CHAPTER 10.—FORMAL LEARNING FROM ESCAPE NARRATIVES THROUGH THE CREATION AND USE OF TABLE-TOP SIMULATIONS[1]

This book has employed miners' narratives to illustrate basic concepts about the escape process. One of the most powerful means by which people make sense of their experiences is through the telling and internalization of stories [Bruner 1990]. By couching one's own and others' motives and actions in terms of a coherent narrative, a person is able to learn from mistakes and plan future behaviors that may help ensure survival. A growing body of research suggests that decision-making skills used to deal with emergency situations can be taught and assessed by simulations based on narratives from the real world [Bransford et al. 1986; Brecke 1982; Brener 1984; Connolly et al. 1989; Halff et al. 1986; Jones and Keith 1983; Lacefield and Cole 1986]. Such techniques have been used to address the decision-making of medical personnel, civil and military flight crews, and even people involved in broader life events such as political and military situations [Babbott and Halter 1983; Dugdale et al. 1982; Farrand et al. 1982; Gilbert 1975; McGuire 1985; McGuire et al. 1976; Flathers et al. 1982; Giffin and Rockwell 1984; Jensen 1982; Janis and Mann 1987]. Given the validity of this method of study and the promise it holds for helping people improve the quality of their responses to nonroutine occurrences, it is perhaps surprising that there have been no studies of emergency decision-making among blue-collar workers prior to those conducted by the present authors and their colleagues.

The purpose of this chapter is to describe underground coal miners' decision-making performance on a table-top simulation whose problem structure is derived from interviews with a group of eight miners who escaped from the 5 Left section at Brownfield Mine. The exercise was constructed by a panel of domain experts (mine safety and rescue personnel) with the assistance of an educational psychologist. The simulation includes actual predicaments with wise and unwise decision alternatives that, in the opinion of these domain experts, are characteristic of such escapes. Results reported in this chapter are the scores of a sample of experienced mine workers who completed the simulation. Because the exercise is a series of objective performance tasks coupled with detailed and immediate feedback, this simulation can be used to teach and refresh critical escape skills, as well as to provide data concerning the proficiency of miners at the time of exercise administration.

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[1]A revised version of this chapter has been published as: Cole HP, Vaught C, Wiehagen WJ, Haley JV, Brnich MJ Jr. [1998]. Decision making during a simulated mine fire escape. IEEE Trans on Eng Management *45*(2):153-162.

Complexity of Escaping From a Mine Fire

When a fire occurs, miners must make their escape to the surface by seeking out and traveling accessible routes to a mine portal or shaft. The ventilation system that is designed to bring fresh air to the working faces, carrying away methane and dust in the process, now provides oxygen to a blaze that has a nearly unlimited supply of coal. Fires therefore may produce very high temperatures, dense toxic smoke, and, as they burn through stoppings and other ventilation control devices, unpredictable changes in the direction and velocity of fresh air moving into the mine. If the mine atmosphere is oxygen-deficient or contaminated with carbon monoxide, as is often the case, miners must promptly and correctly don emergency breathing apparatus in order to stay alive.

The process of escaping from a mine fire presents myriad predicaments and requires quick decisions in the face of uncertainty. Information about the location of the fire, conditions in the mine at points along various escape routes, and the whereabouts and condition of other miners are often unknown. The choice of evacuation methods may present dilemmas. For instance, riding out on a mantrip can enable a rapid escape but could ignite a lethal methane explosion if there has been disruption to the ventilation system. Walking out may forestall a methane explosion, but would require increased time and effort, and might result in miners becoming lost. When escaping miners make decisions about these sorts of concerns, many of their subsequent actions are irreversible. Furthermore, the outcomes of these actions cannot be known until they are completed. It is evident, therefore, that miners should be prepared to predict as accurately as possible how future events will be influenced by their choices among alternative actions.

Need for Research and Training in Mine Escape Decisions

In a review of decision-making theory and research, Halpern [1984] made the following points: A decision always involves choosing among two or more competing alternatives. Decisions are made in response to a recognized problem. Yet, unlike traditional academic problem solving, real-world decision-making involves dilemmas in which there is no clear "best" solution to a problem. Inadequate or conflicting information about alternatives always exists. Risks are associated with each choice, and these choices, once made, are often irreversible. The difficulty lies in making judgments about which alternative action is best for maximizing gain and minimizing loss. The decision-maker must attempt to predict how future events will be influenced by his or her choices and does so in an atmosphere of uncertainty.

Halpern also noted two additional characteristics of decision-making as determined from empirical studies. First, even highly trained professionals often make errors in real-world decision-making. Second, when teaching decision-making there is a tendency to use case studies where the outcome of persons' choices are known to those who review the case study, and where the choices of the persons facing the problem are judged sound or unsound in light of the outcome (often by reference to some algorithm). However, this type of instruction may be counterproductive, because during the dilemmas faced in real-world decision-making, the choices among alternatives must be made without knowledge of their effects on outcomes. Good decisions depend on inference and flexible use of heuristics rather than rigid application of algorithms based on a post hoc analysis of events.

The information miners are given in their initial classroom training, required annual refresher training, and mandatory fire drills tends to provide little opportunity for them to engage in problem solving and decision-making [Digman and Grasso 1981; Cole et al. 1988a,b]. That is because traditional classroom instruction tends to produce "inert" knowledge rather than "active" knowledge [Bruner 1990; Cole et al. 1988a,b]. Generally, inert knowledge is presented in the form of simple rules (algorithms) such as the following: "At the first sign of smoke, don your FSR and proceed to the [mine evacuation] assembly point." "Remember the location of the nearest cache of SCSRs (self-contained self-rescuers) and when you get to them, immediately don an apparatus." "Stay together at the designated assembly point until your section foreman orders an evacuation from the mine." "Follow the primary escapeway and stay with the other members of your group." "If the primary escapeway is impassable, exit from the mine by the secondary escapeway." "If escape is not possible, find a good place to barricade, then barricade and wait for rescue."

In actual emergency situations, many factors may prevent the simple application of these rules. For example, although miners are drilled that they should all gather at designated assembly points to begin their evacuation, during actual fires some workers are usually missing and do not arrive at the assembly point. In this event, the gathered miners must decide whether to wait for their missing coworkers, conduct a search, or leave without them. If and when all of the workers are assembled on a working section, they must still decide which routes and methods will be used to leave the mine. Miners are taught that they should stay together when they evacuate, but if a section crew is forced to walk out of the mine, the crew members may have to hurry or risk becoming trapped by the fire. Often, travel is difficult because of low seam height, poor footing, and heavy smoke. Because of individual differences in physical fitness, some miners will always be able to travel faster than others, yet the possibility that individuals may fall behind is rarely addressed in miner training classes, or during fire drills in the mine.

When individual differences do enter the equation, what ought miners do? Should the entire group travel as slow as the slowest crew member and thus risk having their SCSRs run out of oxygen, or risk becoming trapped? Should the group split up, allowing the most able to escape, and perhaps get help for their slower coworkers? A confounding factor is that on many mining sections there are only one or two persons who fully understand the complex escape routes out of the workplace. During an escape, when the smoke becomes thick and the crew is strung out along several hundred feet, what can be done to make sure the persons at the front of the line and those at the rear all make correct turns at key intersections of the giant maze that composes the mine?

The rather cut-and-dried rules that miners are usually taught concerning evacuation and escape procedures do not address these types of questions. Consequently, when workers are involved in actual mine fires, they may be ill-prepared to deal with the ambiguities and complex interactions of real-world variables that turn what might appear to be a straightforward escape task into an ill-defined problem.

Utility of Simulation Exercises for Fire Escape Decision Training

Active knowledge that helps workers become better problem solvers can be facilitated by simulation exercises based on actual mine fires and escapes. These exercises are one way to provide miners with more accurate and realistic conceptualizations of escape procedures. Most workers will never experience an escape from a mine fire. Yet all miners need a good understanding of what such situations are like and how the basic escape rules in which they are drilled must always be moderated by the types of situational factors described in the previous section. Well-designed simulations can provide powerful vicarious learning experiences that may better prepare miners to cope effectively with actual mine emergencies. It is for this reason that the training of mine rescue teams, military personnel, and firefighters routinely make use of both full-scale field simulations and so-called "paper and pencil" (or "table-top") exercises. It is the table-top simulation with which this chapter is concerned.

