Expectations vs. Experience: Training Lessons Based Upon Miners' Difficulties When Using Emergency Breathing Apparatus

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ABSTRACT

Interviews of 48 miners who escaped underground coal mine fires revealed that none of them had ever, before that incident, worn their self-contained self-rescuer (SCSR) either in training or in a real emergency. Consequently, they were ill-prepared to use this emergency breathing apparatus. One persistent problem stemmed from the fact that miners had no notion of breathing resistance, nor of the fact that it would get more difficult to breathe the longer they wore their device. As a result, many of those who were interviewed had simply removed their mouthpieces and breathed ambient air. This is obviously behavior that should be trained out of the workforce. Unfortunately, because of high costs and difficult logistics, miner training is unlikely to ever include donning and wearing an apparatus on a regular basis.

In order to give workers a better idea of what to expect from their devices, therefore, the National Institute for Occupational Safety and Health researchers developed a tabletop (paper and pencil) simulation based upon actual predicaments evacuees had reported encountering. The simulation is designed to emphasize important points related to donning and wearing a self-contained self-rescuer in a mine fire escape, and, by doing so, to bring miners' expectations more in line with what their actual experiences would be. The simulation was field tested in six training classes at three different mining operations. In all, 99 individuals were involved in completing the exercise and rating its properties. In their ratings 88% of the respondents indicated they thought the scenario could definitely happen in real life, and over 80% agreed they had learned something new. From the field test data it was concluded that the simulation had authenticity and potential value as a teaching tool. The simulation was therefore used in a pre-test/post-test control group experiment to determine whether it led to improvements in miners' scores on a true-false test of their SCSR's functional capabilities and proper usage. Eighty-three miners were included in this part of the study. As expected, miners who had participated in the training exercise scored significantly higher on their post-test than miners who had not.

INTRODUCTION

When a coal mine fire occurs in the United States, the self-rescue protocol for miners requires them to evacuate the workings, if possible. Only as a last resort are the workers to try to barricade. Given that a miner would have to travel through an atmosphere that could quickly become toxic or oxygen deficient, escape might be impossible unless the individual was able to isolate his or her lungs from ambient conditions.

Federal regulations require that every person who enters an underground coal mine in the US be supplied with a self-contained self-rescuer (SCSR; a closed circuit emergency breathing apparatus) capable of delivering a one-hour supply of oxygen to the wearer. A training regimen mandated by these regulations requires (no more than once annually) performance of "complete donning procedures in which each person assumes a donning position, opens the device, activates the device, inserts the mouthpiece ***or simulates this task while explaining proper insertion of the mouthpiece*** (emphasis added), and puts on the nose clip (30 CFR 48.8)." Motor task training research conducted by the US Bureau of Mines in the late 1980's has shown that instruction which does not go well above this minimum mandated by law is inadequate (Vaught et al., 1991; Vaught et al., 1993).

There are two reasons that cursory training is inappropriate for an oxygen rebreather such as the self-contained self-rescuer. First, donning and activating the apparatus requires mastery of a fairly complicated motor task. It is the nature of motor tasks that they must be practiced repeatedly in order to be learned and remembered (Schmidt, 1988). 30 CFR Part 48 requires neither repeated nor distributed practice. Second, effective use of an oxygen rebreather entails a certain familiarity with how the device is supposed to work.

A study of worker response to realistic evacuation training was conducted using nontoxic theatrical smoke and training models of an oxygen generating SCSR (Kowalski et al.,1997). In this exercise small groups of miners were required to don their SCSRs, enter a smoke filled area, and travel approximately 885 feet (270 meters) to an exit door which led to fresh air. After leaving the smoke area and removing their SCSRs, trainees completed a one page questionnaire regarding their perceptions of the smoke evacuation experience including physical and emotional symptoms they experienced. The study suggested some level of previous familiarity with an SCSR resulted in miners experiencing fewer physical and emotional symptoms.

Because training simulators are expensive and difficult to maintain in a hygienic state, however, and because an actual $500 SCSR must be refurbished each time it is used, there is little opportunity for a miner to acquire this experience first-hand. Nor is there a proven program to deliver at least some of the knowledge vicariously.

