine floor so the lamp shines on the SCSR.
4. Work with both hands to open the case and complete the three critical donning steps first. Then do the three secondary steps.

it is faster and easier to work with both hands to open and activate the unit. Fourth, the cap and lamp lie still on the same surface as the SCSR. Thus, the unit is constantly illuminated and the miner can see what he or she is doing. Fifth, if the miner drops something (like the goggles, or the whole unit) he or she can quickly find and retrieve it. If the whole unit or goggles are dropped from the standing donning position much time is required to find and retrieve the object, especially in conditions of heavy smoke, and when the mine bottom is wet and muddy.

The earlier SCSR donning training materials provide too much detail and background information about the equipment. Simple overall conceptual organizers that could help miners remember and carry out in proper sequence the many individual donning tasks were insufficiently developed. Research has established that people have difficulty remembering complex multiple step performance sequences. Remembering to perform each of several steps in a specified sequence can be facilitated if the component parts of the task are broken into a few segments that "chunk" several smaller steps (Anderson, 1985; Bransford, Sherwood, Vye, & Rieser, 1986; Cole, 1971; Halpern, 1984; Mayer, 1983; Segal, Chipman, & Glaser, 1985). This "chunking" to facilitate memory of a complex sequence of tasks is the intention of the

1. Activate Oxygen

2. Insert Mouthpiece

3. Put on Noseclips

\+

1. Put on Goggles

2. Adjust Straps

3. Replace Cap

Figure 4.6: Graphic depiction of the "3 + 3" donning position and sequence

new "3 + 3" method.

The information in Table 4.3 is organized to help miners group the many specific SCSR donning subtasks into two logical groups of activity, e.g. rapidly isolating the lungs from the mine atmosphere, and preparing to move out of the mine once the miner is breathing from the SCSR. Figure 4.6 depicts both this "3 + 3" sequence and the proper donning position. These simple verbal instructions and graphic illustrations help miners to remember each of the dozen or more individual SCSR donning tasks. Furthermore, the logical sequence of simplified steps helps miners to remember to complete all the component tasks in the optimum sequence. The steps and donning position in Table 4.3 and Figure 4.6 apply to all models of SCSRs. The "3 + 3" list of steps is easier to remember than earlier, less conceptually organized detailed lists of

Table 4.3: A simplified sequence for SCSR donning

For all SCSRs there are a few critical steps.

The three critical first steps are to properly*:

1. Activate the oxygen,
2. Insert the mouthpiece,
3. Put on the nose clip.

Doing these three thing first rapidly isolates the miner's lungs from a toxic mine atmosphere.

The next steps are to properly:

4. Put on the goggles,
5. Adjust straps to place the SCSR close to the chin and chest,
6. Put on the hat and lamp and move out.

---

*"Properly" doing each step is different for different kinds of SCSRs.

12 to 14 donning steps.

Not all the donning steps are included in the generalized sequence, as can be seen using the CSE SCSR as an example. The first critical step in Table 4.3 is "Activate the oxygen." To complete this step the miner must actually position and open the case, move the breathing bag and goggles slightly to expose the valve, and locate and rotate the valve lever to the open position. Likewise, to "insert the mouthpiece" requires pulling the head strap, mouthpiece, and breathing hose from the case. The hose must be fully extended, the mouthpiece plug pulled out, the head strap and nose clips properly positioned, and then the mouthpiece inserted. Then the nose clips can be put on. The sequence described thus far is fewer than half of the 14 required steps. The full donning sequence presents a large amount of information to remember and is the type of task people soon forget. What people forget is not how to do the individual steps. Rather, errors on these kinds of complex tasks tend to be omitting steps, and performing steps out of sequence. Shortly after miners are trained to do all the individual steps in the full sequence, one would expect to see persons jumping around from one task to another, forgetting particular steps and skipping them entirely, and beginning but not completing a given task before starting another one. In fact, the data from the experimental study showed many miners behaved this way following training with the earlier 14 step sequence for the CSE SCSR. It is much easier for a miner to remember to do all the steps in the proper sequence if the entire process is placed within a simple logical framework that organizes all the subtasks. The instructions in Table 4.3 and Figure 4.6 serve this purpose.

The basic steps in Table 4.3 assume that details about how to complete the

critical steps for each type of unit have been demonstrated for and practiced by miners in hands-on training. How to open the case, how to activate the oxygen, how to insert the mouthpiece, how to put on the nose clips, where to locate and how to put on the goggles, and how to adjust and fasten neck and waist straps differ across models of SCSRs. Likewise details of how to care for and inspect the units, as well as where they are placed in mines, vary across both SCSR models and mines. The specifics for each of these variables need to be made explicit and practiced by miners. Once this is done, the generalized sequence outlined in Table 4.3 and Figure 4.6 serves as a mental organizer that can help miners remember to do the critical tasks first for any SCSR. Consequently, the sequence has potential to reduce the errors miners make when donning SCSRs.

The new training materials are included in an instructor's manual (Mine Safety and Health Administration, 1987a, 1987b, 1987c, 1987d) . The performance objectives for the new "3 + 3" donning method are listed in Table 4.4. The instructor's guide explains how to conduct a hands-on SCSR training session. It also includes a simple evaluation form for recording individual miners' donning performances. A short videotape demonstration of an expert donning an SCSR using the new position and sequence accompanies the instructor's manual.

The instructor's guide is designed to be simple and easy to use. Large type overhead transparencies depicting the kneeling position and the new simplified donning sequence are included. Short verbal statements explain the advantage of the new donning position and the simplified donning sequence.

The instructor's guide suggests that the diagrams for the new donning position

Table 4.4: Performance objectives for SCSR donning exercise

Following instruction the miner shall:

1) Explain how to get to the nearest SCSRs from any specific place in his or her mine section.
2) Demonstrate proficiency in donning the SCSR efficiently and rapidly (with no major errors).
3) Recall and name the three critical steps and the three secondary steps for donning all SCSRs.
4) Describe and demonstrate procedures for the care, inspection, and placement of SCSRs.
5) Describe and demonstrate the proper methods for activating the oxygen, inserting the mouthpiece, putting on the nose clips, putting on the goggles, and adjusting straps for the type of SCSR used in his or her mine.
6) Demonstrate proper body positions for donning the SCSR in low or high coal.

and sequence be shown using overhead transparencies, the advantages of these new procedures explained, and the method further demonstrated by showing the short videotape. The instructor then demonstrates the procedure step by step. Then miners don the SCSR in individual hands-on training sessions, with no prompting from the instructor or colleagues. While one miner dons the unit, the instructor and other class members work in pairs to record the trainee's performance. One person records both the part time the miner requires to complete the critical three steps, and the total donning time. The second miner draws a continuous line through the dots on the performance rating form shown in Figure 4.7. The line records the order of each main step completed by the miner in the donning sequence. The finished form provides a permanent record of the miner's SCSR donning performance, the part and whole times, and any errors made. In every class, each miner practices donning the unit, preferably until the task is performed correctly without prompting. Class members continue to work in pairs to observe and record the performance of others. Observing and recording the performance of others helps miners rehearse and remember the

Performance Evaluation Sheet

Name Marvin Letcher Date April 7. 1988

1. Did the miner answer the following?

   A. Name the exact place where you started working last shift.

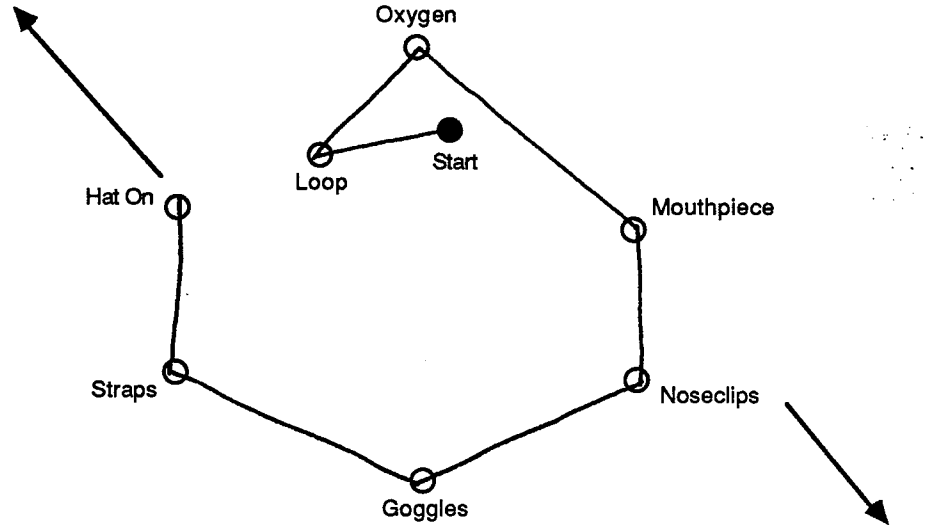
   ✓ Yes _____ No

   B. Tell how to get to the nearest SCSRs from that place.

   ✓ Yes _____ No

2. Draw a line that connects the dots in the diagram below to show the steps the miner took in donning the SCSR. Draw the line near but do not touch the dot if he or she did the step incorrectly.

56 Total Time (Seconds)



Part Time (Seconds) 21

3. After the task is completed please list any errors that need to be corrected and then correct them.

No Errors!

Trainer's Signature Nicole E. Gilbert

Figure 4.7: Sample completed SCSR donning performance evaluation form

basic steps and positions. A complete copy of the instructor's manual for the new "3 + 3" method is included in Appendix D.

Field Test Results for the New Donning Procedure

The new SCSR donning instructional materials were field tested mainly in Kentucky. Many of the persons who were trained in the field test classes returned to their organizations and trained hundreds of miners in the new procedures.

The demographic characteristics of the field test sample are described in Table 4.5. Data are reported for 283 persons who were enrolled in 28 classes at 11 different sites. These persons averaged 13 years experience in their mining industry job with a mean age of 38 years. They were employed by coal companies and by other agencies such as MSHA, state mining departments, and in a few cases by private contractors who provide annual refresher training for mining companies. Nearly all of the persons included in this sample were routinely involved in training miners in safety and health matters including SCSR placement, inspection, and use.

Table 4.6 summarizes performance data from classes held in Kentucky. Two hundred and seven complete sets of first trial donning data obtained immediately after instruction were available for analysis. The data represent nine classes using the Draeger, seven using the Ocenco, three using the CSE, and two using the MSA. The data in Table 4.6 were pooled by type of SCSR and plotted in Figure 4.8 to show the mean total time and critical donning times observed for each of the four models.

After being instructed in the new procedures, miners' performance tended to be proficient. Inspection of the mean donning times for critical and secondary tasks reveals that the new method of SCSR donning instruction resulted in a much faster

Table 4.5: Characteristics of the field test sample for the revised SCSR donning procedure (11 sites, 28 classes)

	age and experience (years)					gender distribution (%)	
	n	mode	mean	s.d.		n	frequency %
age	283	29	38.3	10.4	female	10	3.6
experience	262	0	13.0	10.5	male	271	96.4

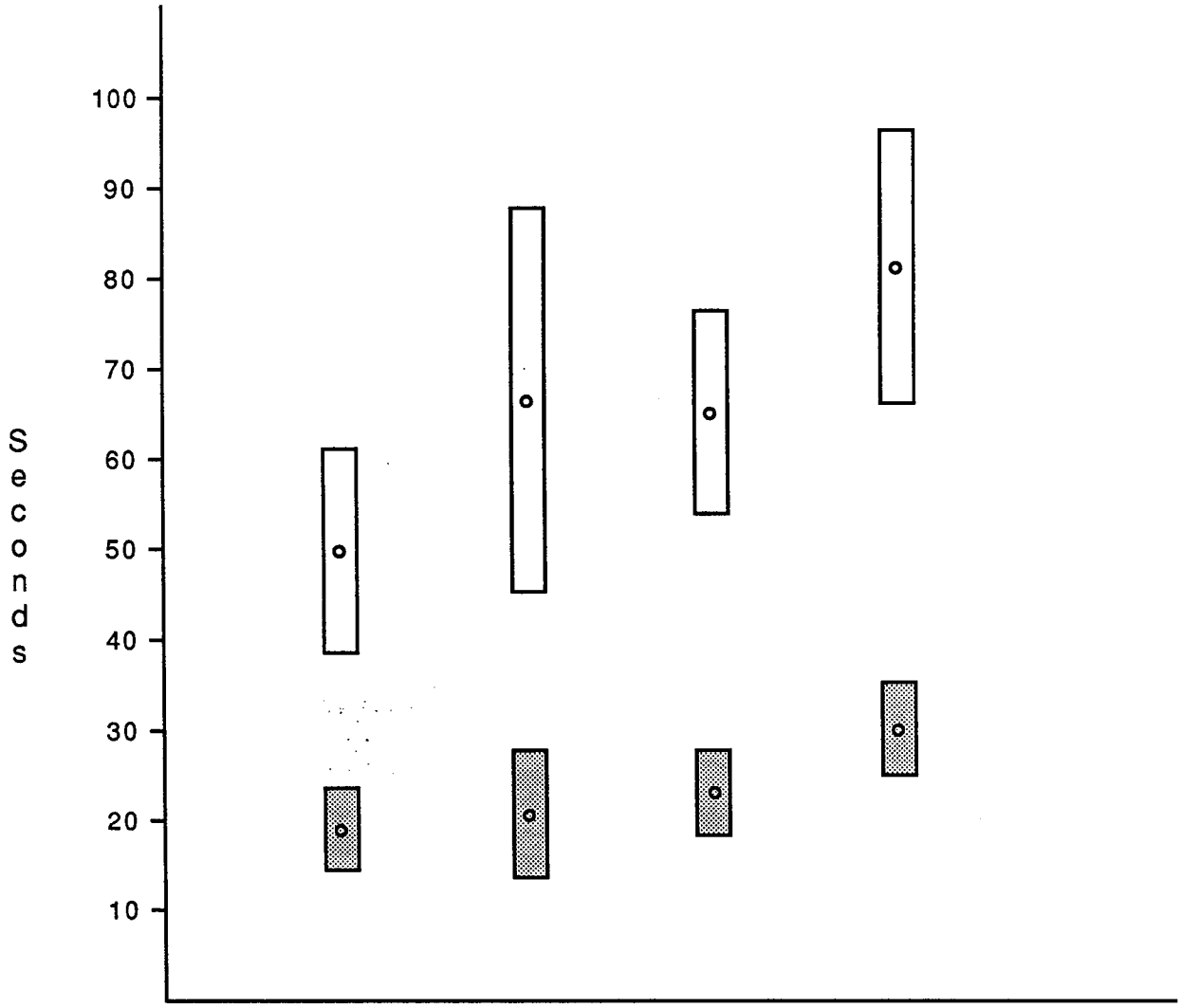
job classification	n	frequency %
miner	8	3.1
maintenance / technical	89	34.5
supervisory / management	133	51.6
other	28	10.9