Table-top simulations are typically based on actual case materials. Unlike case study reviews, however, table-top exercises do not present the outcome of an emergency as a means for evaluating individual decisions made during the course of the event. Rather, the simulation problem unfolds and requires decisions to be made among alternatives with incomplete information similar to the process involved in an actual emergency. Good exercises will simulate the conceptual and emotional decision-making aspects involved in coping with an event.

Table-top simulations have some advantages over full-scale field problems, or even participation in actual emergencies. First, a table-top exercise can foreshorten lengthy problem situations and long sequences of decision-making. An event that might be days in the making can be concluded in 1 to 2 hours with a table-top simulation. Second, errors made during a table-top simulation may be embarrassing but are not dangerous. Similar errors in a full-scale field exercise or during an actual emergency response could be dangerous or even fatal. Third, table-top simulations can provide the learner with a system perspective on the problem situation. During an actual mine fire an individual focuses on his or her situation and role, and may not pay much attention to key relationships and interactions among the other personnel, physical factors, and equipment. A simulation can show such relationships as well as reveal both the predictable and capricious events that are always part of any emergency. This type of overall comprehension of the "problem space" is thought to result in greater insight on the part of the participant. Fourth, table-top simulations provide individuals an opportunity to reflect upon, debate, and gain enhanced wisdom from their decisions. In aviation circles, interactive table-top simulations of the paper and pencil or computer-administered type are used to teach what is often referred to as "air wiseness," with promising results [Flathers et al. 1982; Giffin and Rockwell 1984].

The *Escape From a Mine Fire* (EMF) Exercise

The 5 Left crew at Brownfield Mine encountered extreme difficulty in making its escape. The workers were located nearly 3 miles from the nearest mine portal, and their first warning of the fire came when they observed smoke being carried into their section by the mine ventilation system. The smoke was coming through the intake entry, which was the section's designated primary escapeway. The smoke made this escape route impassable. The return entry, designated as the secondary escapeway, was also filled with smoke. The belt entry, which was not a designated escape route, but which was the only entry not filled with smoke initially, was selected by the miners as the most viable alternative. This entry was constricted by a conveyor belt on one side and a double row of roof support timbers on the other. These obstacles and the 48- to 54-inch seam height left a walkway approximately 3 ft wide, 4 ft high, and a 0.5 miles long (at which juncture the section connected with 6 West Mains, a set of eight entries that eventually led out of the mine over an additional 2.5-mile route).

The workers did not know the location of the fire, were not provided such information by surface personnel, and did not make adequate attempts to obtain this critical knowledge. During their escape, the eight miners worried that they would exhaust the 1-hour supply of oxygen in their SCSRs, because they knew it would take much longer than an hour to stoop-walk the nearly 3 miles to the portal, and as far as they knew, the mine atmosphere could have been contaminated by smoke the entire distance. They therefore chose to "save" their SCSRs by not donning them immediately. Thus, the workers traveled in increasingly heavy smoke until it became impossible to proceed without the breathing apparatus. All eight miners were in dense smoke before they donned their SCSRs and might very well have died from carbon monoxide poisoning if the smoke had been more toxic.

Once they donned their breathing apparatus, and after traveling only a short distance (approximately 200 ft), two miners found that they could not keep up with the group. One was physically unfit and the other old. The older miner could travel, although slowly. The younger, unfit man soon became unable to travel at all without help. The eight miners then made a decision to split up. Four members of the crew who could move rapidly left the section. The older miner followed these four at his own pace. Two fit individuals remained with the disabled worker and attempted to half-carry and half-drag him from the section. After falling down many times and stopping frequently, all three men were exhausted, out of oxygen, and were exposed to smoke. One person then left the other two. The disabled miner and his lone companion remained behind in the smoke, with one man semiconscious and the other hoping they might be rescued, but fearing they would die. The individual who left the section reported being nearly overcome by carbon monoxide, and stated that he was incoherent when he finally encountered fresh air approximately 1,000 ft outby the place where he had left his two coworkers.

Structure and Design of the EMF Exercise

Given the widespread practice of longwall mining, the setting described above is typical of many sections on which miners now work. Additionally, the problems these workers encountered during their escape are characteristic of those recounted by miners who have escaped other fires. Because of these two factors, it was decided to construct a simulation exercise around the experiences of workers on the 5 Left section. The initial simulation was developed by six individuals. One of these was a Federal inspector who happened to be on the 5 Left section that shift. This person escaped with the crew and subsequently helped conduct an official investigation of the fire. Four other developers were domain experts in mine safety or mine rescue who, collectively, represented a wide range of mining conditions and methods. All five experts worked together and in conjunction with an educational psychologist. The mine fire exercise was designed to be both a teaching tool to improve miners' decision-making skills and a research instrument to provide information about the proficiency of workers in planning an escape. The domain experts agreed that data from an administration of this problem applied to a large group of miners could help direct future training as well as the design and deployment of mine monitoring systems.

The structure of the *Escape From a Mine Fire* (EMF) exercise is based on the theory of narrative thinking from Bruner [1990], Bower and Morrow [1990], Sarbin [1986], and others. Bruner notes that there are two ways to understand one's own behavior and the conduct of others. The first way is through narrative thinking. The second is through formal analysis of behavior through logical rules and systems. Persons generally make important personal decisions by reference to compelling stories that they have internalized, *not* by applying formal logical rules. These life-directing narratives have been called "culture tales" and "stories we live by " [Howard 1991]. Since the beginning of human culture, stories and parables have been recognized universally as one of the most effective forms of instruction [Vitz 1990]. On a personal level, lessons learned and insights gained through stories also tend to be highly memorable and easily generalizable to one's own circumstances and plights [Bruner 1990; Sarbin 1986].

The EMF exercise is presented as an interactive story. The content and structure of the story are derived from the actual events that occurred in the mine fire on which the simulation is based. The miners who work the exercise interact with each other and with characters in the story. The exercise is constructed so that each miner assumes the role of a character who must make decisions as the story plot develops. The plot includes obstacles and predicaments that thwart the achievement of the goals (escaping from the fire, staying together, and saving one's buddies). At key points throughout the unfolding story, the miners select from among alternative actions and strategies. The consequences that follow each choice are subsequently presented as part of the interactive story line. Thus, the narrative exercise simulates many of the affective and cognitive dilemmas experienced by miners who are involved in similar decision-making when escaping from actual underground mine fires.

The paper and pencil exercise consists of a linear series of questions at each major decision point. The first 10 questions interspersed in the narrative represent what the domain experts determined to be key decision points encountered by the 5 Left miners during their escape from the fire. The experience of these miners provides the basis for the scenario. The last three questions ask miners to make additional judgments about the merit of particular persons' actions in the face of events that occur in the simulation. Twelve of the questions are followed by three to eight decision alternatives presented in a multiple-choice format. One requires a short written response in which the learner must decide among four alternative actions. The alternatives consist of both correct and incorrect actions (as indicated by expert consensus) at each major decision point (question) in the scenario. The consequences of incorrect answers range from useless to harmful or potentially lethal. These wrong alternatives were compiled from case studies and the interviews of miners who escaped from real fires, and represent judgment errors that workers actually made in such situations (some reasons why they made these errors are echoed by subjects' responses to the simulation questions).

Four of the questions or decision points have only one correct action among the alternatives listed. However, the remaining questions have a combination of two or three correct alternatives along with the incorrect ones. A miner's performance on a given major decision point is not scored dichotomously as a 0 or 1, but is awarded full or partial credit based on the total number of good decision alternatives selected, and the total number of poor decisions avoided (not selected). Finally, each decision point is weighted equally so that when the 13 question scores are added together the exercise total score is scaled from 0 to 100. Thus, the final observed total score for any given miner can be directly interpreted as a percentage of mastery of the exercise skills and content.