The present study is concerned with the second issue mentioned above - a basic lack of familiarity with the apparatus, and what might be done about it. The question is not about how best to train, since that is known though not practiced, but whether there is some approach between ideal training and none at all that could be used to give workers a better idea of what to expect from their devices. In order to address this question, the National Institute for Occupational Safety and Health (NIOSH) researchers concentrated upon actual predicaments evacuees have reported encountering over the years since SCSRs were introduced. Their purpose was to find a way to bring miners' expectations more in line with what their actual experiences would be by emphasizing important points related to donning and wearing an SCSR during a mine fire escape.

THE MINE ESCAPE SETTING

The workings of underground coal mines are vast, consisting of parallel tunnels called "entries" intersected at right angles every hundred feet by tunnels called "crosscuts." In plan view, this arrangement assumes a grid pattern for each section of the mine, whose total area may be as extensive as that of a large city. The various sections in this city-sized layout connect in such a way as to allow the use of mine-wide "systems" which include electrical, haulage, and most important, ventilation. There are only a few points of access to the surface, one of which may be dedicated to the routine movement of personnel, another used for supplies, and two or three employed for the intake and exhaust of air.

Mine ventilation is a complex undertaking, because air currents naturally take the path of least resistance. In order to get air to flow where it is needed, an operation will use a system of aboveground exhausting fans (to create a partial vacuum inside the mine), and a maze of "stoppings" (concrete block partitions) that seal crosscuts in order to route air through the entries to a mine's working sections. At every section, air is directed across each working face by means of plastic curtains, called "brattices."

The air current sweeps smoke, dust, and liberated gasses away from the faces and into the mine's "return" air courses for its journey to the return air shaft, at which point it is exhausted into the outside atmosphere.

Ventilation, the same system that makes mining possible in the first place, can render an escape virtually impossible during a fire. Not only is the ventilation arrangement likely to bring a continuous flow of oxygen to the fire site, feeding the fire, it may, if it becomes compromised, carry heavy concentrations of toxic smoke and gases into the working sections and into miners' escapeways. Workers are taught that escapeways aren't supposed to be contaminated, because the US Code of Federal Regulations requires underground operations to maintain separate and distinct passages, ventilated by fresh intake air, extending from each working section to the outside. In truth, either direct human action such as a worker's failure to close an access door, or environmental factors such as the deterioration of a stopping due to heat or pressure, can turn an escapeway into a horizontal chimney. The confusion caused by such an unanticipated occurrence then becomes a compounding factor in an already problematic event.

In order to escape through mine entries that may be smoke-filled, oxygen deficient, and contaminated by carbon monoxide, miners have to be able to do two things: First, they must don their emergency breathing apparatus correctly in order to isolate their lungs from the ambient atmosphere. Second, they must wear and use their device for an extended period of time as they attempt to find their way out of the mine. It seems apparent that the greater one's understanding of the situation, and the better grasp he or she has of those factors that may arise as predicaments, the better equipped he or she will be to deal with the emergency. Since real world events are rare and full scale mock drills are very expensive - and hence also rare - expectations have to be forged in a different way. Several organizations that must maintain a high level of preparedness for non routine occurrences have used simulations in their training programs (Halff, et al., 1986; Lacefield and Cole, 1986).

USING A SIMULATION FOR EXPECTATIONS TRAINING

The authors have long been involved in the construction and field testing of paper-and-pencil ("tabletop") exercises based upon case studies of actual mine fire escapes. Unlike the case studies they are based on, however, these simulations do not present the reader with a seamless narrative about the emergency and lessons learned from its resolution. Rather, they require active information seeking and problem solving with no foreknowledge about how a particular course of action might turn out (until it is chosen). This uncertainty, along with the predicaments engendered by having to make critical choices based on incomplete information, have proven effective in the use of simulations to transfer some of the cognitive skills miners would need in order to cope with an actual emergency (Cole et al., 1998).

To date, exercises developed by the authors have focused on the two large domains of emergency decision making and first aid skills. Because of workers' reported problems using their SCSRs (Vaught et al., 2000), however, it was decided to design a simulation entitled "I Can't Get Enough Air." This simulation is centered much more upon the mechanics of SCSR usage than upon escape behavior itself. The following subsections describe the exercise origin and structure.