Self-reported level of expertise (frequency %)

category	training	certification	performance
foreman	20.4	56.7	8.1
mine safety committee	14.4	6.0	11.6
mine rescue	40.5	34.5	15.8
CPR	42.6	48.9	14.1
advanced first aid	41.2	43.0	15.5
EMT	21.8	33.8	12.7
advanced life support	12.7	8.5	5.6
other	7.4	6.0	4.6

Table 4.6: Mean donning times for four SCSR models for miners trained with the new donning procedure

SCSR model	class number	critical times (seconds) n	mean	s.d.	total donning times (seconds) n	mean	s.d.	perfect donning sequence (%)
CSE	01	1	18.00	-----	1	115.00	------	0.0
CSE	02	9	21.67	4.77	9	68.89	17.95	66.7
CSE	03	17	24.24	11.40	17	60.47	21.81	41.2
DRAEGER	04	2	13.50	4.95	2	45.50	13.44	0.0
DRAEGER	05	27	23.89	10.61	27	64.70	29.08	53.8
DRAEGER	06	7	17.00	5.77	7	55.00	20.78	28.6
DRAEGER	07	20	19.00	7.28	20	53.95	19.74	47.1
DRAEGER	08	10	16.90	5.63	9	43.78	20.73	20.0
DRAEGER	09	6	15.17	3.87	8	38.13	12.55	0.0
DRAEGER	10	10	26.00	17.88	9	72.22	15.71	60.0
DRAEGER	11	8	13.88	3.72	8	42.75	9.05	12.5
DRAEGER	12	18	14.72	4.08	17	39.35	10.74	72.2
MSA	13	3	19.67	5.51	3	74.33	4.51	100.0
MSA	14	11	22.45	15.88	11	65.45	48.24	45.5
OCENCO	15	4	41.75	10.40	4	129.25	66.24	50.0
OCENCO	16	10	25.60	5.72	10	79.50	27.58	70.0
OCENCO	17	11	33.73	10.00	11	82.45	24.11	25.0
OCENCO	18	8	28.13	7.34	8	75.88	25.89	12.5
OCENCO	19	8	24.75	2.87	7	61.29	24.37	11.1
OCENCO	20	9	39.11	12.03	10	80.70	22.95	50.0
OCENCO	21	8	38.13	10.76	9	86.11	15.42	33.3



		DRAGER (n=107)	MSA (n=14)	CSE (n=27)	OCENCO (n=59)	F-Ratio (signif.)
Total Time	Mean	52.92	67.36	65.29	81.98	15.16
	Std.Dev	22.74	42.52	22.51	30.28	(p<.0001)
Critical Time	Mean	19.14	21.86	23.15	32.31	21.53
	Std.Dev.	9.51	14.14	9.46	10.37	(p<.0001)

Figure 4.8: Means and standard deviations for critical step time and total donning time by SCSR model

performance than either the earlier traditional method or early attempts to develop the new sequence. Comparison of the data in Figure 4.8 for the CSE using the the new "3 + 3" method, and the data presented earlier in Figure 4.5 for the traditional method and the initial improved donning sequence is revealing. For the new method, the mean critical task times and the mean total donning times drop to about 23 seconds and 65 seconds. This is a substantial improvement over the averages of 85 seconds for critical tasks and 130 seconds for total donning time observed for miners trained with the traditional method. (See Figure 4.5). It is also much faster than the averages of 45 seconds for critical tasks and 127 seconds for total donning time that resulted when the earlier and not fully developed new donning procedures were tested. (See Figure 4.5).

Examination of performance records of the miners instructed by the new method revealed that their donning actions tended to be smooth, that they made few interruptions of subtasks, and that they carried out most steps in the proper sequence. Very few serious errors were made in completing the three critical tasks. Most of the errors resulting in imperfect donning sequences reflected frequent minor sequencing problems. For example, the proper donning sequence is to remove the cap and lamp, loop the neck strap over the head, activate the oxygen, insert the mouthpiece, put on the nose clips, put on the goggles, adjust and tie straps, put on the hat, and move out. Miners frequently made small sequence errors that are inconsequential. Persons sometimes removed the cap and lamp, looped the neck strap, activated the oxygen, put on the nose clips, inserted the mouthpiece, adjusted straps, put on the goggles, put on the cap and lamp, and moved out. The two underlined tasks in this sequence are

out of order. Yet the miner's overall proficiency is high. The miner still did all the critical steps first and rapidly isolated his or her lungs from the mine atmosphere. Putting on the goggles also is often omitted until after straps have been adjusted, but again this is a minor error that does not lower overall functional proficiency.

The new "3 + 3" method is clearly superior to the earlier training methods. Both group 3 in the experimental study and the CSE classes in the field tests of the new "3 + 3" method were trained with the new position and sequence. The large observed differences in critical and total donning times for these groups are probably caused by the improved and more explicit instruction developed after the first experiment. The new method of instruction includes the use of simple visuals and verbal statements to make explicit the new donning position and sequence, the modeling of the new position and sequence in the short videotape and by the instructor, and the opportunity to repeatedly observe and record the donning performance of others. Providing simple verbal instructions and the diagrams like those in Table 4.3 and Figure 4.6 appear to make a large contribution to improved SCSR donning proficiency.

The critical step completion times for participants trained in the "3 + 3" method who used the CSE SCSR unit can be compared graphically with the times depicted in Figure 4.2 for the baseline, control, and experimental participants in the original SCSR donning study, who also used the CSE unit. Figure 4.9 overplots data for 17 persons from one CSE class that field tested the new "3 + 3" method on the plot of the experimental group performances shown earlier in Figure 4.2. The order of persons in each group is plotted as a function of time they needed to complete the critical steps and to isolate their lungs from the mine atmosphere. The percent of persons who

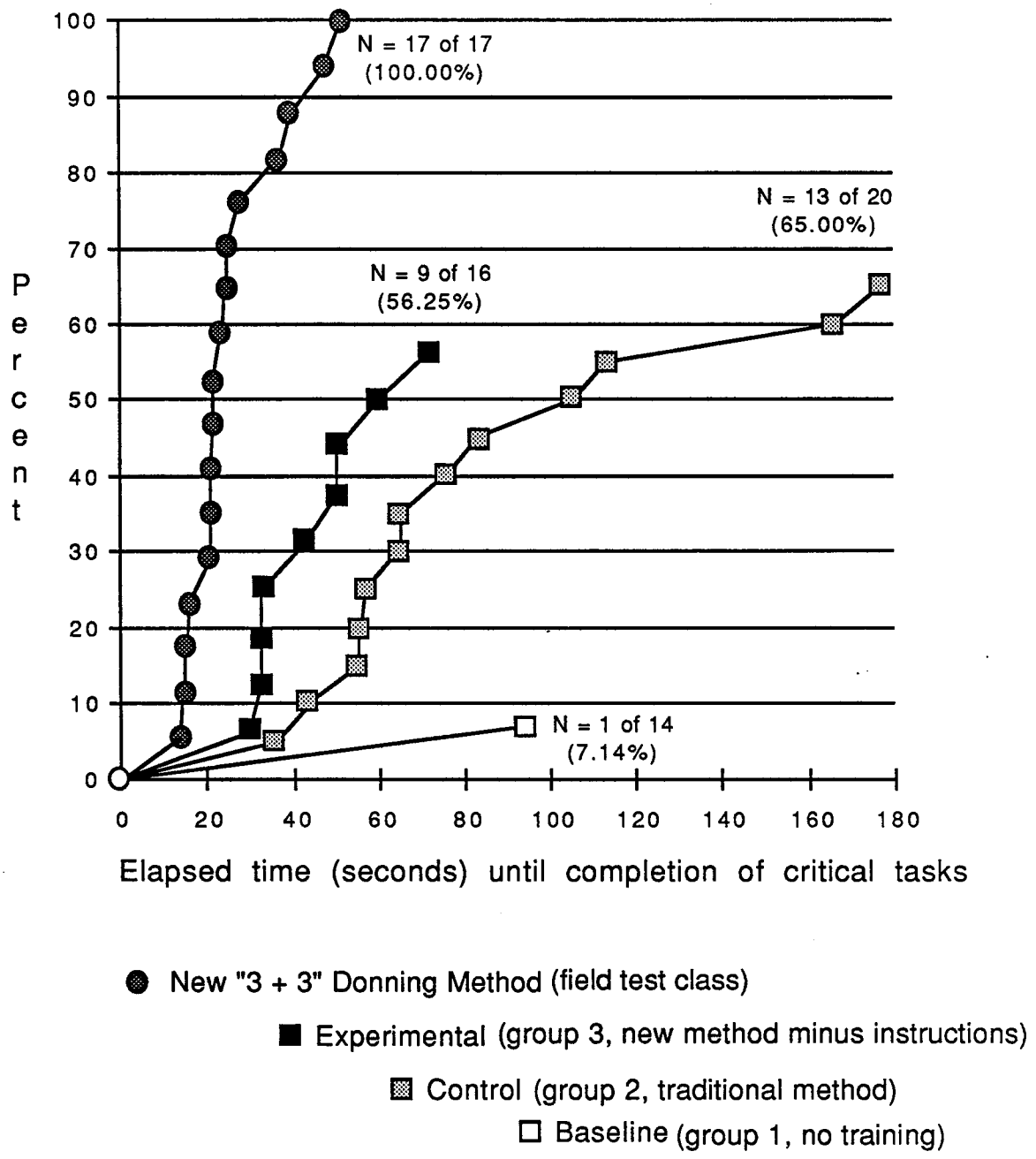


Figure 4.9: New "3 + 3" donning method critical task completion times versus earlier training methods and no training for the CSE SCSR

completed critical tasks within specified time limits can be read directly from the graph. Inspection of Figure 4.9, reveals all 17 miners trained in the new "3 + 3" method completed the critical tasks in 50 seconds or less. Only 6 of the 16 (37.5%) of the miners in the experimental group in the earlier study completed the critical tasks in under 50 seconds. The overplot in Figure 4.9 vividly demonstrates the effectiveness of the explicit instructions included in the training materials for the new "3 + 3" donning procedure.

The data shown in Table 4.6 and in Figure 4.8 for the new "3 + 3" donning method represent the first hands-on SCSR donning performance for most persons. Therefore the improvement in performance must be related to the instructional procedures and not to prior hands-on practice. The individuals participating in the revised training were experienced miners. Most trainees were mine supervisors, inspectors, and safety instructors and some were mine rescue team members. Nearly all of these persons also taught other miners to don SCSRs. Yet, most of these persons had themselves never actually donned and breathed with an SCSR. Of the 283 persons in the study, only 81 (28.6%) reported any prior donning experience, and of these only 13 (4.6%) reported more than one prior occasion for practice. When questioned about this, many of these trainers reported that they had difficulty in obtaining SCSRs for training. Training was most often done with a defective unit that had been opened and that remained open. The instructor explained each step of the donning sequence using the same unit class after class. Frequently, no one, the instructor included, actually fully donned the unit. These instructors reported that training films and slides were also often used in place of the actual SCSR apparatus.

These common teaching practices were problematic. Donning an SCSR is clearly a psychomotor task. While the new donning procedure described in this chapter has the potential to facilitate this psychomotor performance, hands-on practice is required if miners are to learn, remember, and exhibit a proficient donning performance.

Field Conditions versus the Training Room

The training sessions with the new "3 + 3" SCSR donning method were carried out in training rooms above ground. Miners' caps, lamps, and belts were used, and the donning took place in low coal simulators set at a height of 36 inches. However, the floors were clean and smooth, the rooms well lighted, and the SCSRs used were all clean and well maintained. Under actual field conditions the mine is dark, the bottom often wet and muddy, the SCSRs dirty and often battered. It is undoubtedly more difficult to don SCSRs rapidly and proficiently under field conditions. Therefore, the donning times presented in this chapter may be lower than those that would be observed under field conditions.

An interesting opportunity to contrast measured SCSR training room performance and partial field based performance was offered by the availability of data from a group of 22 mine inspectors trained with the new "3 + 3" method using MSA SCSRs at a site in Pennsylvania. These inspectors had personal SCSR units which they carried with them daily during mine inspections. Consequently, these SCSR units had seen much service in actual mine environments. The trainer asked the inspectors to bring their SCSR units with them when they came to class. The inspectors received the first part of the new SCSR training. Then the instructor had the inspectors don the

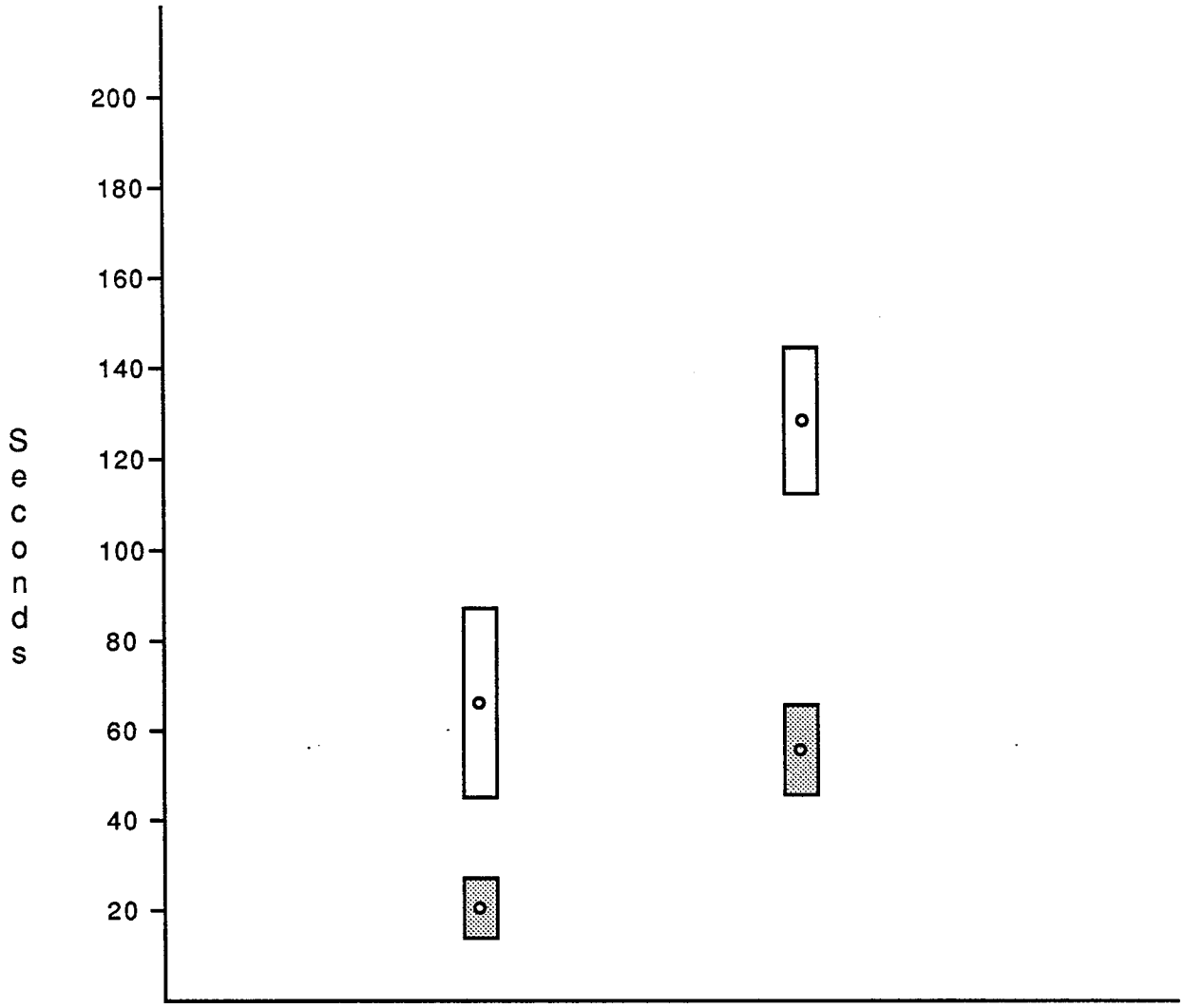
SCSR units that they routinely carried with them in the mines to practice the hands-on donning performance portion of the training. (New units were issued following the training.) These trainees also donned the equipment in a clean, well lighted room.