The exercise consists of two parts: a problem booklet and a latent-image answer sheet with an attached questionnaire. The problem booklet presents the relevant background information that any miner who was at work in this mine would know, e.g., information about the height of the coal seam, mine ventilation, location and distances of the portals, and the type of mining method and equipment used. The miner working the exercise is directed to play the role of the section foreman, and to make choices among decision alternatives at each question in the exercise. The initial observation is then presented as the arrival of smoke on the section where the crew is working. The booklet includes a section map (see figure 10.1) that shows the number and layout of entries, the location of the smoke, workers' positions, equipment locations, and the direction and distance from this section to the mine's main entries (and to the portal where the miners must exit). Each decision point (question) determined by the domain experts to be a major one is presented in the problem at the rate of one frame (page) at a time. After the miner examines the question and studies the alternatives, he or she then selects the "best" actions by using a special developing pen to mark the appropriately numbered space on the answer sheet.

Each numbered space on the answer sheet corresponds to a numbered decision alternative in that frame of the problem booklet. When the blank space on the answer sheet is rubbed with the developing pen, the invisible ink or "latent-image" answer immediately becomes visible. The message contains two types of information: first, it tells if the decision was correct or incorrect (as determined by the panel of domain experts); second, it provides additional information related to the decision. For example, in question D (the sixth frame and fourth major decision point in the exercise), miners are asked which actions they should take as they prepare to leave the section on foot in the belt entry. One of the eight decision alternatives for this question is:

> *Before you leave, send one miner to the pager (section telephone) to ask for information about the location of the fire, and to report (to the surface) that you are walking out.*

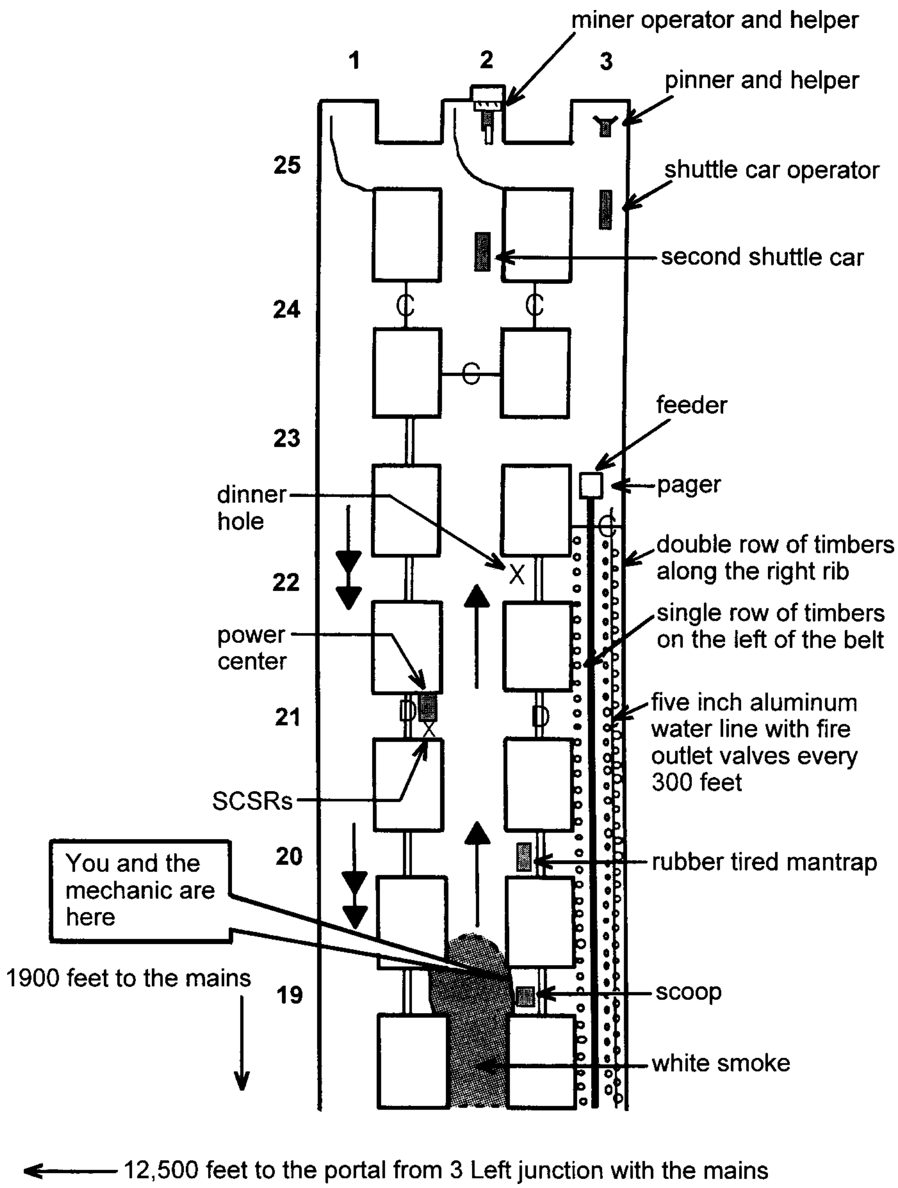

Figure 10.1.—Section map of imaginary mine in problem booklet.

When the miner rubs the corresponding blank space between the brackets on the answer sheet, the following message is instantly developed:

> *[Correct! But the miner returns and says the pager is no longer working.]*

Each frame in the problem booklet presents the scenario over a sequence of time and contingencies. The miner working the exercise knows only what has happened to the point at which the problem has been worked. The correctness and consequences of the decision alternatives selected for each question are also known only as these choices are made. In this manner the trainee must work through the problem as it unfolds, without knowing the outcome or the effects of his or her decisions until after they have been made.

Figures 10.2 and 10.3 depict two frames in the problem booklet. Figure 10.2 shows question B with six decision alternatives; figure 10.3 shows the latent-image answers that correspond to the decision alternatives. The entire exercise is constructed to teach and assess the choice of alternative actions at major decision points like those encountered by the miners who experienced the fire.

The major decision points include (1) deciding what to do when the smoke is first noticed, (2) ordering priorities in terms of alerting other miners versus first donning emergency breathing apparatus, (3) seeking more information about the fire, (4) choosing an escape route and method, (5) deciding what equipment to take along during the evacuation, (6) modifying the escape plan when heavy smoke reduces visibility to less than 2 ft and when two miners in the crew are unable to keep up, and (7) deciding how best to rescue a worker who had to be abandoned in a smoke-filled area of the mine. The options chosen by those working the exercise are discussed in a section to follow.

Interactive Latent-Image Format

The paper problem booklet and latent-image answer sheet system were chosen because they were inexpensive to develop and are easy to administer in any setting with a minimum of equipment. Only a problem booklet, a specially printed latent-image answer sheet, and a developing pen are needed. This combination of high technology instructional design with respect to exercise structure, combined with the low-technology latent-image delivery mode, provides a very effective interactive simulation—a basic format which has, in fact, been used for many years in medical education [Bollet 1984; Kacmarek et al. 1985].

Field Evaluation of the Exercise

After its construction, the EMF exercise underwent two rounds of field testing. A preliminary round involved authentication of the exercise by a group of 10 nationally recognized mine fire and mine rescue authorities using well-established mine rescue criteria. The criticisms, corrections, and comments of these persons were used to revise the exercise before its formal field test. This second round of field testing was conducted at four sites with six groups of experienced miners from several States.

Question B

While still in No. 19 crosscut, you and the mechanic put on your FSRs and then begin to move toward the face to warn the others and to call outside. As you approach the power center, you see the SCSRs. What should you do now? (Select as MANY as you think are correct.)

7. Stop at the power center and you and the mechanic each don an SCSR.

8. Tell the mechanic to grab a couple of SCSRs, and you grab a couple and continue on to warn the others and to call outside.

9. Wait at the power center until the other miners assemble.

10. Stop and check the condition of each SCSR, and then lay them out to make it easier for the other miners to get the units on.

11. Deenergize the power center.

12. Wearing your FSRs, go directly to the face area to warn the others and to call outside.

Figure 10.2.—Question B with six decision alternatives in problem booklet.

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

7. [Your FSR is sufficient for now. You need to warn the others and call] [outside.]