Exercise background: As part of their investigations regarding worker responses to mine fires, NIOSH researchers interviewed 48 miners about their escape experiences. Accounts given by these workers have been analyzed regarding how SCSRs were used during their escapes.

In general, workers reported several problems that indicate they weren't adept at donning their devices. The problems included difficulty locating the oxygen lever on compressed oxygen SCSRs and leaving the mouthpiece plug in place when inserting the mouthpiece. Slightly more than 40% of the miners who donned compressed oxygen apparatus said that they blew into the SCSR (to inflate the breathing bag) on the first breath. This is not only an incorrect action, but also potentially dangerous. Many workers reported difficulty adjusting the neck and waist straps. In sum, more than 40% of all the interviewees recounted having trouble of one sort or another when they donned their SCSR. Of these, about one half indicated that they needed help from a buddy to get the apparatus on.

Many miners said they did not immediately don their SCSRs, but "saved" them instead, because: 1) they had been taught the devices were designed to provide only 60 minutes worth of oxygen; and 2) they often did not know where the fire was located and how far they would have to travel to get past it. As a result, two-thirds of the workers reported that they traveled barefaced through smoke for 10 minutes on average before donning their SCSR, and consequently donned it in smoke. It is interesting to note that none of the workers who escaped any of the fires had a CO monitor available. The interviews revealed that some did not really understand the dangers that CO can pose.

Based on their comments, it also appeared that a majority of the workers were unaware there is breathing resistance when SCSRs are used and that this resistance increases with the length of time the unit is worn and with increased levels of physical exertion. This was because none of them had ever worn an SCSR before the fire, either in a training class or in an actual emergency. When breathing resistance was encountered, therefore, they tended to think their apparatus was not working properly. In some instances, miners' oxygen demands were greater than the SCSR could provide, in which case the miner "out breathed" the device. Of the workers interviewed, almost two-thirds reported that, for one reason or another, they had trouble breathing from the device. Subsequently, over half of the miners indicated that they either took the mouthpiece out to breathe or "breathed around" the mouthpiece while in smoke.

<u>Exercise scenario</u>: The research team wrote a set of performance objectives based on the accounts related above: 1) *recall* and *apply* basic information about toxic gases and oxygen deficiency; 2) *recall* and *apply* the sequence of steps for proper SCSR donning; 3) *recall* and *comprehend* factual knowledge about SCSR operation, as well as its capabilities and limitations; 4) *recognize* and *comprehend* breathing resistance when it occurs, and its cause; 5) *anticipate* and *predict* the point at which a device will be used up and a second apparatus must be donned; and 6) *order* priorities and decisions in the face of insufficient oxygen to effect an escape using only one SCSR. These objectives were then used in the design of "I Can't Get Enough Air" (Brnich, Vaught, and Calhoun, 1999). The scenario is summarized below:

> *The trainee is given the role of section foreman on the 17 Left longwall development section at the Paula Ann No. 3 mine. The section has been driven about 4,000 feet from 4 West Mains. One of the shuttle car operators has taken a call from the fire boss saying that there is smoke from an unknown source coming into the section. The section foreman attempts to contact someone to find out where the smoke is coming from but gets no response. He assembles the crew and starts riding out of the section on the mantrip, when heavy smoke is encountered. At this point, the section foreman decides to take his crew and travel on foot in the belt entry that is on a neutral split of air. After traveling about six crosscuts in the belt entry, the crew encounters heavy smoke, at which time the section foreman and crew don their person-wearable SCSRs (PWSCSR). After donning the apparatus, the section foreman and crew continue traveling outby in the belt entry. Near the mouth of the section, one miner in the group starts to have trouble breathing from his SCSR. Because breathing resistance is increasing with the length of time the apparatus is worn, the miner is "out-breathing" the device since his oxygen requirements are greater than the PWSCSR can supply. Although the section foreman slows down the pace of the crew's escape, soon more miners, including the section foreman himself, are having trouble breathing. The section foreman must decide when to switch to another PWSCSR that was obtained from a cache along the escape route. At one point, a miner's PWSCSR is completely used up and the group must then stop and change devices.*

As with most tabletop simulations, the story sketched above actually unfolds as a chronological sequence of events with choice points at which the trainee must decide upon an action(s) from among available decision alternatives.