Figure 4.10 compares the average donning times for these inspectors using their actual field units to persons trained in University of Kentucky classes using training units. As the comparison reveals, the mean times for completion of critical steps and for the whole donning sequence were much longer for the inspector group using field equipment than for the comparable trainees using clean and relatively new equipment set aside for training purposes. Likewise, the variability in donning times was greater for the inspector group.

The instructor who trained the inspectors was contacted. He reported that the longer times required were related to dented, damaged, and dirty SCSR cases that were difficult to open. Dried clay and mud often encrusted the case seals, making it difficult to open the case. These results suggest that the donning times reported for trainees using new and good condition units, typically reserved and maintained for classroom use, may be optimistic estimates of donning times than may be expected in the workplace using older equipment exposed to typical mining environments. The harsher conditions that prevail in actual mine emergencies, e.g. dense smoke, mud, darkness, stress, and confusion, can all be expected to make donning SCSRs more difficult and time consuming.

Mining Industry Evaluations of the New Procedures

Data concerning miners' judgments of the worth and relevance of the new SCSR donning procedures were collected on a standard questionnaire for 276 of the persons



		classroom equipment (n = 14)	field equipment (n = 22)	T-test (signif.)
total time	Mean	67.36	127.36	4.53
	Std.Dev	42.52	31.87	(p<.001)
critical time	Mean	21.86	55.05	5.83
	Std.Dev.	14.14	19.98	(p<.001)

Figure 4.10: Mean SCSR donning times for field and classroom equipment

Table 4.7: Ratings of SCSR training relevance, utility and quality (n = 276)

content	yes	no
The training is close to real life	83.7	16.3
The training will help me remember important things	100.0	0.0
I learned something new	95.3	4.7
The exercise is too long	5.8	94.2
I liked doing the exercise	99.3	0.7
The instructor's directions were clear	98.4	1.6
The written directions and diagrams were clear	99.3	0.7
The performance evaluation form is easy to understand	97.2	2.8
The videotape is easy to understand	99.1	0.9

involved in the initial training sessions. These data are reported in Table 4.8. These mining industry trainers, supervisors, and inspectors thought the new hands-on training methods that required wearing a cap, lamp, and belt, as well as no prompting from the instructor, created a situation closer to real life than typical SCSR training. However, many thought such training would be more realistic if it were conducted underground in darkness and smoke, rather than in a well lighted and clean training room.

Subsequently one western coal company did train 180 of its miners in the new procedures, underground, and in smoke. University of Kentucky and Bureau of Mines researchers participated in and observed this training. As many of the mining industry personnel in the field test classes suggested, donning an SCSR was observed to be both more realistic and more difficult when working underground. Many of the miners

made errors and had difficulty donning their SCSR in the darkness and smoke. The two to five inches of mud and water on the mine floor made it difficult to place the SCSR on the mine floor while opening the case, and difficult to locate dropped items. Everyone worked simultaneously, hurrying to get their unit on so they could leave with the others and not get left behind. From this experience, we learned it is better to first train miners thoroughly in the new procedures in individual hands-on sessions above ground in a training room to produce mastery of the donning task. When training occurs underground in smoke and darkness, many persons are donning their SCSRs all at the same time. The instructor and other miners cannot observe and record individual miners' donning performance. Thus, opportunity is lost for miners to receive individual feedback that can correct errors and improve their donning performance. They also lose the opportunity to learn from careful observation of other miners.

In Chapter 2 it was noted that effective instructional materials must meet design criteria concerned with their acceptability to the groups for which they are intended. These criteria include the materials' perceived utility, relevance, ease of use, and clarity of content and procedures. If these criteria are not met the materials will not be used, no matter how well justified, nor how important the objectives and content. Evaluations of the worth and utility of instructional materials by representative samples of persons from the intended audience are important indicators of the degree to which these basic instructional design criteria have been achieved.

Inspection of the ratings in Table 4.8 suggests the training package for the new "3 + 3" SCSR donning method meets the basic design criteria of perceived worth and utility. Furthermore, the data suggest that each of the several components in the

training package function as they were intended.

All of the persons in the classes reported that the training helped them to remember important information and procedures for donning SCSRs, the key objective for the activity. Over 95 percent reported that they had learned something new. Only about 6 percent thought it took too long to complete the training. Over 99 percent reported they enjoyed participating in the training. Approximately 98 percent thought the instructors' presentation and directions were clear. For each model of SCSR, and for each class, the instructors' presentation and directions followed the lesson plan in the instructor's guide. (See Appendix D for an example of the lesson plan.) Different instructors taught different classes. However, all instructors used the presentation materials in the instructor's guides. Thus, it appears that the materials in the instructor's guides equip a variety of trainers to effectively and clearly communicate the goals and procedures for the new donning procedure to trainees.

Over 99 percent of the participants reported that the written materials and diagrams presented on the overhead transparencies were clear and easy to understand and that the videotape demonstration of the donning position and sequence was easy to understand. Approximately 97 percent of the trainees found the performance evaluation form to be easy to understand and use.

In addition to the formal evaluative data reported in Table 4.8, many informal observations concerning the worth of the new donning procedures were noted. It was estimated that over half of all the persons who participated in the initial field test classes immediately began training the miners they worked with using the new procedures. Many of these trainers reported that managers in their organizations and

agencies thought the new methods and procedures were valuable, and directed that their entire work forces be trained. It was difficult to obtain performance data from these subsequent sessions. The trainers and miners involved saw no need for further data collection, viewed themselves as being involved in teaching more efficient means for SCSR donning as opposed to a research study, and tended to regard the performance evaluation sheet as a record that should be kept by the miner and the company to indicate the person's proficiency level and date of training. Subsequently many trainers reported informally that the performance of miners in these other classes produced data similar to the values reported in Table 4.6 and Figure 4.8. Trainers also reported that the miners, inspectors, supervisors, and others involved in the classes enjoyed the training and thought it to be very important.

Limitations

One limitation of the research reported in this chapter is that the early experimental work was carried out with only the CSE SCSR. Using each of the other three major types of SCSRs that are in use in the United States, subsequent Bureau of Mines studies have replicated and improved upon the experimental study reported in this chapter (Vaught, Brnich, & Kellner, 1988; Vaught & Cole, 1987b). These more recent studies have supported the results from the earlier study reported in this chapter.

Although only the CSE SCSR was formally studied in the initial experiment, the researchers practiced donning the other three types of SCSRs and observed many miners doing so. Through this activity, information gathered in the experimental study of donning the CSE SCSR was generalized and adapted to other models of SCSRs.

Although each model of SCSR is different in terms of the specifics of the donning procedure, the experimental data obtained from the CSE study provided information and insights that were valuable for understanding the donning procedures and problems for each of the other three models. Thus, the new "3 + 3" training procedure that emerged was based upon experience with all four types of SCSRs. From the beginning the intention was to produce a generalized procedure that would facilitate the rapid and proficient donning of any type of SCSR. The field test data for the new donning procedure presented earlier in this chapter suggest that this goal was achieved. Subsequently, large studies by Bureau of Mines researchers have confirmed the generalizability of the method for models of SCSRs currently available.

A second limitation has been mentioned previously. This concerns the lack of information about how long miners trained with the new procedures retain their proficiency in donning SCSRs. Studies completed and currently underway at the Bureau of Mines Pittsburgh Research Center are providing preliminary data on this topic for each of the four models of SCSRs for periods of time up to one year. These studies also include various ways of presenting the new donning procedures, the effects of short refresher sessions for maintaining miners' SCSR donning proficiency, and the use of low cost high fidelity SCSR simulators (Bureau of Mines, 1988; Vaught, Brnich, & Kellner, 1988; Kellner, 1988a, 1988b, 1988c; Vaught & Cole, 1987b).

Conclusion

The experimental study reported in this chapter was undertaken because no prior research of this nature could be located. The information gained was needed to conceptualize and design the new generalized "3 + 3" SCSR donning procedure. The

study became possible because a coal company donated the use of the CSE SCSRs and the opportunity to conduct an experiment with three classes of their miners who were engaged in annual refresher training. Bureau of Mines staff assisted University of Kentucky researchers in videotaping and conducting the experimental study. Kentucky Department of Mines and Minerals staff, and other persons from coal companies assisted in developing the prototype videotape demonstration materials. Later, MSHA helped fund the field testing of the new method. The equipment manufacturers provided multiple sets of equipment and assistance in operating the many field test classes. Without the assistance of these groups the experimental study and the field evaluations of the new method could not have been completed.

The inherent complexity of the SCSR donning task, the infrequency of hands-on training, the complexity of the earlier training procedures, the failure to order critical tasks first, and the standard donning position all contributed to miners' difficulty in getting the units on rapidly and flawlessly. The research reported in this chapter led to a more efficient donning position and sequence that is easier to remember and perform.

Two important issues have not been addressed in the research reported in this chapter. First, it is not known how well or how long miners retain proficiency in SCSR donning, nor how frequently miners must be trained to maintain high levels of proficiency. Second, the research reported in this chapter revealed problems in the design of all four models of SCSRs. The donning of each unit (and of future SCSRs) can be made easier by ergonomic changes in the equipment. Donning subtasks that are time consuming and difficult to perform, and that result in frequent errors, have

been identified in an earlier technical report (Cole et al.,1988b). This information can be used to improve the design of existing and future SCSRs. Controlled human performance studies, like the one reported in this chapter, can reveal which design modifications optimize miners' rapid and flawless donning performance.

The inherent complexity of donning an SCSR, the infrequency of hands-on training, and the design of the earlier training materials help explain why miners have difficulty in donning the units in an emergency, as reported in the Fesak and Cavanaugh (1984) MSHA investigation of the Greenwich Colleries mine explosion. The investigation revealed that the 11 miners near the explosion (four of whom were burned) had difficulty donning and using their SCSRs. Some never got their SCSRs on; some got the units on but could not function with them, and took them off. If the atmosphere had been toxic it is likely these 11 miners would have perished. Studies like those reported in this paper, and those currently underway at the Bureau of Mines, may help prevent future tragedies.

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Chapter 5: First Aid Role Play Simulations for Miners[1]

This chapter provides information about the design and effectiveness of role play simulation exercises for annual refresher training classes. The material in this chapter, and the sample role play simulation exercise included in Appendix F, also provide practical information and guidelines for persons who wish to develop similar exercises.

Chapter Organization

The first section reviews the role of simulation exercises in teaching critical skills. Miners' experience with simulation exercises like mine rescue contests is then discussed. Then, the inexpensive Ohio State University simulation method developed by Gilbert (1975, 1981) is described. Its potential application to the training of miners is noted. Results of the University of Kentucky studies of miners' first aid strengths and weaknesses are then presented. Implications of these findings for the improvement of first aid training of miners are discussed.

The next part of the chapter describes the design and effectiveness of the first aid simulation exercises. The exercises emphasize initial diagnostic evaluation of the victim's simulated injuries through hands-on primary and secondary surveys, as well as the performance of standard first aid treatment procedures once the injuries have been identified and treatment priorities determined. Then, the field testing procedures used to evaluate one exercise are described. Miners' and trainers' evaluation of the exercise are presented along with information about the miners' performance.

[1] An earlier version of this chapter was published as part of the proceedings of a Bureau of Mines Technology Transfer Seminar (Cole, Wasielewski, Haley, & Berger, 1988).

The last part of the chapter interprets the data from field tests of one of the new simulation exercises. The design and use of role play simulation exercises in annual refresher training classes is discussed. The discussion and conclusions draw upon the field test results, as well as findings from other studies concerned with miners' first aid strengths and limitations.

Simulation Exercises for Teaching and Testing Critical Skills

Simulation tests of real life problem solving are often an effective way to train and assess proficiency for dealing with emergency situations. Simulated emergencies can be realistic and motivating. They can also demand a broad range of responses from the individual including a) recognizing cues that indicate an emergency is developing or underway, b) gathering additional information to diagnose the nature and extent of the emergency, c) making decisions about various courses of action that should be taken, and d) implementing and carrying out appropriate procedures to alleviate or control the emergency (Distlehorst & Barrows, 1982). For these reasons, well designed simulation exercises can mimic many aspects of emergency situations. Consequently, a simulation exercise can provide opportunity for persons to learn and practice critical skills needed to cope with actual emergencies.

Because of these characteristics, simulation exercises are widely used in training medical personnel for responding to emergency situations. Elaborate interactive computer controlled human patient simulators, patient actors, computer generated patient evaluation problems, and paper and pencil latent image patient care and management problems (PMPs) are frequently used for training physicians, nurses, and dentists to diagnose and treat medical illnesses and emergencies (Babbott & Halter,

1983; Dugdale, Chandler, & Best, 1982; Farrand, Holzemer, & Schleutermann, 1982; Fleisher, Schwenker, & Donnelly, 1982; Jones & Keith, 1983; McGuire & Babbott, 1967; McGuire, Solomon, & Bashook, 1976; Norman, Tugwell, & Feightner, 1982; Pryor & Racey, 1982; Saunders & Wallis, 1981; Umbers, 1981). Similar simulation techniques are used in assessing proficiency of emergency skills of air crews (Flathers, Giffin, & Rockwell, 1982; Giffin & Rockwell, 1984; Jensen, 1982), power plant operators (Hunt & Rouse, 1981), and other technical personnel (Olsen, 1979).

Figure 5.1 depicts a first aid simulation exercise developed for the proficiency testing and refresher training of industrial and laboratory workers (Olsen, 1979). The simulations are carried out as staged accidents in actual work locations. Human actors and simple props are used to stage a realistic accident scene. (In one training program described by Olsen (1979), animal blood and entrails obtained from slaughter houses are used as props to simulate major injury accidents to workers.) The simulation begins when other workers "discover" the simulated accident and begin first aid care for the victim. The "discovery" may be with or without prior knowledge of the trainees as part of a planned training activity. Although they provide a realistic context for teaching and assessing proficiency in critical first aid skills, such full scale work location simulations are difficult and costly to arrange. Yet these and other types of exercises provide workers experience with first aid situations rarely encountered otherwise. A main purpose of such simulations is to maintain proficiency in infrequently used, but critical skills.