8. [When you leave, other miners may come to the power center and] [find SCSRs missing. They may think you have left the section.]

9. [You need to make sure all the other miners are warned and go to the] [assembly point by the power center.]

10. [Warning others to assemble is more important.]

11. [Correct! This is a proper procedure and is an additional warning for the] [crew that something is wrong.]

12. [Correct! Smoke is light. You are protected from CO. You need to warn] [others on the section and outside, and you need more information.]

Figure 10.3.—Latent-image answers that correspond to the decision alternatives shown in figure 7.

A total of 134 underground coal miners, including two females, were involved in formal field testing of the exercise. The mean age of these workers was 41.1 years, with a standard deviation of 8.83. These miners averaged 15.9 years of experience in underground coal mining, with a standard deviation of 7.16. The persons in the sample represented three major job categories found in the underground mining industry. These include (1) miners/laborers who are hourly employees and who are engaged in the various jobs directly related to extracting and transporting the coal out of the mine; (2) maintenance/technical staff who are electricians, mechanics, health and safety inspectors, engineers, surveyors, and other personnel who do not directly mine coal but who work underground in and around the sections; and (3) supervisors/managers who are salaried employees and who include the first-line supervisor (section foreman) all the way up to the mine superintendent. Figure 10.4 presents the proportions of these persons in the sample.

In the mining industry the job categories depicted in figure 10.4 are associated with increasing levels of skill and knowledge. Mine foremen and other supervisors must pass examinations and be certified in such areas as mine maps, ventilation, health and safety, first aid, escape, and rescue procedures. Similarly, mine maintenance and technical workers must be certified in their specialties. In addition, their work often requires them to travel widely throughout the mine, usually in pairs. Because they have to be responsible for themselves as they work and travel about, maintenance/technical workers need to be more aware of the mine layout, escape routes, and escape procedures than do the typical miners/laborers.

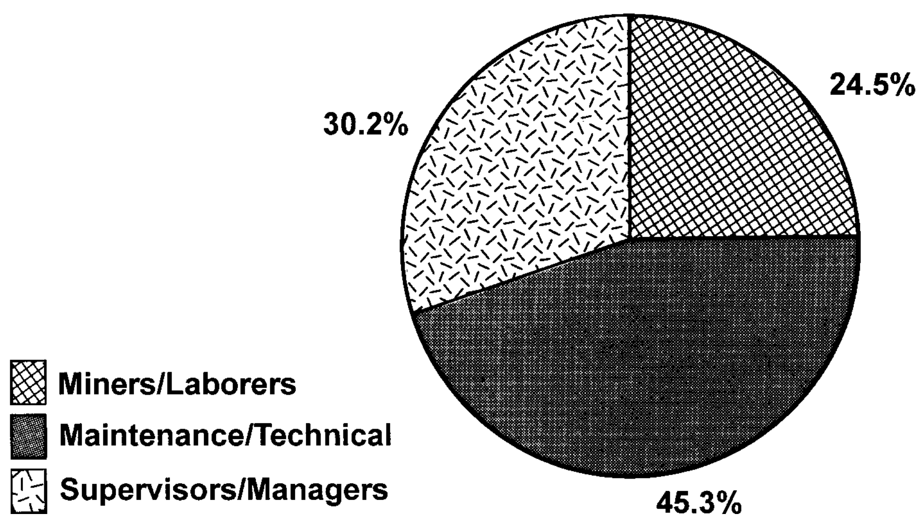

Figure 10.4.—EMF exercise: percentage of sample by job category (n = 134).

This sample is somewhat older than and has greater experience than a more typical sample of miners. In addition, miners/laborers are underrepresented in the sample, while mine maintenance/technical personnel and supervisors are overrepresented. An earlier national sample of 3,658 underground coal miners from 12 States found a mean age of 37.2 years with a standard deviation of 9.0, and a mean of 11.9 years of mining experience with a standard deviation of 7.2 [Cole et al. 1988a,b]. Miners/laborers comprised about 50% of that much larger sample; maintenance/technical personnel and supervisors comprised about 25% each.

Two important generalizations can be made about the field test sample. First, this group of miners had more experience and better training in either fighting or escaping from mine fires than would a representative grouping of miners. Second, most of the working miners, technical personnel, and supervisors included here were attending regional health and safety meetings for persons in the mining industry. These facts suggest that the exercise performance scores of this sample ought to be higher than the scores of miners from a completely random selection.

Results

The results of the field test are presented in three parts. The first part presents miners' evaluation of the authenticity and utility of the simulation. The second part analyzes psychometric properties of the exercise, including assessments of its validity and reliability. The third part describes the performance of miners in choosing among the 63 alternatives contained in the 13 questions or major decision points.

Miner Evaluation of the Exercise

Each person who worked the simulation was asked to complete a standard 10-item Likert scale rating form. The first three items on the form were designed to elicit the miner's evaluation of the authenticity of the problem and its worth as a training device. The remainder of the items addressed the functionality of the exercise structure and design. Ratings of all miners on each of these 10 items are presented in table 10.1. Even though this sample consisted of highly experienced workers, all persons reported that the exercise was authentic and would help them remember important details. Additionally, nearly 94% reported that they learned something new from working the exercise.

Validity

Four estimates of exercise validity were obtained. First, the 10 experts who reviewed the simulation during its authentication stage and in its final form judged the content validity to be high. This is not surprising, since the problem was based on the behavior and decision choices of miners who had escaped from actual mine fires. Second, the 134 miners in the field test sample judged the face validity of the exercise to be high, as can be seen from their ratings in the first three items in table 10.1. Third, the 63 decision alternatives discriminated positively with respect to the exercise total score. When decision alternatives are valid, the number of wrong alternatives selected should correlate negatively for persons with high total scores, but correlate positively for persons with low total scores. Likewise, the number of correct alternatives selected should correlate positively for persons with high total scores, but negatively for persons with low total scores. When multiple-choice test questions (or exercise alternatives) behave in this manner, they are said to discriminate positively among levels of ability within the sample. Table 10.2 presents the proportion of exercise alternatives that positively and significantly discriminated with respect to high exercise total score.

Table 10.1.—Miners' rating of exercise validity, relevance, quality, and utility (frequency %, n ' 134)

Content	4 (definitely yes)	3	2	1 (definitely no)	Mean	Standard deviation
Exercise is realistic/authentic	88.5	11.5	0.0	0.0	3.9	0.32
Helped me remember important things	62.3	37.7	0.0	0.0	3.6	0.49
Learned something new . . .	52.7	41.1	3.1	3.1	3.4	0.71
Exercise is too long	3.1	7.0	29.5	60.5	1.5	0.76
Liked working the exercise .	60.6	31.5	6.3	1.6	3.5	0.69
Instructor's directions are clear	64.9	29.1	1.5	0.0	3.7	0.51
Written exercise directions are clear	62.2	35.4	1.6	0.8	3.6	0.57
Graphics are easy to understand	65.1	33.3	0.8	0.8	3.6	0.55
Scoring is easy to understand	43.1	44.8	6.0	6.0	3.3	0.82
Exercise is easy to read . . .	66.4	33.6	0.0	0.0	3.7	0.47

Table 10.2.—Proportion of answers discriminating positively, negatively, and not at all with the exercise total score (p<.05)

Positive	51/60 (85.0%)
Negative	2/60 (3.3%)
No relationship	7/60 (11.7%)

The final estimate of exercise validity was determined by conducting an ANOVA of exercise total scores by job category. As explained earlier in the section that described the sample, knowledge of mine rescue and escape skills may be expected to increase across job categories from miners/laborers through maintenance/technical workers to supervisors/managers. The analysis was run on 106 persons for whom there was a complete vector of exercise question and total scores, and for whom there was also a definitive job category assignment. Table 10.3 presents means and standard deviations of the exercise total score for these three groups, and table 10.4 presents the ANOVA results by job categories. Figure 10.5 plots observed total score means and standard deviations for the three job categories. Job category was found to account for approximately 29% of the observed variance in exercise total scores.