Mechanically, the simulation has two components. A problem booklet presents background information, a statement of the problem, a map of the affected section, and the story with its nine major decision points (Question A through Question I) one to a page. At each decision point the trainee is presented with a list of five or six plausible actions (some correct, some incorrect) from which to choose.

The responses are marked (using a developing pen) on a corresponding answer sheet that has been printed in invisible ink. As each chosen response is marked, a message appears that contains two types of information. First, the trainee is informed whether or not the choice is "correct." Then, whether the choice is correct or incorrect, further information is given related to his or her decision. The first problem frame is shown in Figure 1. The trainee, after studying the question and its five alternatives, will turn to the answer sheet (Figure 2) and highlight the space between the numbered brackets of his or her choice. The response(s) being highlighted will then appear, while the rest remain invisible. As Figure 2 suggests, the consequence of selecting any alternative (or the consequence of not selecting a particular alternative) becomes known only after the decision has been made. In this manner, miners being trained will work through a series of predicaments, making wise or unwise choices at each juncture of the problem, until there is a final resolution.

Question A

You and your crew go through the mandoor at #31 crosscut into the belt entry. The air is clear and you travel about six crosscuts, at which point you find light smoke. What should you do now? (Select as MANY as you think are correct.)

1. Watch the smoke for a while to see if it subsides.
2. Tell everyone to don their SCSR now.
3. Tell everyone to open their SCSR and loop it around their neck, but not to activate the apparatus.
4. Take your crew, lead them back to the section, and go out the return escapeway.
5. Check the time.

When you have made your selection(s) do the next question.

Figure 1. The first frame of the "I Can't Get Enough Air" simulation.

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

1. [This can be dangerous. You need to act now.]
2. [Correct! You need to get your SCSR on now.]
3. [Although you find light smoke in the belt entry, you don't know what toxic gasses are]
   [in the air. You need to use your SCSR now.]
4. [You have already come 15 crosscuts outby the faces. Going back to the section to]
   [get into the return escapeway will waste time.]
5. [Correct! Since you will be in smoke, you will need to have some time reference]

Figure 2. Responses for the first frame of the "I Can't Get Enough Air" simulation.

Whether the resolution is a good one or not depends on the quality of miners' choices as they contend, on paper, with heavy smoke, dry throats, mouthpieces that trigger the gag reflex, sweat collecting under their goggles, inability to get as much air as they think they need, and general confusion about the best way to proceed. It is their decisions vis a vis these conditions that may be evaluated in terms of proficiency.

Evaluating the responses: Each frame of the problem poses a question (decision point) with a mix of both correct and incorrect decision alternatives. The trainee's score on a particular question reflects either full or partial credit, which is arrived at by combining the number of correct decision alternatives selected with the number of incorrect decision alternatives avoided in that frame. The nine decision points are equal in weight so that, added together, they can total from zero to 100. The total score for a miner may therefore be interpreted as a percent mastery of the content of this exercise. As a general rule, skills that are meant to prevent death and injury must not only be learned, but mastered. A rule of thumb in setting the level for mastery under such circumstances is that 90% of the trained population should exhibit a 90% proficient performance (Cole, et al., 1984).

It is also possible to calculate item scores and mastery levels for each trainee so that one may compare individual performances at each choice point. The item scores are very useful for determining how individuals with differing levels of training or experience respond to different predicaments - how a mine rescue team member might react to increased breathing resistance versus how a rank-and-file miner might react, for instance.

The simulation was field tested in six training classes at three different mining operations. In all, 99 individuals were involved in completing the exercise and rating its properties. The miners' average age was 43.3 years with a standard deviation of 7.54. They averaged 19.3 years of experience, with a standard deviation of 8.49. All-in-all, the scores are moderately high for the simulation, indicating that this highly experienced sample was familiar with emergency breathing devices and how they should be used in an escape. Thus, the responses are not distributed normally. However, only 41% of the trainees scored 90% or better. Therefore, in terms of mastery, the scores are skewed but not skewed enough to show 90% mastery by 90% of the workers.