Simulation exercises can be expensive, especially when they involve complex interactive computers in combination with mechanical mock-ups of human patients,

SCENARIO

EMERGENCY RESPONSE TRAINING

DATE _____ TIME _____

NATURE OF EMERGENCY: Acid battery explosion

TRAINING TO BE UTILIZED/TESTED: First aid in acid environment

LOCATION OF EXERCISE: Emergency generator building

NOTIFICATIONS OR SPECIAL INSTRUCTIONS: Fire Department. Request that the fire department take information from the plant emergency response team and advise that no ambulance is available for transport of injured.

DESCRIPTION OF INCIDENT: A maintenance man is checking the bearings on the emergency generator. Batteries are being charged. Upon completion of his job, he lights a cigarette. The flame ignites hydrogen which is trapped in the area because of a ventilation problem.

The battery explodes.

The man is hit by flying debris.

His head is cut.

His hand is burned by the exploding hydrogen gas.

He is covered with acid.

PROCEED AS IF THIS SITUATION WERE AN ACTUAL EMERGENCY.

Figure 5.1: Example of realistic simulation exercise from Olsen (1979)

aircraft cockpits, or other equipment. However, simpler paper and pencil simulations are often used for teaching and assessing proficiency in critical skills, especially those involving problem recognition, information gathering, and decision making (Giffin & Rockwell, 1984).

Chapters 2 and 3 describe paper and pencil simulation exercises recently developed for teaching coal miners how to cope with underground mine emergency situations. Knowledge gained from constructing and field testing these paper and pencil simulations contributed directly to the design of the role play simulation exercises described in this chapter. As McGuire (1984) notes in a review of medical simulation research, it is not the format of problem presentation but the content and logic of the simulated problem that is basic to the simulation's effectiveness. Simulations may take many formats including computer administration, paper and pencil versions, gaming situations, full scale drills and contests in the workplace, or structured classroom role playing activities. This chapter deals with the latter type of simulations. However, the principles noted often apply to other types of simulation problems.

Miners' Experience with Role Play Simulations

If designed appropriately, role play simulations are motivating and effective means for teaching and assessing problem solving skills needed to cope with emergency situations. If they are not carefully designed, classroom role play simulation exercises fail to achieve their potential. Both well and poorly designed role play simulations have been experienced by most miners and their instructors.

The simulations experienced by most miners fall into three general categories.

These are mine rescue contest exercises, first aid contest exercises, and impromptu and less complete classroom role playing situations that are usually carried out in the context of teaching interpersonal dynamics. This generalization is based upon visiting and observing many of these types of training activities in the mining industry in six states over a four year period.

Mine rescue training exercises are widely used in the mining industry. They are elaborate and detailed problem solving exercises that involve the use of actual mine rescue equipment and many props to simulate an underground mine environment. Sometimes the exercise is carried out underground in an actual mine. During the exercise some persons play the role of injured or trapped miners while others adopt the multiple roles of the mine rescue team and its support staff. The exercise is structured around a complex and realistic problem, such as a mine fire or explosion. The "victims" and the "mine rescue team" do not know all of the problem structure as the exercise begins. Rather, they know only the information that would typically be available to them in a similar actual mine emergency. Thus, as in real life, details of the problem become known to the role players only as they develop a plan, enter the "mine," and attempt to locate and rescue the missing miners. The problem unfolds and changes as the rescue team explores the mine, gathers information, encounters barriers and hazards, and modifies strategy to achieve the goals of locating and evacuating trapped and/or injured miners and restoring the mine to a safe condition.

Although there are well established procedures and protocols for mine rescue work, every mine rescue exercise is a different problem. A good solution (rescue) requires a flexible and unique combination of prior knowledge and skills. The

development and execution of constantly changing plans and strategies is required. Standard protocols must be recalled and applied when appropriate. As the rescue proceeds, inferences must be constructed about mine conditions based on available information. A good solution creatively integrates the large amount of information and the many procedures basic to any problem. Miners and trainers enjoy these elaborate simulations and learn much from them.

First aid exercises and contests are also widely used in the mining industry, often in conjunction with mine rescue contests. These exercises also involve miners who role play injured accident victims and others who adopt the roles of a first aid team. The simulated injuries are usually severe. First aid kits and supplies normally available in mines are available to the first aid team. However, unlike mine rescue exercises, most mine first aid exercises and contests place less emphasis upon initial problem identification and formulation. The nature and extent of the victim's injuries are usually given to the first aiders, often printed on a piece of paper. The exercise usually focuses upon the skill and speed of the first aid team in applying standard procedures to stop bleeding, dress and bandage wounds, splint and bandage fractures, and immobilize the victim on a stretcher. These types of exercises present the first aiders with an already well defined problem. The emphasis (and scoring) is on the rapid and skillful application of first aid procedures according to standard protocols. The early and crucial information gathering, problem formulation, and strategy development aspects of the problem tend to be ignored. These include 1) the first aider's initial evaluation of the accident scene to determine if it is safe to treat the victim, or if some other action(s) must be taken first; 2) the approach to and removal of

the victim from the accident scene, once the mine area in which the victim is located is judged safe for the first aiders to enter; 3) the evaluation of the victim's injuries through a detailed primary and secondary survey; 4) the use of information from the primary and secondary surveys to construct inferences about what injuries are present, which should be treated, in what order, and by what methods, and; 5) the planning and implementation of complex details of communicating with surface personnel and transporting the victim to the portal.

The third type of role play simulations with which many trainers and miners are familiar are designed for use in classroom settings. Constraints of time and location generally require these simulation exercises to be brief, perhaps no longer than 20 minutes, and to require no elaborate props or equipment. The content of these role play simulations usually concerns interpersonal dynamics among miners and their supervisors. Sometimes the content is technical, such as the role playing of a mine inspector's and a mine foreman's conversation about a list of violations found by the inspector in a current visit to the mine. If carefully planned and introduced at the appropriate time and in an appropriate manner, these types of shorter simulations can also be engaging and elicit the participation of miners. However, even short classroom simulation exercises are more difficult to design and structure than they may at first appear.

Instructors often have difficulty designing and using role play simulations like these in their classes. Sometimes there is too little planning and preparation on the part of the instructor, or the persons who designed the simulation. Few instructors are sufficiently skilled and experienced in the effective use of impromptu and open ended

role play situations. Frequently the method fails to achieve its potential because the trainer fails to select and structure an authentic problem that challenges participant's present level of knowledge and skill. Oftentimes the problem structure is not clear to the trainer or to the miners. The content and logic of the problem is often not well articulated. The roles of the players are often not specified clearly, and class members feel uncertain and uneasy about what they are to do. Sometimes, little thought is given to what the members of the class who are not involved in the role play situation are to do during the activity. Usually there are no objective criteria for evaluation of the role player's performance. Following the activity, it is easy for the persons who observed to be critical of the actors. Thus, the role players may feel uneasy and defensive. One or two experiences with poorly structured role play simulations like these serve to disenchant both miners and trainers. In the future, both will tend to avoid classroom activities that they perceive as similar to these simulations.

Much preparation prior to the simulation is necessary if the instructor is to present the simulated problem in a realistic, and time efficient manner, and if trainees are to become fully and quickly engaged in the activity. Effective role play simulation exercises incorporate a number of components. These include 1) simple props that simulate key aspects of the problem setting, 2) carefully chosen graphics and illustrations that help describe the problem, 3) a brief written description that clearly presents the initial problem, 4) brief and clear instructions to the individual class members who are to play various roles in the simulation (and to those who observe the role play simulation), and 5) a means to evaluate specific aspects of the problem solving performance of the participants.

First aid role play simulations for classroom use that meet good design criteria, and that are known to be motivating and effective instructional tools, have been developed and researched with college student populations at the Ohio State University (Gilbert, 1975). This earlier research was useful for designing the first aid simulation exercises discussed in this chapter.

The Gilbert First Aid Simulation Technique

In his dissertation, Gilbert (1975) set out to develop an inexpensive, easy to use, and effective simulation method for teaching basic first aid skills. His review of earlier research categorized simulation exercises into eight different approaches. Many of these approaches, such as computerized mechanical models of injured human victims, full scale field simulations of accidents with injury makeup kits and human actors (as are often used in the military), and complex flight or other equipment simulators are not available to instructors in typical first aid courses. Other methods, such as those described by Olsen (1979) using human actors with animal blood and entrails to simulate industrial accidents at actual work stations, are difficult to stage, time consuming, and fraught with potential health, safety, ethical and legal problems.

Using ideas and techniques from simulation methods and research across the eight approaches, Gilbert developed an inexpensive, but effective simulation approach. The procedure provides short verbal descriptions of the problem situation, brief written instructions for human actors (victims and bystanders) in brief role playing situations, injury tags placed on the victim, and a performance scoring sheet. The simulation is presented to the trainee as if he or she had suddenly encountered an accident victim. The trainee must first gather information from the victim and

bystanders, by observation and questioning. Information about the nature and extent of injury to the victim is partially revealed by the trainee's primary and secondary surveys of the victim. Bleeding, puncture wounds, dislocations, fractures, and other injuries are not fully simulated with makeup kits. However, they are simulated by the victim actor and by "injury tags" placed on the victim's body at appropriate places, e.g., a small label stuck to the patient's ear that says, " small amount of clear, slightly yellow fluid running out of ear," a small label on the upper left chest that says "small puncture wound making a sucking noise," or a large red card on a limb that says, "dark red blood soaked clothing."[2] The size, location, and prominence of the injury tag is related to the size, location, and prominence of actual injury cues on real victims with the types of injuries being simulated. To perform effectively, the trainee must find and make use of all the cues (position of victim, bystanders' observations, injury card cues located on the victim, etc.). He or she must then decide upon a course of action and administer first aid. For each simulation exercise there is a performance check list that is used by the instructor to score the proficiency of the trainee. An example of a Gilbert simulation exercise appears in Figure 5.2.

Gilbert tested his simulation method in a large experimental study with college students. He found the method to be highly motivating to students, inexpensive, and effective in teaching basic first aid skills as outlined in the First Aid and Personal Safety Course of the American Red Cross (1981). He also found his method was effective in

[2]These injury tags are similar to the labels used in mine rescue contests. Labels on cards placed on the ground or the simulated mine rib simulate the presence of roof falls, water, methane and other information encountered as the team advances.

Situation #7B: Industrial Accident

Situation:

You are working on a construction project when there is a cave-in and material strikes a co-worker.

Where:

Ground level of a new building project

Miscellaneous Information:

You fear the building will continue to cave in.

Position of Victim:

On back

Special Instructions for Victim:

You are Unconscious and remain so.

Supplied Materials:

1. Assorted bandaging materials
2. Coat

Tags:

1. Moderate bleeding (1)-front of scalp
2. Mild bleeding (1)-nose
3. Mild bleeding (1)-back of neck
4. Moderate bleeding (1)-front of left lower leg

Figure 5.2: Example of a Gilbert simulation exercise and performance scoring sheet

Name of First Aider _____ Grader _____

Situation #7B: Industrial Accident

	Yes Well Done	Yes Adequate	No
1. Was the victim removed from the dangerous area in proper fashion?	3,2	1	0
2. Was the victim properly examined for all injuries?	2	1	0
3. Was moderate bleeding of leg controlled and bandaged properly? A. Direct pressure and elevation (1) B. Pressure point (1) C. Proper bandage and dressing (2)	4,3	2,1	0
4. Was moderate bleeding of scalp controlled by a loose bandage and dressed so as not to stop flow completely?	4,3	2,1	0
5. Was concussion suspected and victim thus handled very carefully?	2	1	0
6. Was mild bleeding of neck controlled and bandaged properly? A. Direct pressure (1) B. Proper bandage and dressing noncircular (2)	3,2	1	0
7. Was mild bleeding of nose controlled in an appropriate fashion?	2	1	0
8. Was victim treated for shock? (In this case elevation of feet is inappropriate and elevation of upper body is acceptable.)	2	1	0

Comments:

Add _____

Deductions _____

Total _____

Possible 22

Figure 5.2: (continued)

measuring his students' knowledge of first aid skills as validated by the Ohio State University First Aid and Personal Safety Achievement Test (Gilbert, 1975). The Ohio State Test is a standardized 100 item multiple choice test. More recently Gilbert (1981) has further refined and validated his simulation method with other samples of persons and with the Burckes Emergency Care Knowledge Test (Burckes, undated).

From his research Gilbert concluded that persons trained in the method were able to learn to perform procedures correctly and that they achieved mastery of verbal knowledge about first aid procedures. However, his study did not determine how long trainees retained this proficiency and knowledge, or how well this classroom practice of first aid skills generalized to actual first aid treatment.

Potential of the Gilbert Simulation Method for Miner Training

Prior to this contract, it appears that the Gilbert method for teaching and assessing proficiency in first aid skills had not been applied to miner training. However, for a number of reasons, the method was judged to have promise for teaching first aid skills to miners in annual refresher classes.

First, it is relatively easy to develop and use simulation exercises patterned after the Gilbert method. Neither the development of the exercises or their use requires any special equipment beyond that typically available to annual refresher class instructors.

Second, the method is adaptable. Where miners might be inhibited about doing a full body survey in a suspected spinal injury victim (including checking for penile erection and toe flexure), a mannequin rather than a human actor might be substituted. (A Resusci Andy or department store mannequin could be used.)

Third, the method is brief and time efficient. A single simulation can be

completed, evaluated, and critiqued in a 20 or 30 minute period. Multiple role play simulations of the same or different problems may be undertaken with small groups of trainees in the same classroom, thus involving all participants in hands-on, skill building activities.

Fourth, the Gilbert method has proven to engage the attention and participation of college students and others in learning first aid skills, and it has also been shown to increase their first aid knowledge and skills.

Fifth, many of the simulation exercises developed by Gilbert and his colleagues may be easily adapted to first aid problems that are common in underground mines.

Sixth, the method can be used to present realistic problems that mimic the full range of problem solving activity required in actual mine first aid emergencies. Unlike most first aid contests and traditional first aid instruction, Gilbert simulations include the front end assessment of the accident scene, diagnosis of the victim's injuries through a hands-on primary survey, and establishment of first aid treatment priorities, as well as the performance of first aid treatment procedures.

Seventh, field interviews revealed that miners' first aid skills and knowledge were weakest in critical information gathering, judgment, and decision making. These specific skill areas are emphasized by the Gilbert simulation method.

For these reasons the Gilbert simulation method was studied and adapted to the production of classroom first aid simulation exercises for use in annual refresher training.