Table 10.3.—Means and standard deviations for exercise total score by job category

Job	n	Mean, %	Standard deviation
Miners/laborers	26	71.1	11.03
Maintenance/technical staff	48	79.9	7.47
Supervisors/managers	32	85.5	7.38

Table 10.4.—ANOVA results for exercise total score by job category

Source	Degrees of freedom	Sum of squares	Mean square	F ratio	p<
Between groups	2	3,051.92	1,525.96	21.31	0.00
Within groups	103	7,302.54	71.59	—	—

Eta squared ' 0.293.

Reliability

The Cronbach alpha generalizability coefficient was calculated for the exercise as an estimate of its internal consistency. The observed reliability of 0.74 might be expected to increase if a more heterogeneous sample of miners were used to achieve a more symmetrical performance distribution on item and total scores.

Question and Total Score Performance

Individual performance on each of the exercise questions was scored by awarding full or partial credit based on the total number of good decision alternatives selected and the total number of poor decision alternatives avoided. A mean percentage and standard deviation for each question score was then calculated. An ANOVA was carried out for each question score to determine which of the 13 items significantly discriminated among the three job categories.

The ANOVA was based on the 106 persons who could be clearly identified as belonging to one of the three categories. Figure 10.6 presents the pooled means and standard deviations for each of the 13 questions for the entire sample of 134 miners who completed the exercise. The total exercise score (TS) and its standard deviation are represented in the last column of the histogram. The scoring metric is the percentage of correct responses, so that all question scores and the exercise total score can be compared to one another in terms of difficulty. The eight questions that significantly discriminated among job categories are marked with an asterisk.

Inspection of figure 10.6 reveals an important finding. Questions H and K were the most difficult decision points in the exercise, as evidenced by the fact that there was no significant difference among the scores on these items across workers in the three job categories. Additionally, the mean score for question H was 53.2%, with a standard deviation of 25.8. The mean for question K was 62.3%, with a standard deviation of 39.9. These means are well below the desirable proficiency level and the variance is very large. Questions H and K are difficult because they have in common a dilemma, described below, that is encountered in actual escapes from mine fires (and that participants reported as a rationale for their chosen options) but that is rarely discussed in training classes because these classes tend to focus on escape algorithms and rules.

Figure 10.5.—EMF exercise: means and standard deviations by job category.

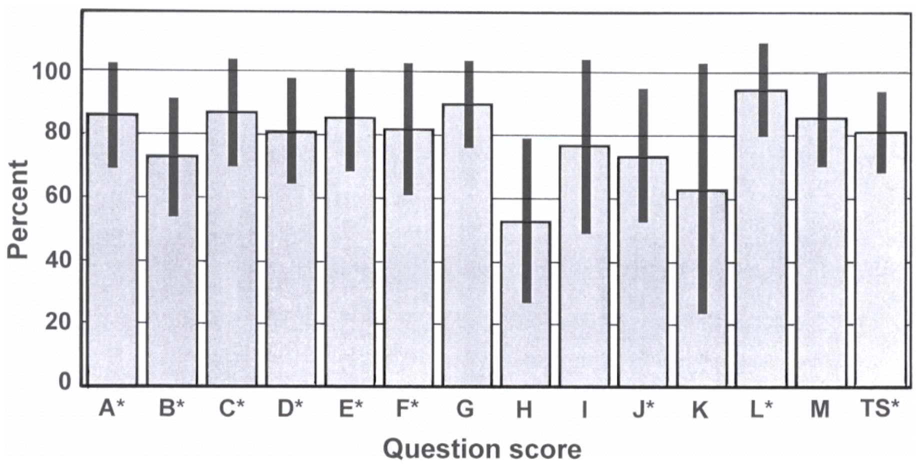

Figure 10.6.—Question score means and standard deviations. (An asterisk (*) indicates a question that significantly discriminates among job categories (p#.05). TS = total exercise score.)

In question H, the scenario has developed to a point at which the miners are in heavy smoke wearing their SCSRs and having difficulty moving in the narrow, low walkway along the belt entry. The unfit miner is unable to maintain a pace needed to escape from the section before conditions become fatal. The three decision alternatives include (1) trying to force the straggler to keep up and having all of the other miners slow down, (2) letting the group split up and leaving the straggler on his own, and (3) having members of the crew take turns carrying the unfit miner. The weight of the straggler (260 pounds), his poor physical condition, the narrow and low walkway, and restrictions on heavy work imposed by wearing an SCSR, make the first and third options difficult and dangerous. The correct (but troubling) decision is to let the group split up so that those miners who can travel rapidly have a chance to escape. Discussions following the exercise suggest that this experienced group of miners understood the dangers of the two incorrect alternatives and the logic of the correct decision. Many persons in all three job categories, however, selected wrong alternatives to this question.

Question K addresses an issue that arises when miners are missing in mine fires and other workers wish to find and rescue them as soon as possible. Prior to this point in the problem scenario, two of the escaping miners had tried to help the straggler but were unable to do so. Finally, he was abandoned, semiconscious but still alive. All of the other miners had reached relative safety in fresh air about 1,000 ft farther along the escape route. The question concerns two miners who wish to don new SCSRs and reenter the smoke filled area to search for and bring out the missing worker. The predicament arises from the need (as perceived by the survivors in our interviews) for prompt rescue of the missing miner if he is to live, and weighed against the dangers of using SCSRs to attempt the rescue. The person working the exercise is asked to weigh the merits of the two miners' rescue plan, and decide if rescue attempts should wait until the fire is under control, fresh air is restored to the area being searched, and/or a mine rescue team with proper breathing apparatus and related equipment arrives. Based on many accident investigations and interviews, such decision alternatives are known to be problematic for miners. Likewise, these decision alternatives proved difficult (as indicated by low scores and failure to discriminate) for the persons who worked the simulation exercise. This outcome was observed even though the sample was a highly knowledgeable and select group who clearly understood the risks.

The issue centers around the design of SCSRs—they are designed for self-rescue and escape. They do not provide an adequate supply of oxygen for rescue work and are not mechanically and ergonomically suitable for such activity. Yet, if a missing miner is not rapidly retrieved from the smoky area of a mine, he or she may die from CO intoxication and smoke inhalation. The issue of mounting rescue efforts with the aid of SCSRs is hotly debated by workers involved in both the field tests of this simulation and other similar exercises. While all persons recognize the good intentions of miners who want to use SCSRs to rescue missing individuals, they disagree on the merit of such attempts. Experienced mine rescue personnel and other experts often argue that it is very difficult to travel and work in smoke while wearing SCSRs, and that the risks are too great to justify any attempt to rescue a trapped miner while using the apparatus. Potential problems associated with such attempts, according to these individuals, include (1) would-be rescuers becoming lost or disoriented, (2) workers having great difficulty finding, lifting, and moving a disabled miner, and (3) potential rescuers displacing their SCSR mouthpiece or nose clips, and/or running out of oxygen during the rescue attempt. Some or all of these difficulties are very likely during the rescue attempt. Singularly or in combination, these problems could easily result in serious injury or death for the would-be rescuers.

Such an outcome would further complicate a rescue of the original missing miner(s), and endanger additional lives because (1) more miners would be missing and need to be rescued, (2) fewer persons would be immediately available at the scene to conduct the support work necessary for a successful rescue, (3) those individuals who subsequently must attempt a rescue of the additional victims would be endangered even when they were properly equipped with mine rescue apparatus, and (4) rescue of the original victim(s) might be delayed, thus increasing the probability of their death.

Mastery Levels

Each question score is weighted equally so that when the 13 subscores are averaged the exercise total score is scaled from 0% to 100% (figure 10.7). Each question score in figure 10.7 is also presented on a 0% to 100% scale. Thus, the final observed total score and the question scores for any given miner or group of miners can be directly interpreted as the percentage of mastery of exercise skills and content.