There were too few inexperienced miners to do comparisons by years of experience. There are, however, three primary job categories that underground coal miners may be placed into for purposes of comparison: 1) miner laborers, who are hourly employees engaged in the mining process; 2) maintenance/ technical workers, who perform such jobs as the equipment repair and electrical installations that keep the mine operating; and 3) supervisors/managers, who engage in planning functions and direct the workforce. In these categories, the sample is not representative of the overall population. A representative sample would contain about 50% miner/laborers and about 25% each of maintenance/technical workers and supervisors (Cole, 1988). Miner/laborers made up only 21.3% of those who field tested the present exercise. By far the largest category consisted of maintenance/technical workers (61.8%), while 14.7% were supervisors.

The significance of such a sample makeup, besides the aforementioned skewing, is that with most simulations requiring technical knowledge, those in the maintenance and supervisory categories tend to exhibit greater expertise and therefore score higher. Thus, if the sort of technical skills acquired in electrical training or engineering courses could be transferred to SCSR usage, the proportion achieving mastery scores might be higher for these groups than for rank-and-file workers. To determine if the exercise did discriminate among levels of technical expertise, a chi-square test was run on mastery scores by job category. Figure 3 suggests little or no difference was found in performance among these technical levels. This is borne out by the results shown in Table I. So, traditional technical knowledge and skill do not appear to offer any benefit in attempts to master SCSR usage.

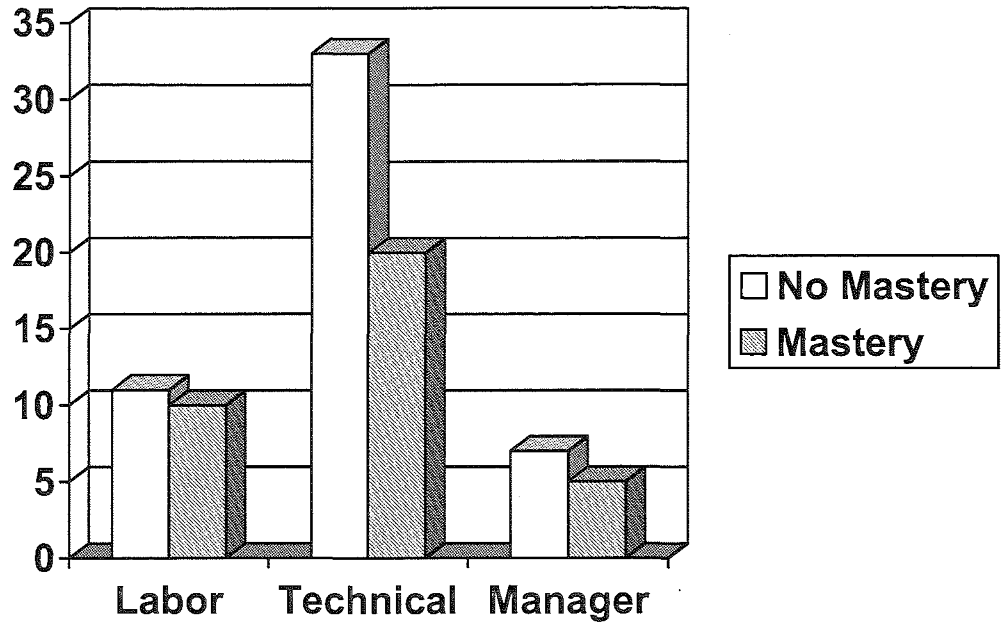

Figure 3. Level of mastery by job category.

Table I. Chi-Square Results for Level of Mastery by Job Category and Mine Rescue Training

Statistic	Job Category			Mine Rescue Training		
	Value	Degree of Freedom	Asymptotic Significance level (2-sided)	Value	Degree of Freedom	Asymptotic Significance level (2-sided)
Pearson Chi-Square	0.614	2	0.736	4.787	1	0.029
Likelihood Ratio	0.610	2	0.737	4.861	1	0.027
Linear-by-Linear Association	0.228	1	0.633	4.733	1	0.030
N of Valid Cases	86			89		

It was when the sample was broken out by whether or not the respondents had ever had mine rescue training or experience that clear differences emerged in terms of performance on the simulation (see Figure 4). Here, even though the apparatuses are different and the protocols are very dissimilar, expertise in the mine rescue domain seems to have helped trainees in dealing with some of the predicaments from the self-rescue problem. The chi-square results for this breakdown (Table I) indicate a significant (.029) difference between the two categories.