Miners' First Aid Strengths and Weaknesses

A study of miners' performance of first aid skills as practiced on injured fellow miners

was undertaken (Cole, Berger, Vaught, Haley, Lacefield, Wasielewski, & Mallett, 1988b, Chapter 1). Medical personnel and miners trained as emergency medical technicians (EMTs) were sampled from four coal producing regions in Kentucky, West Virginia, and Virginia. The sample included those first aid experts who first see and treat injured miners who have earlier received first aid from their fellow miners. The observations of these experts were gathered from interviews. Interviewers used critical incident and structured interview forms designed to elicit these experts' direct observations of what first aid tasks miners usually perform well and what tasks they often perform poorly. About 120 first aid experts were interviewed, some in group settings. Reports from 77 experts who made individual responses were collected and tallied. Table 5.1 describes the geographic distribution and the types of experts involved in this sample. In the interviews, it was made clear that the expert's frame of

Table 5.1: Types of first aid experts interviewed and their geographic distribution

	Geographic Location				
Expert Type	Eastern KY	Western KY	Central WV	Southwest VA	Total
Emergency MD	1	-	2	4	7
Emergency room RN	2	3	3	5	13
EMT instructors	6	1	-	1	8
Working EMTs	-	13	1	-	14
EMT miner trainees	16	17	-	-	33
Other	2	-	-	-	2
Totals	27	34	6	10	77

reference should be the strengths and weaknesses of miners' actual first aid performance. The quality of performance was to be judged by the expert's examinations of the victims, following initial first aid treatment by non-EMT trained miners.

The working EMTs shown in Table 5.1 included five underground coal miners who routinely are called to the scene of underground first aid emergencies, and seven EMT ambulance personnel who routinely meet injured miners at the portal. The 33 EMT miner trainees were all experienced miners, many of them foremen, who had nearly completed 16 weeks of EMT training, but who had not yet passed the certification examination.

The experts in Table 5.1 reported miners were most skilled in following standard procedures for treating obvious injuries, especially splinting and bandaging simple fractures, caring for cuts, abrasions, and sprains, and controlling bleeding. Miners were reported as most often making serious errors when 1) immobilizing and transporting victims with back and neck (spinal) injuries, 2) dressing and immobilizing compound fractures, 3) rushing to move an injured miner without first immobilizing and stabilizing the victim, and 4) failing to do a victim evaluation through a primary and secondary survey. Poor performance on these tasks was reported to be caused primarily by failure to discover "hidden" or nonobvious injuries. Miners' missing the hidden injuries was said to result from their failure to conduct an adequate initial hands-on patient evaluation. Thus, the victim's injuries, unless obvious, tend to remain unidentified. Properly evaluating the victim for injuries tends to improve first aid care because hidden injuries may be found and treatment priorities established.

Analysis of the data suggested there is a consensus among the experts on both first aid treatments performed well and those performed poorly. Obvious injuries are generally treated well; hidden injuries and illnesses are not. A major exception is that obvious compound fractures also are often not treated well because the treatment procedures are difficult.

Sometimes obvious and hidden injuries are combined in the same victim. Table 5.2 reports the experts' estimated percent of injuries miners treat well or poorly when the injuries are obvious, hidden, or combined. Table 5.3 shows there is a strong positive correlation between those first aid treatments miners do well or poorly and the obvious or hidden nature of the injury. The observed correlation between these two dimensions is 0.53. When the obvious but difficult to treat injuries (compound fractures and amputations) are omitted from the "obvious/done poorly" cell, the relationship is stronger and the correlation increases to 0.64.

What differentiates miners' treatment of obvious and hidden injuries? It appears

Table 5.2: Percent of obvious, hidden, and combined injuries treated well/poorly

	Type of Injury			
First Aid	Obvious	Hidden	Combined	Other
Done well	68	7	26	*
Done poorly	32	93	74	*
Total	100	100	100	100
no. cases reported	117	41	43	9

*These frequencies were too small to compute meaningful percentages

Table 5.3: Relationship between first aid done well/poorly and obvious/hidden injuries

Reported frequencies of well/poorly done first aid

	Including compound fractures & amputations			Excluding compound fractures & amputations		
	Done well	Done poorly	Total	Done well	Done poorly	Total
Obvious	79	38	117	79	23	102
Hidden	3	38	41	3	38	41
Total	82	76	158	82	61	143
	Chi square = 44.09, 1 df $p < 0.001$ phi coefficient = 0.53			Chi square = 58.81, 1 df $p < 0.001$ phi coefficient = 0.64		

that treatment of obvious injuries requires knowledge of technique and appropriate use of first aid equipment, the skills that are emphasized in annual refresher first aid training and first aid contests. Appropriate treatment of hidden injuries or illnesses appears to require more emphasis upon gathering information, evaluating the accident scene and victim, constructing inferences about what the probable injuries are, and prioritizing first aid treatment procedures. Interviews with the 120 experts also yielded other information, including a consensus that miners often failed to communicate clearly and effectively with each other and with surface personnel when they are involved in a first aid emergency. Lack of clarity in communication, or failure to communicate the details of an injury accident, can have severe consequences for a victim. Examples cited include 1) a mantrip transporting an injured miner being forced to wait for the track to be cleared of other equipment, when an earlier call could have cleared the track, 2) an injured miner (who subsequently died) who was transported four miles to an elevator, but had to be transported back in the same direction from

which he had started and an additional four miles to another elevator because the first elevator was temporally inoperative while being repaired, and 3) getting an injured miner to the surface promptly and into the company ambulance only to find the single roadway to the mine property was blocked by a long surface unit train.

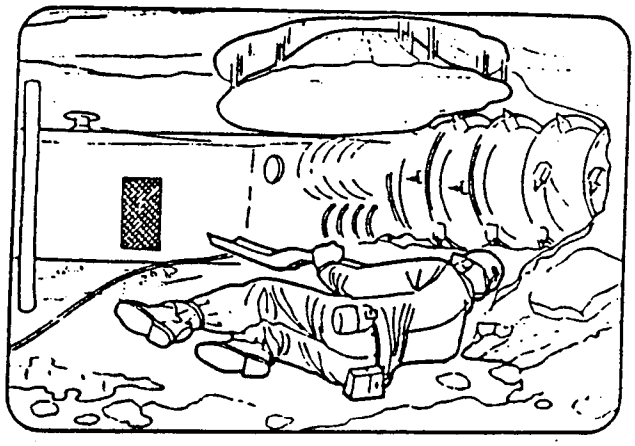
After the field interviews of the 120 first aid experts from the underground coal mining industry were completed, a meeting at the National Mine Health and Safety Academy was convened with thirteen additional experts familiar with medical emergencies in underground coal mines in six states. These experts, who routinely teach first aid, as well as provide first aid and emergency medical treatment to miners, were also asked to identify the most common and most serious errors made by miners in first aid treatment of fellow accident victims. The group members identified failure to do a careful injury assessment, failure to prepare and stabilize the victim prior to transport to the surface, and failure to monitor the victim during the transport period to be the most serious and most frequent errors. Miners were said to often act too quickly, moving the victim out of the mine without first searching for and identifying the extent and nature of injuries, and determining treatment priorities. More extensive injuries and complications frequently result for the victim when first aiders fail to conduct critical injury evaluation, fail to find and care for serious injuries, and hurry transport. These 13 experts reviewed the findings from the field interviews and independently judged them to be valid. The results of the field interviews of first aid experts, and the independent observations of the 13 experts, are also consistent with an earlier set of findings and recommendations from a study concerned with the first aid needs and skills of miners (Pickar, 1977).

In summary, good first aid in underground mine emergencies requires a broad problem solving focus, not only knowledge of specific first aid procedures. Good first aid simulations should be structured much like good mine rescue contest problems. They should present a simulation that mimics the complexity of problem identification, information gathering, decision making, communication, strategy development, rapidly changing conditions and unknowns, and the application of specific techniques required to administer effective first aid in actual mine emergencies. The research results from studies of miners needs for first aid training, and the practical knowledge gained from studies by Gilbert and his colleagues, contributed to the development of the short and time efficient first aid simulations developed under this contract. A sample exercise that resulted from this integration of research and practice is included as Appendix F.

The New Role Play Simulations

Many of the approximately 50 simulation exercises in the Gilbert (1981) manual are relevant to underground coal mine first aid situations and can be used with little modification. (All of Gilbert's simulations are available for duplication without copyright restrictions). Other Gilbert type simulations of coal mine medical emergencies can easily be developed from accident reports, as is the case for the exercise shown in Figure 5.3. The graphic depiction of the accident situation is taken from the Mine Safety and Health Administration (1985) Coal - Underground Fatalities, First and Second Quarter, 1984. The problem situation, injury tags, and scoring sheet are designed for this case. Although the miner in the accident case was fatally injured, for purposes of the exercise, the miner's injuries are severe, but not necessarily fatal if he

Situation #1: Roof Fall Injury



Situation:

A miner is hit by 12 inch thick, 4 x 5 foot kettle bottom while shoveling coal

Where:

48 inch coal near a continuous miner

Miscellaneous Information:

There are two other members in the crew and you are the most experienced. Nearest phone 5 minutes away. It is twenty minutes to portal by mantrip.

Position of Victim:

Lying on side under part of broken kettle bottom

Special Instructions for Victim:

You can talk but are dazed and cannot move your arms and legs.

Special Instructions for Crew Members:

Act excited but do what you are told.

Supplied Materials:

Mine first aid kit and stretcher (5 minutes away).

Tags:

1. Part of kettle bottom on top of miner (Simulate with cardboard box or other similar object)
2. Left upper chest pulls in when miner breathes in. (Apply label to left chest under shirt)
3. Bones of upper spine are out of line. (Apply label to upper spine under shirt)

Figure 5.3: Sample Gilbert type exercise modeled after a coal mine accident

Name _____ Grader _____

Situation #1: Roof Fall Injury

	Yes Well Done	Yes Adequate	No
1. Was the kettle bottom promptly, gently, and properly removed from the victim?	3	0	0
2. Was the victim properly examined and questioned for all injuries?	2	1	0
3. Was the victim not moved unnecessarily?	3	2	0
4. Was the victim given verbal encouragement?	2	1	0
5. Was crushed chest properly diagnosed and splinted?	2	1	0
6. Was possible spinal injury properly diagnosed and victim handled correctly?	3	2	0
7. Was victim treated for shock?	2	1	0
8. Was help sent for?	1	1	0
9. Was victim properly immobilized and moved properly?	3	2	0

Add _____

Deductions _____

Total _____

Possible 21

Figure 5.3: (continued)

is given prompt and proper first aid care. Many other problem situations can be taken from the MSHA Fatal Injury Abstracts and Illustrations program, as well as from MSHA and state accident investigation reports. Consequently it is an easy task to make up an array of Gilbert type simulations based on case materials.

The first aid simulation shown in Figure 5.2, and two others involving other mine injury first aid situations, were distributed to a group of instructors who routinely teach annual refresher training classes. While these persons found the content of the exercises to be of interest, they were unsure about how effective the exercises might be in their classes, and also unsure how to go about presenting the material. Some thought miners in their classes might be unwilling to participate in such an activity. Others thought the simulation would require too much preparation, or would be too difficult to carry out. Subsequent to these meetings, the Gilbert method was modified to make the exercise purpose more explicit, to make it easier for trainers and miners to use the simulations, and to produce a realistic simulation similar in many ways to the traditional mine rescue exercise simulations popular with miners and trainers.

Examination of the sample exercise in Appendix F illustrates all the basic features of the Gilbert method have been retained, while additional design features have been added that make the simulation easier for miners and instructors to use.

Table 5.4 lists the design guidelines for these newer role play simulations. Each guideline is illustrated by reference to the appropriate part of the simulation exercise in Appendix F.

There are two primary instructional design differences between the Gilbert simulations and these newer first aid simulations. First, with the new method the

Table 5.4: Design guidelines for first aid simulation exercises for miner training

1. The problem should challenge participants' present level of first aid knowledge and skill. There should be an opportunity for the trainee to identify and solve problems, not only the opportunity to demonstrate first aid procedures such as giving artificial respiration or bandaging a wound.

2. The problem context should be authentic with respect to the trainees' workplace experience. The problem, the language used to describe it, the roles and relationships of the victim and role players, the graphic illustrations and the props used to help present the problem, the types of injuries simulated as well as their cause must all be seen as authentic and realistic by the trainees with respect to their workplace experience.

3. The initial problem situation, descriptions of additional background information, and instructions to the role players, should all be brief and articulate statements written in simple language. Drawings, diagrams, graphics, and simple props should be used along with verbal descriptions to present the main aspects of the problem and its context.

4. The initial problem situation needs to be described adequately. Relevant background information that would be known to the persons in an actual problem situation like the simulation should be briefly presented. However, only that information that would be immediately available to the first aiders from the emergency scene itself, from the victim or witnesses, should be available in the initial problem narrative statement. Otherwise, the simulation does not provide the opportunity for the trainee to identify the problem(s), establish treatment priorities, and select and apply relevant first aid procedures.

5. The simulation exercise should be designed to reveal additional information to the problem solvers role playing the first aiders as the simulation unfolds. The instructions to the victim, the placement of injury and accident scene cues, and all other aspects of the problem should be designed to release additional relevant information to the problem solvers as appropriate inquires are made as the problem is worked.

6. Simple props that simulate the key elements of the accident scene, the injuries to the victim, the materials and resources at hand, and any special conditions in the specific accident situation need to be developed and presented throughout the exercise as the problem unfolds. These props can include simple drawings and diagrams of the accident scene including the location and appearance of equipment and the victim, depictions of obvious and hidden injuries through the appropriate placement of injury tags and simulated injuries, special instructions to the victim about how he or she should act or speak, as well as collections of equipment and materials that would usually be available at or near to the accident scene, e.g. other persons, telephones, first aid kits, jackets, tools, etc.

7. The brief printed instructions to those class members who are to role play the victim(s), witnesses, and/or the first aiders need to be prepared on separate cards and presented to the role players when the simulation is introduced. Similar sets of brief instructions need to be prepared and given to trainees who are not involved as actors but will observe the simulation. Prior to the simulation, each group of trainees (victim, first aiders, and observers) need their own set of instructions to define their role in the activity.

8. A performance evaluation sheet by which to rate the effectiveness of the first aid treatment administered to the victim by the first aiders should be prepared. All the key steps in proper first aid treatment for the simulated case should be listed in order on a short and easy to use rating scale. Following the simulation, all the members of the class including the instructor,

Table 5.4: (continued)

the victim, the first aiders, and the observers should rate the first aid performance on the scale. Discussion of the ratings awarded by the instructor and the class members should be used to correct errors, reinforce correct performance, and illustrate first aid concepts, procedures, and techniques.

9. In addition to the materials to be used with the miners in the classroom, an instructor's guide should be prepared for the trainer to meet the following conditions.

10. The instructor's guide should present the problem situation in the brief narrative and graphic form that will also be used to help present the problem situation to the miners. This helps the instructor to grasp quickly the content and context of the problem. (See pages 2 - 4 in Appendix F.)