Self-rescue skills like those presented in this simulation should be learned to high levels of mastery in order to minimize errors that can be very costly in terms of death, injury, economics, and public image. As a general rule, proficiency levels for these types of critical skills are set at a minimum of 90% correct performance by at least 90% of the trained population [Cole et al. 1984]. Figure 10.7 plots the percentage of individuals in the sample who scored in one of seven mastery level intervals. As shown, only 13.6% of the miners scored at or above the 90% mastery level as assessed by total score performance. Nearly 50% of the sample performed below 80% mastery. A completely random sample of miners might be expected to perform at lower levels of mastery than did this group of highly experienced and well-trained workers. If the exercise is valid and reliable, this suggests that miners need additional training in the decision-making that is involved when escapes from mine fires must be planned and executed. Simulations like the *Escape From a Mine Fire* exercise may be one cost-effective way to provide realistic practice in these critical nonroutine skills.

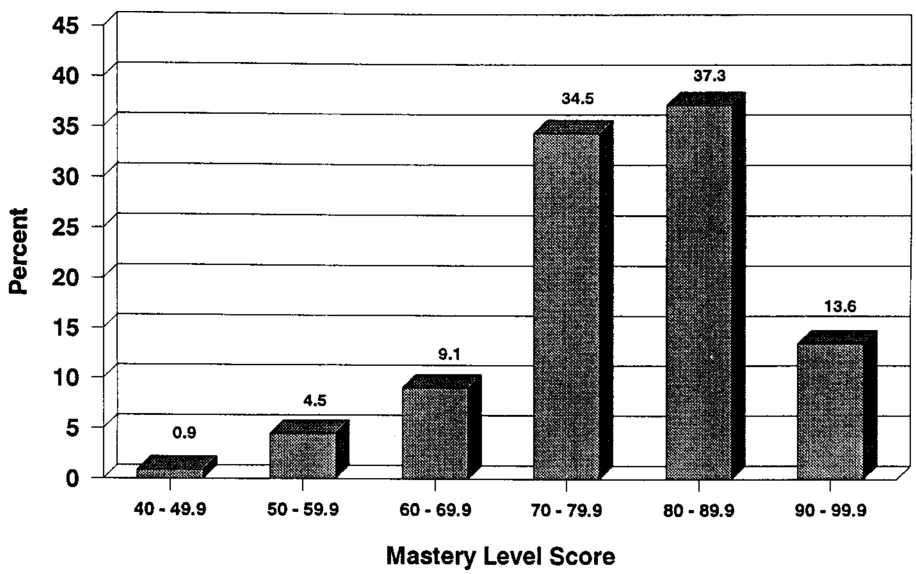

Figure 10.7.—Percent of miners attaining various mastery levels on the EMF exercise.

Conclusion

The mean performance scores of groups in all three job categories fell well below the 90% level of mastery for the self-rescue and escape skills presented in the EMF simulation. However, the exercise total score discriminated significantly among job categories (F = 21.314, p#0.0001), with supervisors obtaining the highest mean score (85.8%), maintenance/technical workers an intermediate mean score (79.9%), and miners/laborers the lowest mean score (71.1%). The exercise total score also discriminated significantly (F=17.352, p#0.0001) between those persons with mine rescue training (mean = 81.6%) and those without such training (mean = 73.0%). For the dilemmas presented in questions H and K, though, there are no significant differences in the mean performance scores by job category or by mine rescue training level. This finding suggests that the issues associated with having to abandon a helpless miner, or engaging in unsafe rescue attempts of missing workers by using SCSRs, are clearly problematic decisions for all miners regardless of training level. Workers in all three job categories appeared to understand the potentially lethal consequences of unsafe rescue attempts, but frequently chose unwisely in the simulation. It should be noted that this also happens in real life, where a significant proportion of deaths in confined spaces are would-be rescuers of victims who are usually already dead [Manwaring and Conroy 1990].

We have observed that when miners and accident investigators alike discuss actual escape or rescue attempts, the merits of workers' decisions are nearly always judged post hoc in relation to the outcome of their actions. If the decision choices were successful, the miners are seen as brave and wise. If the decisions were unsuccessful, and especially if more persons were injured or died, the workers' actions may be seen as well intentioned but foolish (and perhaps illegal). Nevertheless, this approach to reviewing the merit of actual decisions in terms of prior knowledge of the outcomes may be counterproductive, because it develops a mindset that cannot be effective in the decision-making required during an actual mine emergency. When these types of decisions are made in real life, the participants cannot know the outcome of their actions prior to the action. Knowledge of the outcome cannot be the basis for the decision [Fischoff 1975]. Rather, such decisions must be based on the incomplete information that is available at the moment, estimates of the feasibility of alternative actions and their likelihood of success, and a weighing of the relative risks associated with each alternative.

The simulation discussed in this chapter was designed to provide a vicarious experience that would enable miners to confront the life and death choices involved in escaping from a mine fire. Undoubtedly the vicarious experience of completing such an exercise is not sufficient to prepare a miner for such a real-world experience. However, it is almost certainly better to have studied and debated the decisions encountered in such a simulation than to encounter them for the first time in a field situation. The EMF exercise is not just a "story." Rather, it is a composite of a type of emergency that too often claims workers' lives. To the extent that such simulations accurately reflect the dilemmas and decisions encountered in actual fires (and the present one is taken directly from a real incident), they provide better training for these nonroutine events than the more traditional method of teaching facts and escape algorithms. Likewise, they are more effective than a post hoc analysis of case studies where the merits of decisions are judged by knowing their outcomes a priori.

The EMF exercise is a dual teaching and testing device that presents a series of decision tasks embedded in a text or narrative. These types of educational materials have a long research tradition. Skinner [1965], Rothkopf [1966] and many others independently developed instructional programs consisting of a series of test items embedded in text. These programs were used to teach and test knowledge and skills of military personnel and many other groups. More recently, simulation problems with embedded test items have been used to teach and test proficiency among a wide range of technical personnel including health professionals, veterinarians, military and civil aviators, and other groups [Cole 1994]. The EMF exercise teaches miners through immediate feedback about the consequences and correctness of each decision they make. The immediate feedback reinforces correct knowledge and judgments and remediates incorrect decisions. At the same time, the objective nature of the exercise decision alternatives allows a performance score to be recorded and calculated for each individual. As demonstrated earlier, these performance data can be treated as test scores. To the extent that the exercise is valid and reliable, performance scores aggregated across groups of persons provide useful information about the degree to which miners have mastered particular skills and concepts and where more training is needed.

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AFTERWORD.—THEORETICAL AND PRACTICAL IMPLICATIONS[1]

A major reason for the previously mentioned scarcity of systematic knowledge about social and behavioral aspects of fire is that most efforts to minimize human and economic loss have focused on engineering solutions. Canter [1980] argued that there is already enough evidence to support the argument that, as far as "hardware" solutions are concerned, "such provisions are frequently insufficient and in many cases inappropriate...human aspects of the causes and developments of fire must be understood if its disastrous effects are to be minimized." According to Canter, what is known empirically about human response to fire follows certain general themes that may be used as a base for understanding the phenomenon theoretically (and which, incidentally, also provide some insights applicable to mining).

First, the literature asserts that the place of human action in the cause of fires must be considered, even when arson is exempted. It is likely that many fires start as the result of human error. For instance, according to a preliminary report released by the Mine Safety and Health Administration [1987], the Wilberg disaster originated with an electric air compressor whose overtemperature safety shutdown switch had been bypassed. At Adelaide, while the cause of the fire is in doubt, a contributing factor is not. A stopping near the head drive had been knocked out because float dust was collecting behind it. This allowed 60,000 cfm of air to go across the belt. According to the account of the mine examiner who discovered the blaze, things got out of hand quickly. At Brownfield, a trolley motor was left energized and on first point. In addition, a door in the supply chute was left open. Thus, not only did combustion take place, the smoke was quickly carried into the mine's primary escapeways.

A second theme in the literature deals with the fact that much information-gathering must take place before an individual comes to understand the nature of the problem, his or her role, and the appropriate rules that should be followed [Canter et al. 1980]. Given that a fire, at least in its early stages, is an uncertain event, it can be seen that a lot of time may be lost in defining the situation. On the night of the Adelaide fire, the dispatcher, who stated that the mine had "been getting tons of those false alarms," engaged in a series of conversations with the dumper underground. Following that, he (1) received a phone call from the face boss on the section contacted by the dumper wanting to know what was going on, (2) got through to another section and told the person who answered that there was a fire on the belt and to "get your guys out of there," (3) contacted the remaining section and "told the man on the phone to get the guys together," and

[1]An earlier version of this discussion is contained in: Vaught C, Wiehagen WJ [1991]. Escape from a mine fire: emergent perspective and workgroup behavior. J Appl Behav Sci *27*(4):452-474.