11. The instructor's guide should describe in a clear and logical manner what the instructor must do before the simulation to prepare for class, what he or she must do during the simulation to ensure an effective session, and what must be done after the simulation to help class members profit from the exercise. This type of detail in the instructor's guide makes it easy for the instructor to prepare for class. Uncertainty about how to proceed is avoided. Detailed prior preparation and planning is assisted by such directions. (See pages 6 - 9 in Appendix F.)

12. The instructor's guide should be designed so that everything needed to prepare for and carry out the simulation is provided. This includes the narrative description and graphics used to present the problem situation to the miners printed in large type suitable for copying to overhead transparencies; injury tags, instructions to the victim, first aiders, and observers all printed neatly on cards that may be cut out and used as is; the performance rating form; additional diagrams, charts, and pictures to be used following the simulation; and suggestions about how to adapt, modify, and enhance the exercise. Those props and materials that cannot be included in the instructor's guide should be commonly available in typical annual refresher training classes. These things include first aid kits, blankets, jackets, tools, and objects like desks and tables used to simulate equipment like roof bolters, continuous mining machines, and such things as rolled up newspapers taped with masking tape to simulate an amputated arm.

13. The instructor's guide and the simulation activity itself should both be designed so that once the instructor prepares for one class, he or she can save the props and materials, and use them again to teach other classes in the future with minimum new preparation time.

14. The instructor's guide and the simulation activity itself should be designed to help instructors generalize these instructional design principles to the planning, development, and use of other simulation exercises generated by instructors themselves.

presentation of the problem scenario is more detailed and complete, but still short and time efficient. In the Gilbert method the problem presentation is accomplished through brief verbal statements and descriptions along with the physical role playing

presentation of the accident scene, complete with the role playing victim and injury tags. (See Figure 5.1.) In the new method the problem situation is presented in more detail. A one page, large typewritten description of the problem and its background features is presented on an overhead transparency. (See page 2 in Appendix F.) In addition, detailed drawings and graphics are presented on overhead projector transparencies. (See pages 3 - 4 in Appendix F.) These diagrams and drawings quickly convey details of the accident scene that would normally be available in an actual emergency, but that are difficult to describe in verbal statements. It is also easy for the instructor to set up the simulated accident scene with reference to the written and graphic depiction of the problem. This simultaneous multiple presentation of the problem through verbal, graphic, and physical simulation of the accident scene and injuries helps make the exercise more realistic and meaningful to the miners who enter the classroom in the role of first aiders or observers.

A second instructional design difference between the Gilbert simulations and the newer method concerns the degree to which the instructor is provided details and assistance in preparing for and carrying out the classroom simulation activity. In typical Gilbert simulation exercises the instructor is provided with little specific information about how to prepare for the simulation, conduct the activity, or engage in fruitful follow up discussion. (See Figure 5.1.) The new method makes these matters explicit. Consequently, instructors who are not skilled in using classroom role play simulations as an instructional method may be expected to do a better job of preparing for and conducting their classes. Examination of the instructor's guide for the sample simulation exercise included in Appendix F illustrates the explicit nature of the

assistance to the instructor in planning and conducting the exercise.

First, the guide presents the problem situation to the instructor in verbal and graphic form. (See Appendix F, pages 2 - 4.) Thus, the instructor immediately knows what the problem is and has information about how the accident scene must be simulated.

Second, the instructor is told how to prepare for the simulation using the materials in the instructor's guide and locally available resources. Specific suggestions include a list of materials and props that must be gathered prior to the simulation, details of how to stage the simulated accident scene, how to recruit the role players, and how to present to the role players and the observers their individual tasks and instructions. (See Appendix F, pages 6 - 7.) Additional directions are provided that explain what the instructor should do during the simulation, and how to conduct an effective corrective feedback and discussion session after the simulation, including using the performance evaluation ratings by class members. (See Appendix F, pages 8 - 9.) Tips are also provided concerning how long the exercise will take, how to save the injury tags and props to make teaching subsequent classes with the same simulation exercise an easy task, and how to adapt and modify the exercise to local situations and needs. (See Appendix F, pages 9 - 10.)

Third, the guide provides the instructor with many of the materials he or she needs to conduct the simulation. A set of performance objectives that define what the class members are to learn is helpful to instructors in clarifying their own thinking about the activity and may be used to report to superiors the purpose and content of the activity. (See Appendix F, page 12.) Ready to use materials needed for the simulation

are included in finished form. These include the performance rating form (pages 13 -14), a trainee questionnaire that allows the miners to evaluate the exercise (page 15), and a similar instructor's evaluative questionnaire (pages 16 -17). The instructor needs only to duplicate these materials with a copy machine. In addition, the instructions to the victim and the first aid role players, the injury tags, and prop tags are all prepared in final form and sufficient number (pages 18-21). Again, the instructor need only make one copy of these, cut out the tags, and mount them on a card. Once this is done the same tags can be used repeatedly in new classes with the same simulation activity. Additional diagrams and drawings are included that may be useful to the instructor when discussing the problem and providing corrective feedback after the simulation. These can be copied to overhead transparencies and shown to the class by the instructor. (See pages 22 -24.) Finally, the reference sources used in the preparation of the simulation problem are provided. (See page 25.)

The observations and studies reported earlier in this chapter suggest that mine health and safety trainers are competent in the technical aspects of what they teach, but less informed about how to design and use effective classroom simulations. An additional important characteristic of these new simulation exercises is their capability to teach instructors how to plan and conduct classroom simulations. The instructor's guide is designed to serve as a model to which instructors can refer as they develop, plan, and carry out their own simulation exercises for annual refresher training classes.

Field Testing the Role Play Simulation Exercises

The sample simulation exercise in Appendix F was field tested in three states at six training sites. Data from three classes were collected and analyzed.

The basic characteristics of the miners involved in these field tests are reported in Table 5.5. There were 59 miners involved in the three classes. The variable number of persons reported in Table 5.5 and later tables reflects missing data in specific categories. Table 5.6 describes the qualifications of the first aid role players in three classes for which these data are reported. The n value is the total number of miners in the class. The number of first aiders is the number of persons who played the part of the first aid care givers. The first class had four first aiders, two of whom are state inspectors with mine foreman certification, a mine equipment sales representative with advanced first aid training, and a mining engineer. The five first aiders in the second class included three mine health and safety instructors, two with advanced training in first aid and who routinely teach first aid, one mine supervisor, and one miner. The three first aiders in the third class included two miners with only the usual training in first aid, and a mine foreman with advanced first aid training. None of the first aid role players were trained or certified as EMTs. Observers from the University of Kentucky were present in the first and and second classrooms.

The data gathered from these three classes were analyzed and used to report two basic types of findings. These are 1) the miners' evaluation of the simulation exercise based on the pooled ratings by all class members on specific criteria (see the Trainee's Questionnaire on page 15 in Appendix F), and 2) the miners' performance ratings of the first aid skills of the three groups of persons who role played the first aiders in each classroom.

Miners' Evaluations of the Simulation Exercise

Miners' evaluation of the exercises provide important information about how

Table 5.5: Characteristics of the field test sample for a first aid simulation exercise (3 sites, 3 classes)

age and experience of miners (years)

	n	mode	mean	s.d.
age	56	37	36.4	9.16
experience	45	-.-	8.3	6.13

gender distribution %)

	n	frequency %
female	0	0
male	56	100

job classification	n	frequency %
miner	28	51.8
maintenance /technical	12	22.2
supervisory /management	13	24.1
other	1	1.9

Self-reported level of expertise (frequency %)

category	training	certification	performance
foreman	17.9	16.1	1.8
mine safety committee	3.6	8.9	1.8
mine rescue	5.4	3.6	1.8
CPR	17.9	26.8	12.5
advanced first aid	25.0	10.7	8.9
EMT	7.1	12.5	1.8
advanced life support	7.1	3.6	0.0
other	3.6	7.1	5.4

Table 5.6: Class size and number and qualifications of "first aiders" at three sites

Class	n	No. first aiders	Qualifications of first aiders	Observer present?
Class 1	18	4	2 state mine inspectors 1 sale representative with AFAT* 1 engineering technician	yes
Class 2	7	5	3 instructors, two with AFAT 1 mine supervisor 1 miner	yes
Class 3	31	3	2 miners 1 mine foreman with AFAT	no

*AFAT = self reported Advanced First Aid Training

acceptable the materials are to the population for which they were designed. If instructional materials are designed well, they not only include worthwhile objectives and content, but they also are perceived as relevant and worthwhile by those who are to use them.

The results of the miners' evaluations of the exercise are presented in Table 5.7. Summing the values in the first two columns of the table, all the miners reported the exercise content to be authentic and realistic. Other qualities of the exercise were also rated highly. The results in Table 5.7, observations by project members, and instructor's comments indicate that both miners and instructors were able to use the simulation effectively. Miners were willing and able to carry out their role play assignments. Both the miners and instructors were able to execute all aspects of the activity as planned in the instructor's guide. Both the miners and instructors used the performance evaluation form properly. It appears that the role play simulation exercises developed are acceptable to miners and instructors.

Table 5.7: Miners' rating of exercise validity, relevance, quality, and utility (n = 59)

Content	definitely Yes		definitely No		mean	s.d.
	4	3	2	1		
problem could happen	94.4	5.6	0.0	0.0	3.94	0.23
help remember important things	78.2	20.0	1.8	0.0	3.76	0.47
learned something new	60.0	27.3	10.9	1.8	3.46	0.77
exercise too long	14.8	20.4	13.0	51.9	1.98	1.16
liked working the exercise	67.3	25.0	7.7	0.0	3.60	0.63
instructor directions clear	72.7	21.8	5.5	0.0	3.67	0.58
written exercise directions clear	59.3	37.0	3.7	0.0	3.56	0.57
graphics easy to understand	58.2	34.5	5.5	1.8	3.49	0.69
scoring easy to understand	67.3	21.8	3.6	7.3	3.49	0.88

Miners' First Aid Performance on the Simulation Exercise

The analyses that follow are based on the performance of the first aiders in each class. Fifteen aspects of the first aiders' performance were rated on a common rating form. Each of the 15 scales on the form was designed to evaluate key aspects of rescue and first aid procedures needed to cope with the simulation problem. The problem involved a miner whose legs were crushed by a roof fall after he went under unsupported top to mark up the bolt pattern for the roof bolter. A proper performance requires the first aiders to assess the accident scene, support the top, remove the rock from the injured miner, and rapidly move the miner out of this dangerous area. Only then is it appropriate to evaluate the victim for injuries, communicate with the surface, provide first aid care, and prepare to transport the victim to the surface. The problem is described in Appendix F on pages 2 - 4. The performance rating form is found on pages 13 - 14 in Appendix F. All members of the class, including the victim, the first

aiders, the observers, and the instructor rated the first aiders' performance on the form.

The performance rating form was found to be a reliable measure. Table 5.8 presents the internal consistency reliability estimates of the form for the miners in each of the three classes, and with the miners from all three classes pooled. Thirteen of the 15 scales on the performance rating form were significantly positively correlated with the total score on the form. Items 9 and 10 (sending for help and communicating clearly to the surface) were not significantly correlated with the total performance rating score.

Comparison of the within classes and between classes sums of squares revealed that 52 percent of the variance in performance scores among the three classes can be attributed to differences in the first aiders' performance in the three classes. The remaining 48 percent of the observed variance in performance scores is attributed to variations in miners' individual ratings of the same observed performance.

Table 5.8: Internal consistency reliability estimates of the performance rating form

Class	Complete ratings*	Number of first aiders	Generalizability coefficient (alpha)†
Class 1	16	4	0.69
Class 2	7	5	0.64
Class 3	26	3	0.77
Classes pooled	49	12	0.80

* Only those rating forms that contained a complete set of ratings on all 15 questions were included

† The generalizability coefficient is an estimate of the internal consistency or reliability of the scale. The maximum possible value is one and the minimum value is zero.

The performance rating total score for the first aiders in each class was summed across the 15 scales for each rater. The average rating was then computed for each group (class) of first aiders. Large significant differences were observed in the total performance scores earned by the first aiders in each class ($F = 24.80$; $df = 2,46$; $p < 0.0001$). These results are reported in Table 5.9.

Table 5.9: Means and standard deviations of total performance score by class

Class	Complete ratings*	No. first aiders	Mean Score*	s.d.
Class 1	16	4	55.34	11.15
Class 2	7	5	73.52	13.09
Class 3	26	3	35.37	15.45

*Total raw scores were converted to a scaled 0 to 100 score.

The difficulty of each part of the first aid performance required by the simulation may be estimated from the raw scores of the 15 individual scales found on the performance rating form. Table 5.10 presents a description of the performance content of each scale on the rating form along with the maximum score for that scale, the mean score observed, and the standard deviation. These data are pooled across all three classes from a total of 49 ratings for the 12 role players.

Table 5.11 presents the same data, but broken down for each of the three classes. The large significant differences in observed total scores for the three classes are reflected in the differences in raw scores on the individual scale items.

Table 5.10: Difficulty for each of 15 rescue and first aid performance tasks*

Scale and performance dimension		Raw score statistics			
Item no.	Item performance content	Maximum	Minimum	Mean	s.d.
1	support mine roof before entering face area	3	0	1.39	1.40
2	safely remove draw slate from victim	2	0	1.12	0.99
3	properly remove victim from under slate	3	0	2.16	1.14
4	verbally encourage victim	2	0	1.08	0.73
5	promptly rescue drag victim under good top	3	0	2.45	1.00
6	handle victim properly when rescue dragging	3	0	1.57	1.15
7	conduct primary and secondary survey	3	0	0.55	0.79
8	find and treat both leg injuries	3	0	0.47	0.87
9	send for help promptly and properly	2	0	1.67	0.55
10	communicate clearly and accurately to the surface	2	0	1.08	0.76
11	properly position and lift victim to stretcher	3	0	1.35	1.13
12	properly immobilize victim on back on stretcher	3	0	1.02	1.11
13	examine and treat victim for shock	3	0	1.33	1.20
14	maintain unconscious victim's airway	3	0	1.27	1.29
15	organize overall first aid and rescue efforts well and efficiently	3	0	0.90	0.85

*Performance data are raw scores for three first aid teams rated by 49 miners on all 15 performance items

Table 5.11: Differences in difficulty of 15 performance tasks by first aid group (class)*

	Class 1		Class 2		Class 3		Significance
Item no.	Mean	s.d.	Mean	s.d.	Mean	s.d.	p less than
1	3.00	0.00	1.57	0.98	0.34	0.85	.0001
2	1.94	0.25	1.71	0.76	0.46	0.86	.0001
3	2.88	0.50	2.43	0.98	1.65	1.23	.0012
4	0.69	0.70	1.86	0.38	1.12	0.65	.0028
5	2.44	1.03	2.71	0.76	2.38	1.06	.6496
6	1.88	1.20	2.14	1.07	1.23	1.07	.1448
7	0.31	0.48	1.43	1.13	0.46	0.71	.0538
8	0.31	0.48	1.00	1.41	0.42	0.86	.0319
9	1.50	0.63	1.86	0.38	1.73	0.53	.1259
10	0.69	0.60	1.00	1.00	1.35	0.69	.0155
11	1.25	0.93	2.71	0.76	1.04	1.08	.0138
12	1.06	0.85	2.14	1.46	0.69	0.97	.0060
13	2.06	1.12	2.43	0.98	0.58	0.70	.0001
14	1.88	1.20	2.71	0.76	0.50	0.86	.0001
15	0.81	0.40	2.43	0.98	0.54	0.51	.0001

*Performance data are raw scores for the first aid teams at each site on each performance item

Interpretation of Miners' Performance Scores

Four features of the performance results stand out. These include: 1) the total performance scores are low for all groups; 2) all groups did an adequate job on only two scales, 3) the worst performance of the first aiders was in conducting the victim evaluation and treating hidden injuries, and 4) large differences exist in the

performance scores of the first aiders in the three classes.