(4) received a call 5 minutes later from the last section contacted wanting to know what was going on. Only one worker (the maintenance foreman) at Brownfield took time to learn where the fire at his mine was located.

The third theme involves people's reactions once the situation has been defined. Sime [1980], among others, has offered evidence that the concept of "panic" does not apply to human behavior in fires. In fact, the reverse is more nearly true; people continue to carry out their normal roles long after the time for action has arrived. The severity of conditions at Adelaide was not communicated to the miners in such a way that they felt obliged to depart from normal routine—individuals who were operating equipment recounted how they went through regular shutdown procedures, tramming back from the face, going to the load center to kill the power, retrieving lunch buckets and coats, and walking to the mantrip. This same tendency to normalize their situation was reported by workers at the other two sites.

A fourth theme involves what happens once the decision is made to take action. Best [1977], in his account of the Beverly Hills Supper Club fire, illustrated the fact that even when people have entered an escape mode, their behavior tends to take place within the organizational parameters that existed prior to the emergency. For instance, waitresses at the restaurant showed their patrons out of the building. One professional firefighter, who happened to be dining at the club, allowed the waitress assigned to his table to lead the group to safety, and then reentered the building to help fight the blaze. At Adelaide, leadership emerged more or less gradually out of an initial state of disorganization. There was no previous determined gathering point in case of a fire like this one, which occurred outby the section. Although an escapeway map was posted on each section, no one thought to take it—despite the fact that there were miners on all three sections who had not had an opportunity to walk the escapeways and hence did not know the way out. At all three sites, the workers delayed donning their self-contained self-rescuers an average 10-15 minutes after encountering smoke—the reason most often given for this delay was "I knew these things [SCSRs] only last for an hour, and I didn't know how long it would take me to get out." Yet, no one thought to protect himself or herself in the meantime by using the filter self-rescuer every miner carries on his or her belt. Individuals took their mouthpieces out to talk or to get a deeper breath at points where the smoke was less concentrated, despite the fact that there was no way to determine how much CO might be in the atmosphere. Miners were disoriented by the smoke, and on at least one section, misinterpreted cues and became momentarily lost.

The final theme concerns the behavior of people once they have reached an area of relative safety. Bryan [1977], in a cross-cultural comparison of two large data sets, noted that fully a third of the individuals who made it to safety subsequently reentered the fire site to look for others, to check on the progress of the fire, to "do something" while waiting for firefighters, or to get personal property. At Adelaide, three individuals went back to search for a miner they believed to have "frozen up," but who had actually left the group and had come out another way. These three miners placed themselves in great jeopardy. At Brownfield, a mechanic put his own safety at risk in order to stay with a co-worker who had given up and believed himself unable to travel farther. Finally, a face boss jeopardized himself in a successful attempt to locate these two men.

In essence, there seems to be enough substantive agreement at this point to suggest that it is possible to arrive at a scientific understanding of people's activities in fire. The present analysis of worker behavior in mine fires supports existing research regarding human responses to structural fires. At the same time, however, it adds some complementary insights into individual and group behavior in a type of social subsystem different from those usually studied. In these mine fires, strong continuities between organized and collective behavior, hypothesized to exist in all emergencies, induced the workers to help each other negotiate thousands of yards of smoke-filled entryways to safety, and led them to define any actions that seemed to violate the sacred code of "buddyhood" as somehow needing explanation.

Given that escape, for many of these workers, seems to have been a very problematic *group* effort, this book can be used to increase an awareness of some difficulties that may be encountered during any escape from a mine. Readers should gain an appreciation for the following factors: (1) Initial warnings are often unclear, sometimes due to the way technology behaves, and sometimes due to faulty or incomplete communication. This can lead to different interpretations of the problem. (2) People frequently fail to gather the right kinds of information which prevents them from making appropriate responses to the situation. (3) Once any decision is made, individuals respond well to a leader. If leadership is lacking, however, people tend to become confused. (4) Apparatus used in mine emergencies, such as page phones and self-rescuers, may not work as expected, or may fail. (5) Individuals become disoriented very quickly in smoke. Additionally, smoke rises, obscuring markers and landmarks in enclosed spaces.

Given these five factors, the following recommendations are offered to mine safety specialists. It is expected they can be related back to procedures in place at their operations:

Trainers should periodically review with workers the escape and evacuation procedures at their mine(s). Include a description of (1) how warning messages will be communicated, who will make the call, or how the warning will be conveyed; (2) what the content of the message will be; (3) what information to seek when communicating with someone outby the fire area (location, distance to fresh air, suggested escapeways, etc.); (4) mine rescue team support; (5) the marking system for primary and secondary escapeways; (6) the storage plan for SCSRs; (7) what equipment, supplies, and materials to take from the section; and (8) the assembly points for workers on each section.

Research on fires in complex structures such as high-rise buildings (some of which was cited earlier) shows that there is an overdependence on the telephone as an emergency warning device. Such was the case at the mines discussed in this book—miners at the operation did not routinely answer section telephones. There are undoubtedly certain aspects of the warning and communications system at any mining operation that are taken for granted and, on reflection, could be a problem. These attributes should be spelled out and, insofar as possible, made foolproof. For instance, a separate device such as a flashing strobe could be mounted on or near the telephone to alert workers that the incoming call is not routine. These features should then be spelled out during training.

There seems to be too much dependence on engineering hardware solutions without a concomitant understanding of how miners will use those systems. For instance, state-of-the-art mine monitoring equipment may be installed without providing adequate training to the dispatcher or communications person. In many cases, a definition of what constitutes adequate training can only be accomplished by testing the system; thus, there is a need for emergency simulations and structured fire drills, activities that are not widely practiced in the industry.

Once a decision is made to take action during a fire, people respond well to leadership. If this leadership is lacking for some reason, they tend to become confused. On Adelaide's 2 Northwest section the foreman took the lead and a section utilityman, who was trained in mine rescue, brought up the rear. Everyone stayed together and had relatively little trouble during their evacuation of the mine. Safety managers should compare this scenario with those situations on some of the other sections at all three sites and develop a strategy allowing for the most competent person (whether a supervisor or a rank-and-file miner with specialized experience) to assume leadership early in an event.

As an emergency progresses, people who are less well-prepared tend to experience sensory overload. This causes them to focus on small parts of the problem rather than trying to comprehend the entire situation. This point is illustrated by the miners' tendency to "save" their SCSRs until the smoke got heavy, but not protect themselves from CO in the meantime by using their filter self-rescuers. Miners should be assisted in developing a protocol for how they will employ their emergency breathing apparatus—one that goes beyond the trainer's rote "put on your SCSR at the first indication of fire or smoke," which may be good advice but obviously is not heeded in actual situations.

Research on fires in buildings has shown that people frequently reenter a fire site after reaching safety, often to search for someone they believe is still inside the structure. This observation is borne out here as well. One of the miners went back with two buddies to look for an individual who left the group. Trainers should impress upon their workers some of the consequences of leaving the group, either to help a buddy, or to escape on their own. If groups are to split up, it should be according to a previously determined plan of action.

Finally, it is recognized that people become disoriented very quickly in smoke. Unless one knows the escape route very well, such disorientation could be fatal in a mine fire. It is suggested that safety managers review their site plan for conducting fire drills. This review might be an opportunity to elicit renewed commitment to a company's emergency preparedness program and procedures for ensuring that miners walk their escapeways periodically. Measures could then be enacted, if needed, to ensure these plans and procedures are implemented in the manner intended by law.