The overall scores are low for each group of first aiders. (See Table 5.9.) When the same exercise is given as a latent image test, miners' scores are typically higher. The role play simulation version of the exercise requires miners to problem solve with less guidance than is offered in the latent image version of the exercise. Latent image exercises provide corrective feedback revealed through the invisible ink messages as these are developed in the course of working the exercise. Thus, miners learn and correct first aid procedural errors as they complete the latent image exercise. In the role play simulation exercise, just as in real life, there is no corrective feedback beyond that available from others present. If the first aiders make errors, they may not know it at the time. In addition, unlike the paper and pencil latent image version, the role play exercise requires not only knowledge of what to do and when to do it, but also skill in performing actual first aid procedures without prompting. Consequently, the role playing simulation is closer to real life situations and is more difficult than the latent image version. Like a well designed mine rescue contest, the first aid simulation is a good test of knowledge, skill, and actual performance capability.

The first aiders in all three classes did a good job on only two tasks, properly removing the victim from under the shale (item 3), and promptly rescue dragging the victim outby the face to get under supported mine roof (item 5). (See Table 5.10.) Both of these tasks are rescue activities and both are obvious actions.

The worst performance for all three groups of first aiders involved conducting a victim evaluation through a primary and secondary survey (item 7), and finding and treating both leg injuries (item 8). (See Tables 5.10 and 5.11.) The first aiders in Class

1 and Class 3 did not carry out an adequate hands-on primary and secondary survey. Consequently, they never found the compound fracture of the femur, even though it was simulated with a broken broom handle taped to the victim's right front thigh along with a large injury tag that said, "MUCH BLOOD AND BONE STICKING OUT." (See Appendix F, page 20.) This simulated injury was concealed underneath a pair of coveralls, and the injured miner was lying face down. Another large injury tag that said, "BLOOD SOAKED CLOTHING" was attached to the outer coveralls directly over the simulated fracture. Even a cursory hands-on and/or careful visual primary survey would have quickly revealed the presence of these injury tags and the simulated compound fracture. The injured miner was loaded and tied onto the stretcher face down. Consequently the injury remained undiagnosed and untreated. The first aiders in Class 2 carried out a victim injury assessment. Because of their survey, they found and treated both simulated leg fractures. However, they had difficulty in properly bandaging and splinting the compound thigh fracture. The types of errors made by these miners in this realistic simulation are precisely those tasks that the 120 experts identified as weaknesses in miners' actual first aid performance they had witnessed in the field. (See Tables 5.2 and 5.3.)

Large statistically significant differences were observed in the total performance and the individual scale scores of the three groups of first aiders. (See Tables 5.9 and 5.10.) The groups with the greater number of first aiders with self-reported advanced first aid training, and with first aid instructors performed better than the less well trained groups without first aid instructors.

Paired Latent Image and Role Play Exercise Administration

After miners have completed a latent image exercise, a role play simulation version of that same exercise can be used to give hands on training in the first aid procedures discussed in the latent image exercise. When used this way, the role play exercise is not appropriate for testing because the miner knows what is coming next. It is, however, an effective training device.

When the role play simulations are given alone, the overall scores are low for each group of first aiders. (See Table 5.9.) When the same exercise is given as a latent image test, miners' scores are typically higher. As noted previously, the role play simulation version of the exercise requires miners to problem solve with less guidance than is offered in the latent image version of the exercise. Unlike the paper and pencil latent image version, the role play situation exercise requires not only knowledge of what to do and when to do it, but also skill in performing actual first aid procedures without prompting. The first aid simulation is a good test of knowledge, skill, and actual performance capability.

A latent image version and a role play simulation version of the same exercise can be used in tandem to obtain the best features of both methods. This method of dual administration was field tested with 49 miners in 5 classes. The basic characteristics of the miners involved in this field test are described in Table 5.12.

Table 5.13 shows the mean and standard deviation of the total performance score for this group. Comparing these performance data with the scores in Table 5.9, it can be seen that miners score considerably higher on the role play simulation after working the latent image version of the same exercise. This is because the corrective

Table 5.12: Characteristics of the field test sample for a first aid simulation exercise given after a latent image version of the exercise (1 site, 5 classes)

age and experience of miners (years)

	n	mode	mean	s.d.
age	49	41	44.6	10.93
experience	48	10	19.4	9.88

gender distribution %

	n	frequency %
female	0	0
male	49	100

job classification	n	frequency %
miner	23	56.1
maintenance / technical	17	41.5
supervisory / management	1	2.4
other	0	0.0

Self reported level of expertise (frequency percent)

category	training	certification	performance
foreman	0.0	2.0	0.0
mine safety committee	0.0	2.0	0.0
mine rescue	2.0	4.1	4.1
CPR	40.8	4.1	55.1
advanced first aid	83.7	4.1	6.1
EMT	0.0	2.0	0.0
advanced life support	4.1	0.0	0.0
other	0.0	18.4	0.0

Table 5.13: Mean and standard deviation of total performance score for a role play simulation exercise administered after the latent image version

Complete Ratings*	Mean Score*	s.d.
46	93.48	11.67

*Total raw score was converted to a scaled 0 to 100 score.

feedback from the latent image exercise, as well as learning about the injuries, informs miners about the extent and nature of the victim's injuries and proper first aid treatment procedures. Working the role play simulation exercise after completing a latent image version of the same problem becomes primarily a session devoted to the practice of specific first aid treatment procedures when injuries are known. Used this way, the role play simulations are still popular and useful teaching tools, but they lose a degree of authenticity. The opportunity for first aiders' initial problem identification and diagnosis of the victim's injuries is lost.

Limitations and Generalizability of Findings

The main results presented in this chapter are based on the performance of only 12 miners who role played first aiders coping with one complex and realistic underground coal mine first aid problem. The performance results observed may not generalize to other groups of miners or to other first aid simulation problems or actual emergencies. Additional data from the first aid simulation described in this report, as well as from other similar simulations, are currently being collected and analyzed. These additional data may help determine the generalizability of the findings reported here.

Some additional observational data were collected. Two additional first aid simulation exercises were observed during administration to two classes. In these classes, the miners role playing the first aiders also performed poorly and made the same types of errors as those reported above. Thus, even though the sample is small, the findings from this initial study may be generalizable to the broader domain of first aid performance of miners in general.

The simulations are carefully designed to be authentic and realistic, and over 94

percent of the miners viewed them as such. (See Table 5.7.) Performing the first aid procedures in front of a classroom, without any prior warning or preparation, is stressful for the first aid role players. Yet, the classroom role play situation can never be as stressful and demanding as is coping with a similar serious injury accident in an underground mine. If miners perform poorly in realistic classroom simulations of first aid emergencies, they may perform even less well in actual mine first aid emergencies. The poor performance is probably related to lack of training in these types of first aid tasks, particularly in the skills required for patient evaluation to define first aid treatment needs and priorities. Miners who are frequently exposed to realistic first aid simulation problems, like those described in this report, may become more skilled in their responses to both simulated and actual first aid emergencies.

Simulation Exercises as Teaching Devices

Although the miners role playing the first aiders in these three classes may not have performed well on the simulation exercise, they reported the activity taught them important skills and information they thought they would remember. (See Table 5.7.) The purpose of these exercises is primarily to teach miners to be better first aiders. The realistic nature of the exercises engages intense participation of the role players and the observers. At the end of the simulation, the first aid role players, the victim, and the observers are anxious to critique the performance, to discuss and correct errors, and to repeat and practice difficult parts of the performance until these have been mastered.

First aid knowledge and skills presented piecemeal, without being embedded in realistic problem contexts, tends to become "inert." Inert knowledge fails to generalize

to real world problem solving and also tends to be rapidly forgotten (Bransford, Sherwood, Vye, Rieser, 1986; Halpern, 1984). It is important for miners to learn how to place and tie dressings and bandages, and to remember first aid facts and information. The teaching of first aid procedures like these, and drilling miners on recall of first aid facts are popular instructional methods in annual refresher training classes. However, when these facts and procedures are presented in fragmented ways, without being placed in the context of first aid cases or problems, instruction cannot be expected to adequately prepare miners to cope with actual first aid emergencies. First aid facts and knowledge, as well as first aid skills in bandaging, controlling bleeding, and other procedures, need to be taught in the framework of realistic problems. Skills of accident scene evaluation, patient evaluation, and the identification of victim's treatment needs and priorities should be practiced. Well designed role play simulation exercises provide one means for the integrated practice of first aid knowledge and skills in the context of realistic first aid problems.

Conclusion

The research reported in this chapter, as well as earlier research by Pikar (1977) suggests miners need more training in information gathering, victim evaluation, and first aid problem identification and prioritization skills. Simulation exercises like those discussed in this chapter can be used to teach and maintain proficiency in these and other skills. Data from field studies at Ohio State University and the University of Kentucky suggests that college students and miners value realistic first aid simulation problems. Time to conduct such realistic simulations need not be a barrier. The simulation described in this chapter can be completed in a 20 to 30 minute period, with

an equal amount of time for discussion following the exercise. Knowing how to design and conduct an effective first aid simulation also need not be a barrier. The guidelines set forth in this chapter, and the sample exercise in Appendix F, can serve as a model for first aid instructors who wish to extend the procedures to other problems.

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Chapter 6: Impact on Miner Training

Chapters 2, 3, 4, and 5 describe the types of simulation exercises developed under this contract. This chapter discusses additional qualities of the exercises and their use. Data reviewed in earlier chapters indicate that the simulation exercises are eagerly accepted and used by mine trainers and miners. Shortly after the recent release of 17 of the 36 exercises for national distribution by the National Mine Health and Safety Academy and the Institute for Mining and Minerals Research, over 20,000 exercise answers sheets were ordered by many different mining companies and training centers. Much of this willingness of trainers and miners to use the exercises is related to exercise design features discussed in earlier chapters. However, the ease with which the exercises can be used in a variety of settings, their low cost, and their ability to integrate factual information and problem solving skills also contribute to their acceptability. The exercises also provide instructors with new ways of thinking about and planning instruction.

Inexpensive and Easy to Use Materials

An important design characteristic for instructional materials is that they be inexpensive. Another design criterion is that the materials be easy to obtain and use. If instructional materials fail to meet these criteria, they are not likely to be disseminated and used by the groups for which they are intended.

Little additional funds, special expertise, or equipment beyond that typically available to mine health and safety instructors is needed to obtain and use any of the exercises. Detailed but simple procedural guides and discussion notes are provided

in the exercise instructor's manuals to assist with preparing for and conducting an effective class session using instructional resources typically available.

The latent image exercises do require special pens and special answer sheets. Pens cost about 60 cents each and answer sheets from 25 to 35 cents each. The pens have a shelf life of about three years. If the exercises are administered in small groups, only about 25 reusable problem booklets, four or five consumable answer sheets, and four or five latent image marking pens are needed per class of 25 miners. Small group exercise administration not only conserves latent image answer sheets and marking pens, but is also popular with miners and instructors. In addition, small group administration also more closely simulates the conditions under which miners gather information and make decisions in actual mine emergency situations.

The exercises and related materials may be obtained at cost from the National Mine Health and Safety Academy in Beckley, West Virginia or from the publications department of the Institute for Mining and Minerals Research, University of Kentucky. Information about ordering materials is found in each exercise instructor's manual.

If mine trainers wish, they can assemble locally all the materials needed for any exercise. The instructor's manual for each exercise contains master copies needed for duplicating all parts of each exercise. The problem booklets can be photocopied. The latent image answer sheets appended to the instructor's manual can be duplicated locally using mimeograph equipment and special invisible ink available from A. B. Dick. The latent image marking pens also can be purchased from local A. B. Dick suppliers.

Effectiveness in a Variety of Training Environments

Another important design criterion is that instructional materials be able to function well in a wide range of training environments. Annual refresher training in the mining industry occurs in well equipped and modern classrooms, conference rooms, lunch rooms, mine bath houses, shops, working sections within the mine, and a variety of other places.

The simulation exercises developed under this contract were designed to work well across this variety of settings. The immediate feedback provided in the latent image exercises has many of the advantages of computer administered testing and instruction. However, unlike computers, the latent image exercises require no electricity and no special equipment other than the marking pen and answer sheet. The pens, answer sheets, and problem booklets are small and portable. They can be used in nearly any location where miners are being trained.

The SCSR donning exercise does require the presence of SCSRs, but these are needed in any type of effective task training to achieve donning proficiency. The only other special equipment needed is a videotape player and monitor and an overhead projector. Yet, neither of these is vital since the diagrams of the correct positions and sequences can be shown as posters and the correct donning sequence demonstrated live by the instructor. Consequently, the SCSR exercise can be carried out in any type of training room or at the mine site in the bathhouse, underground, or in a parking lot.

The first aid simulation exercises provide all the injury tags and labels needed by the instructor as well as the problem scenario and graphics that depict the accident scene. Detailed instructions are also provided for the victim and first aider actors. The

instructor's guide provides a list of materials the instructor needs to gather and explains how to prepare for, carry out, and follow up the simulation. Again, no special materials or equipment are required beyond those that are typically available to annual refresher class instructors. If an overhead projector is not available, the graphics and problem scenario can be shown as posters. Because they make use of equipment and materials already on hand, there is little additional cost for an organization or an instructor who decides to use one or more of the role play simulations.

Effective Integration Into Ongoing Instruction

When new instructional materials work well, they assist instructors in doing a better job of their ongoing instruction. This is another design criterion established for the exercises developed under this contract.

Instructors easily and effectively integrate the simulation exercises into their ongoing annual refresher training classes. This observation is supported by data obtained from completed instructor questionnaires, many observations of annual refresher training classes, and frequent discussions with instructors while arranging for field tests of materials. These results are reported in earlier chapters.

Several reasons why the exercises are easily integrated into ongoing annual refresher training have been discussed earlier. The exercises are inexpensive and easy to use. They deal with authentic and interesting problems that stimulate the interest of trainers and miners. They rarely require more than one hour of classroom time. The directions for working the exercises are simple, and the exercises themselves require little reading, or are easy to read. Working the exercises encourages dialog and debate among miners. But the exercises have additional

properties that make them easily integrated into annual refresher classes.