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APPENDIX A.—DESCRIPTION OF APPROXIMATE ESCAPE ROUTES TAKEN BY THE GROUPS

Adelaide Mine

1 Right

This group boarded the rail-mounted mantrip and started to come out of the mine. They traveled nearly 0.7 miles before encountering smoke. At this point the crew stopped the mantrip, got out, and began walking off in various directions. The foreman and another miner got the crew back together. After reassembling, the crew decided to go to the intake escapeway and walk the rest of the way out of the mine. After getting into the intake escapeway, the crew traveled about 500 ft on foot before encountering smoke in this escapeway. The crew then moved into the left-side return entry where they confronted smoke again. After putting on their rescue breathing apparatus, group 1 continued for about 0.3 miles before turning right. After turning right, this crew continued to move through the smoke-filled return entry for another 0.8 miles before finally getting past the location of the fire and reaching clear air.

2 Northwest

This group boarded the rail mounted mantrip and started to come out of the mine. The crew traveled about 0.1 miles in the mantrip before encountering smoke. At this point, the crew stopped the mantrip, got out, and decided to move to the intake escapeway and continue to egress the mine on foot. The crew traveled about 0.1 miles on foot in the intake escapeway before encountering smoke. Upon being confronted with smoke, the crew moved to the right return entry to continue their escape. After traveling several hundred feet more in the return entry, this group encountered smoke again. At this point, the group put on their rescue breathing apparatus and continued their escape, traveling about 0.4 miles in the return before turning right. After turning right, the group traveled another 0.2 miles in the smoke-filled return entry. At this point, the group became disoriented in the smoke and began to go the wrong way by walking back toward the working section. The group traveled about 200 ft in the wrong direction before a miner in the group realized that they were going back into the mine. At this point, the group turned around, and continued to egress the mine, traveling an additional 0.4 miles before passing the location of the fire and reaching clear air.

3 Left

This group boarded the rail-mounted mantrip and started to come out of the mine. The crew traveled about 0.1 miles in the mantrip before encountering smoke. At this point, the crew stopped the mantrip and decided to go back to the section. The crew rode the mantrip back to the section, got off the mantrip, proceed to the intake escapeway, and began walking out. This group walked about 500 ft before encountering smoke in the intake escapeway. The crew then moved into the right-side return entry and continued to proceed out of the mine. After moving into the return entry, this group walked several hundred feet more before running into smoke in the return. At this point, the miners put on their rescue breathing apparatus and then continued on foot about 1 mile through smoke before passing the location of the fire and reaching clear air.

Brownfield Mine

4 South

The foreman and mechanic with this group noticed smoke coming up the intake escapeway. This crew assembled at the section power center. This group elected not to follow the intake escapeway since it was already filled with smoke. Similarly, the miners chose to avoid the alternate escapeway in the return aircourse since they knew that it would be filled with smoke. The crew decided to escape via the mine entry in which the conveyor haulage belt was located, since they believed that this entry should have clear air. This group walked the belt entry for about 600 ft when they encountered smoke. Group 4 traveled for about 0.4 miles in heavy smoke to the point where the conveyor belt entry intersected with the main supply haulage track. Here, the group turned right and moved into the haulage entry and followed the main haulage entry for about 0.1 miles until they were past the fire location and in clear air.

5 South

This group assembled at the rescue breathing apparatus storage station in the No. 1 intake entry. The group traveled on foot several hundred feet and, after being confronted with heavy smoke, moved into the belt conveyor entry where the smoke was lighter. This group traveled about 400 ft on foot in the belt entry until they hit heavy smoke again. At this point, the group moved into the alternate escapeway entry and proceeded to travel the section and main return aircourse through smoke for about 0.25 miles before passing the fire location and reaching clear air.

6 West

These miners assembled at the beginning of the intake escapeway on the working section. After putting on their rescue breathing apparatus, this group traveled on foot for about 700 ft in the intake escapeway before being confronted with heavy smoke. At this point, the group moved to the alternate escapeway where the smoke was lighter. After moving to the alternate escapeway, the group continued to travel on foot for about 0.25 miles before passing the location of the fire and reaching clear air.

Cokedale Mine

7 Butt

Because the primary escapeway was filled with smoke, this group decided to follow the alternate escapeway out of the section. These miners got into the alternate escapeway in the left return aircourse of the section and traveled this escapeway on foot for about 0.3 miles. The crew then made a right turn and followed the escapeway for another 0.25 miles. At this point, the group turned left and continued on foot for about 1 mile before reaching fresh air.

8 Face Parallels

These miners gathered at the beginning of the primary escapeway and proceeded to travel this escapeway on foot about 0.3 miles before being confronted with heavy smoke. Upon hitting heavy smoke, the crew turned around and followed the primary escapeway back to the section. After returning to the section, the group then got in the section's left return aircourse. The group followed the left return aircourse for about 0.2 miles before realizing that they were not in a designated escapeway. The group turned around and followed this aircourse back to the section. At this point, the group crossed the section and made their way into the right return airway (the designated alternate escapeway) and followed it for 0.1 miles before turning left. After turning left, the group continued on foot through the alternate escapeway for about 0.2 miles before turning right. After turning right, the group continued on foot for another 0.3 miles before turning left into the main alternate escapeway. After turning into the main alternate escapeway, the crew continued for about 1 mile before reaching clear air.

APPENDIX B.—MINE FIRE INTERVIEW GUIDE

1. Where were you when you first became aware that there might be a problem in the mine, and how did you learn of it?

   - Who told you?
   - What were you doing? Did you finish?
   - What were your feelings at this time?
   - Did you think that there might be a problem in getting out of the mine?
   - Did you communicate with anyone? With whom?

2. What did you do after making sure that there was a problem?

   - Walk with anyone? Where?
   - Did you go anywhere to get anything after you left your equipment?
   - Did you pick up anything on the section?
   - Did you talk with anyone? About what?

3. Was there a point where the crew assembled?

   - Where was the assembly point?
   - Was this a designated point? Were you trained to go to it?
   - What was the conversation about when you met up with the whole crew?
   - Does anything about the conversation stand out?
   - How would you describe the feeling within the crew?
   - Did you or anyone have any concerns about getting out?
   - Was there any sign of smoke at this point?

4. When did you first encounter smoke?

   - What was the crew's reaction?
   - Did someone take charge?
   - What was being said at this time?
   - Was there any confusion or indecision?
   - What were your thoughts at this point?

5. How was the plan of action to escape decided on?

   - Did the crew meet to decide the course of action?
   - Did anyone distribute assignments?

- Was there general agreement about what to do? Who disagreed? How was that handled?
- What was the feeling within the crew?
- Would the crew have walked out the intake without donning their SCSRs if it were smoke-free?
- How did you begin to go out?
- How much time passed between starting out and donning the SCSR?
- How would you describe that period of time?
- Did you at any time feel that this was a life-threatening situation?

6. What was it like when you first began to don your SCSR?

   - Who made the decision to don?
   - What were the conditions? Could you see?
   - Did anyone take a CO reading?
   - Did you check the apparatus?
   - Did you get more than one?

7. What part did you SCSR training play when you began donning the apparatus?

   - Which of the devices have you been trained on?
   - What position were you in?
   - Can you show us the steps you used to get the SCSR on?
   - Did you have any problems? Did you see anyone else having problems?
   - Did anyone help you? Did you help anyone?
   - Did you have confidence that the SCSR would work correctly?
   - Did anyone experience any problems once the device was on? What were they?
   - How long did it take everyone to get ready to move out?

8. How did you go about actually escaping from the mine?

   - Who made the decision?
   - Did you escape alone or in a group?
   - How was the escape route chosen and followed?
   - Were markers visible?
   - Were there communications along the way? What was it like?
   - Were there problem, especially with the SCSR?
   - Were you aware of any risks in taking out your mouthpiece?

- Did anyone advise you not to remove the mouthpiece?
- How many times did you or the crew stop to rest or talk?
- Did you get rid of anything along the way?

9. At what points were there strategic decisions in making your escape?

   - What were the conditions?
   - How was decision made? Who made it?
   - Was there any disagreement or confusion?
   - Did you feel other crews were in trouble?
   - Where did you think the fire was?

10. Thinking back, what would have made your escape less complicated?

    - Would you have done anything differently?
    - Would you have taken anything else with you?
    - Probe about walking the escapeways.
    - Probe about SCSR donning.

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