First, the exercises focus on topics that are generally included in annual refresher training. The content of the exercises includes material that trainers frequently teach and discuss. However, the exercises cast this content into interesting problem solving situations. Thus, while the content and details of the simulation problems are not new to miners and trainers, the problem solving method of instruction is different and interesting. As noted in earlier chapters, problem solving approaches to instruction are especially effective for helping people learn, remember, and apply information and skills to their personal lives and work, and for motivating high levels of learner participation and achievement.

Second, each exercise is performance based. That is, the exercise objectives set forth the specific performance capabilities that miners must display to work through a simulated problem. These include things miners should know, as well as the judgments, decisions, and actions they should take to prevent or to resolve a problem.

Third, the simulation exercises provide opportunity to both practice and discuss the problem solving skills required for an effective performance. Traditional annual refresher training tends to focus on conveying and discussing information miners should know about topics like roof control, mine gases, or primary and secondary escapeways. There tends to be less emphasis upon the judgments, decisions, and actions miners must take to prevent or resolve problems. The critical skills involved in these types of problem solving situations tend to be discussed rather than practiced. On the other hand, the simulation exercises emphasize the practice of these critical skills as well as discussion of relevant information and its articulation with actions to

prevent and solve problems.

The typical content oriented instruction that precedes and follows the use of a simulation exercise can easily be related to and strengthened by inclusion of a relevant problem solving exercise in the days' training plan. For example, information about sources, detection, and effects of carbon monoxide is often taught in annual refresher classes. The same information can be taught and made more meaningful when a simulation exercise like the Chester O. Peterson or Water Line Repair problem is used. (See Appendix A for descriptions of the content of these exercises.) The simulation exercise provides a realistic problem and context that reveals why this information is important and how it must be used in combination with judgment and decision making skills when coping with an actual emergency. It is this ability of the exercises to integrate relevant information and critical skills in the context of solving problems that make them valuable instructional tools for annual refresher training classes. This important design characteristic for simulation exercises is discussed in earlier chapters of this report, the two earlier technical reports (Cole, Berger, Vaught, Lacefield, Wasielewski, Haley, & Price,1988a; Cole, Berger, Vaught, Haley, Lacefield, Wasielewski, & Mallett, 1988b), and other publications (Bransford, Sherwood, Vye, & Rieser, 1986; Cole, 1971; Cole, Moss, Gohs, Lacefield, Barfield, & Blythe, 1984; Halpern, 1984; Jones, 1987; McGuire & Babbott, 1967; McGuire, Solomon, & Bashook, 1976).

Modeling New Ways to Teach and Learn

The consistently high ratings assigned by miners and trainers to the exercises suggest that both see these new approaches to teaching and learning as relevant and

interesting.

After instructors experience using an exercise or two, many develop ideas and insights for other classroom activities. The most frequent insight gained by instructors, as reported to project researchers, is that miners in their classrooms work productively in small groups when given an interesting problem situation to resolve. The exercises suggest and model new ways for instructors to think about and to arrange instruction.

The SCSR exercise illustrates this point. This exercise demonstrates simple means by which to conduct performance oriented task training. The methods and procedures can be generalized to other tasks that require manipulation of equipment and knowledge of procedure. Examples include performing the start up and shut down walk around inspection for a piece of equipment, or the operation of a piece of firefighting equipment.

The role play simulation exercises demonstrate vividly the need for hands on practice in first aid, not only in treating injuries and wounds that are clearly identified, but in assessing the accident scene, removing and rescuing the victim, and actively looking for and diagnosing the vicitm's hidden injuries through a hands-on head to toe primary and secondary survey. The importance of good communication with the victim, fellow first aiders, surface personnel, and medical personnel into whose care the victim is delivered also becomes apparent, skills <u>not</u> usually emphasized in typical first aid instruction. Instructors who witness miners having difficulty performing the patient assessment skills and communication skills during the simulation exercise may place greater emphasis on these areas in their subsequent first aid instruction. The format of the role play simulation exercises also makes it easy for instructors to adapt

the technique and procedures to other first aid problems of their choice.

The paper and pencil simulation exercises also demonstrate new ways to approach discussion of hazard recognition and correction, accident prevention, and emergency response procedures. Both miners and trainers are familiar with reviewing accident and disaster reports. However, neither are usually familiar with presenting these as unfolding problems that require information gathering and decision making as the problem emerges and runs its course. Yet, both quickly recognize the validity of the problem solving approach and more fully appreciate the many information gathering and decision points that are present in nearly any mine emergency situation. Working the exercises emphasizes that prevention of accidents and disasters is closely related to proper mining procedures and safe work practices, and not primarily a matter of luck.

Each exercise also focuses on one accident case. Working and discussing the exercise enhances the comprehension of the accident situation. Its contributing factors, its consequences, and the means for its prevention become fully apparent. During and following the exercise, miners and instructors talk about the case as if they were personally involved in the situation. However, unlike the casual discussion of an actual accident that is often uninformed or misinformed, the discussion of the exercise accident case is fully informed by the detailed class analysis. Furthermore, the details of the exercise accident case are purposely generalizable to other potential and actual accident situations that miners have experienced or may experience in the future. The process of working the exercise makes explicit the critical skills and knowledge for preventing and/or coping with such an emergency. The exercise stimulates discussion

of procedures, methods, and policy for preventing and dealing with such events. Points that are unclear or misinformed in existing mine section or company procedures and in miners' knowledge become apparent and can be clarified and corrected. Thus miners may be better prepared to prevent and cope with actual mine emergencies in the future.

Cautions in the Use of Exercises

The many mine health and safety instructors involved in the field tests generally used the exercises intelligently and well. However, a few trainers were occasionally observed using the exercises in ineffective ways.

Perhaps the most common misuse is to administer the exercise to a class, but to allow no time for discussion. Earlier sections of this chapter make it clear that the exercises are designed to be integrated with ongoing annual refresher training. The instructions in each instructor's manual also emphasize this point. Miners need the opportunity to discuss the exercise, express their opinions and concerns, and debate the merits of various actions and choices at points in the problem. This type of classroom dialog is central to the purpose of the exercises. It helps miners internalize the relevant knowledge and skills presented in the problem, and to generalize these to their work and life.

Another misuse of the exercises is to use too many of them during the course of a training session. Most of the trainers involved in the field tests of the exercises suggest that about two of the simulations per day are optimum in an eight hour annual refresher training class. Many trainers use one exercise in the morning and another in the afternoon. These instructors tend to carefully select exercises that are appropriate to

the capabilities of the persons being trained, and that deal with content and topics the trainer wishes to emphasize. When exercises are used in this manner, instructors are able to integrate and articulate the working of the exercises with the other instruction that occurs during the day.

Even when exercises are appropriately selected and matched to the needs and capabilities of the trainees, including more than two exercises in a half day or day long training session may be problematic. Although interesting and enjoyable, the exercises tend to be demanding in terms of the concentration required and the emotional involvement they stimulate. Trainees can become weary from working too many exercises in too short a time period.

A clear misuse of the exercises is to perceive them as a convenient way to fill up instructional time because the instructor is not prepared or not willing to become prepared for class. To be used effectively, the instructor should carefully select exercises that match his or her goals, and that fit the needs and capabilities of the class members. A very easy basic first aid exercise may be boring and insulting for a group of well trained EMTs. A complex first aid problem designed for paramedics will frustrate and anger a group of miners with only basic first aid skills. A technical exercise designed for mine ventilation engineers is not appropriate for persons without this special training and interest. The exercise description list in Appendix A, and the instructor's copy of each exercise contains a concise description of the exercise performance objectives, the content, and the intended audience for the activity. Instructors should use this information to choose exercises that match and can enhance the instructional needs and goals for their classes. In addition, once an

instructor has selected an exercise, he or she should first work through the exercise, and then study the instructor's manual, especially the discussion notes. Otherwise the instructor may not be prepared to include the wealth of additional information that can be discussed and taught during and following working an exercise. The exercises and their discussion notes are designed to encourage and assist the instructor to contribute his or her own ideas and insights to the activity. This requires time for the instructor to think about and reflect on the problem presented in the exercise and its relevance to particular workers and their mining operation.

Occasionally one encounters an instructor who views the exercises as problems with specific right and wrong answers, and who has little sympathy for any opposing views or solutions. The exercises are not designed to be used in this manner. When they are used this way, they will not work well, and may anger and frustrate miners. Earlier chapters of this report, as well as the instructor's manual for each exercise, make it clear that the exercises are designed to help miners think about and solve problems. Each problem has a sequence of actions and choices that experts generally agree to be the best solution. However, the exercises contain predicaments at many points. This helps makes them realistic. Even the experts do not agree on every detail concerning what actions should be taken at given points in a problem, and why or why not. Proper use of the exercise involves encouraging miners to understand this point, and to express and discuss their views. If miners are not permitted to do this, the exercises will be seen as less interesting and valuable, and an opportunity to assist the further reflection and internalization of exercise content and skills will have been missed.

Longevity of the Exercises

The 36 exercises developed by the project provide a sample of training materials that mine health and safety trainers can use for approximately a four year period without ever using a given exercise more than once for a particular group of miners. An annual refresher class may be expected to use about two exercises per year. Sufficient variety and content exists in the exercises presently developed so that most trainers can find material that is relevant for their classes for at least a four year period. Over the four year period eight exercises might be used. Of course, the exception to this is the SCSR exercise. To maintain miners' proficiency in this critical skill, it should be used repeatedly, at least once a year and perhaps more often.

Unlike a training film, the same latent image or role play simulation exercise cannot be used over and over again with the same class. This is because exercises simulate actual problems that unfold over time. The unfolding of the problem, and not knowing what will happen at the next stage, is required to simulate the information gathering and decision making activities that the miners must perform at each of several points in the problem. Therefore, new exercise material must be developed for future years.

It is not difficult to develop or to modify existing exercises to create a succession of newer exercises for use with the same miners in annual refresher classes in subsequent years. The present exercises were developed from actual case materials. There is no shortage of such material. It is also possible to revise the story line and change the background and problem scenario of an existing exercise and thus create a new exercise. For example, the Low Coal Fire exercise deals with a burning scoop

in the intake airway of a 28 inch coal seam, with an exhausting ventilation system, in a nongassy mine where there is no water line. If the problem situation were changed to high coal, in a gassy mine, with a blowing ventilation system, with a belt fire in neutral air, the entire problem and the optimum actions would change. The problem would be a new and different exercise, even though the same basic principles would be involved, and the performance objectives would remain the same.

Existing exercises can be adapted to new formats, and new exercises can be developed in a variety of formats. Several independent lines of evidence suggest that it is not the latent image format that makes the exercises effective instructional tools. Poorly designed latent image exercises are not accepted by miners and instructors. The SCSR exercise, the nonlatent image paper and pencil exercises, and the role play simulations are equally as interesting and engaging to miners as are the latent image exercises.

Miners do not tire of working the exercises. Some miners at specific field test sites have worked as many as six different exercises over a three year period. These miners and their instructors have not tired of the exercises, nor of the techniques used to administer them. Field evaluation data reveal that both want more exercises for future classes. These data suggest the exercises are not a new fad in a series of short lived techniques that may appeal to persons because of some technological gimmick. Rather, it is the design, the content, and the problem solving nature of the simulations that appeal to miners and instructors. These observations are consistent with the finding of other researchers concerning the effectiveness of problem oriented performance based instruction.

This modification of existing exercises, and the development of new exercises assumes those involved have a knowledge of the basic instructional design features that underly the exercises, as well as technical expertise in exercise content.

Teaching Trainers to Develop Similar Exercises

Since the initial field test of the first exercises, a number of trainers have expressed an interest in developing similar exercises. Some trainers have developed their own simple exercises, usually in the first aid area. Others have experienced difficulty, finding the development of a good exercise to be more time consuming and difficult than they first anticipated. Still other instructors have adapted a few of the exercises developed under this contract to better meet their own local situation. Most of these adaptations have changed first aid exercises designed for underground coal mines to surface mining situations.

A completed exercise appears deceptively simple. Careful planning and design work is involved in selecting and constructing an exercise. In the course of completing this contract, much has been learned about how to design simulation exercises for annual refresher training classes. This information can be taught to other miner health and safety trainers who are located in technical schools, community colleges, and company training centers. Trainers located in these types of centers worked closely with trainers from many mining companies and conducted many classes during the field testing of the exercises. The Bureau of Mines and the University of Kentucky are currently funding a year long project that will assist groups of trainers in these centers to continue to adapt and develop new exercises for use in future classes. Many more exercises will be developed for surface mining, and for metal and nonmetal mining.

New exercise formats will also be conceptualized and designed.

Developing an exercise is a time consuming process. However, only one or two exercises are typically needed per annual refresher training class. If groups of instructors in a region collaborate, they can easily develop and share a sufficient number of exercises for use in their classes. Instructors located in centers in different regions can exchange exercises and ideas. An exercise developed to teach and assess electrical equipment diagnostic procedures and safe work practices for a drill at a surface coal mine in Illinois can easily be adapted to teach similar skills and safe work practices for a similar piece of electrical equipment at another surface or underground mine in some other region.

To date, regional workshops for trainers have been conducted at three regional centers. The training is designed to teach mine trainers the basics for adapting and developing new simulation exercises. Instructional materials for this purpose have been prepared and are currently being revised. Persons at each center have begun adapting some of the existing exercises to their own local and regional mining conditions. The development of new exercises is beginning.

The personnel in these regional centers include instructors from regional vocational schools, community colleges, technical schools, state mining departments, company training centers, and private trainers. This array of persons and organizations has sufficient interest and resources to adapt, develop, field test, and disseminate exercises within their regions. Once a year or so, key persons from each region may be brought together at a meeting like the National Mine Instructors Conference at the National Mine Health and Safety Academy to exchange ideas,

information, and materials. Once in place, such a network can serve not only as a means to develop and disseminate new exercises, but also to disseminate other technology and knowledge. The network can also serve as an entry point for planning and conducting future research projects.

Conclusion

This chapter calls attention to qualities of the exercises not reported in earlier sections of the report. It also discusses effective and ineffective ways to use the exercises. The results of the field tests reported in earlier chapters suggest that the exercises developed under this contract have potential for improving annual refresher training for miners. Although the exercises developed under the contract are designed mainly for underground coal mining, the techniques are generalizable to all types of mining, mining related, and other industries. In the future, the work completed for this contract may help others to develop similar approaches for refresher training of personnel whose work requires performance of critical skills. The contract technical reports and materials have been designed to provide models for others who may have an interest in refining and extending the principles and techniques presented. This is fitting insofar as the work reported in this report has grown from many years of prior research by others. Much has been learned concerning the design of materials that teach and test adult technical personnel proficiency in nonroutine critical skills. The authors of this report are honored and pleased to have been part of this effort.

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