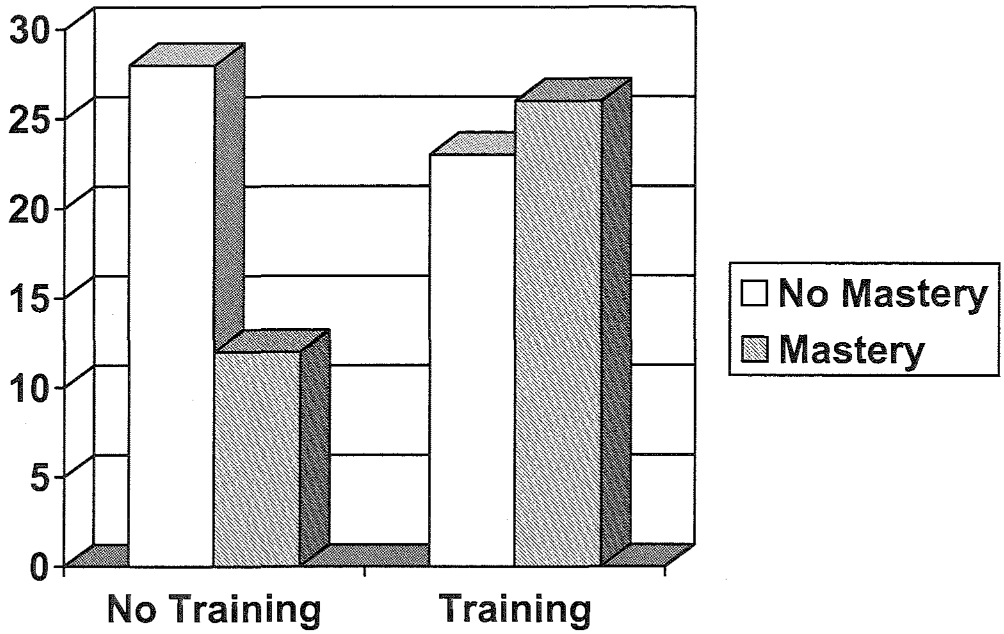

Figure 4. Level of mastery by mine rescue training.

Given that table top simulations are paper and pencil teaching tools, and self-contained self-rescuers are hardware, how can table top simulations be used to give a trainee a better idea of what to expect from his or her apparatus in an emergency? Such tools can be useful because individuals working the simulation receive feedback about what impact their chosen alternative may have upon the situation; whether to don the SCSR immediately or "save" it for instance. Thus, the exercise teaches by reinforcing good decisions, concepts, and strategies, while providing a basis for the remediation of incorrect thinking. There are also accompanying study notes which, upon review and discussion following problem administration, further elaborate the strategies and information that are exercise objectives. The notes help to situate this information in the specific experience of those individuals who work the simulation. In this sense, instructional simulations have an interesting advantage over participation even in actual emergencies. They can provide a trainee with an overall perspective on the interactions among personnel, equipment, and physical factors, while revealing both the predictable and unpredictable events that are always part of an emergency. This type of overall comprehension of the "problem space" is thought to result in greater wisdom on the part of the participant. In aviation circles, table top simulations are used to teach what is often referred to as "air wiseness" with good results (Flathers, et al., 1982; Giffin and Rockwell, 1984). The "I Can't Get Enough Air" simulation was intended to teach "SCSR wiseness."

The fact trainees felt they had gained some "SCSR wiseness" is shown by their responses to questions regarding the exercise validity and quality (Table II). Each person who completed the simulation filled out an instrument with 10 items that had them rate the exercise in terms of its authenticity and value as a teaching tool. Given the experience level of this sample, it is not too surprising that 88% of them thought the scenario could definitely happen in real life. It is highly gratifying, therefore, that 65% of them *definitely* agreed the exercise would help them remember important things, and 47% *definitely* agreed they had learned something new. As Table II shows, there were almost no negative responses, either to the exercise's authenticity or its functionality as reflected in the final seven items.

Table II. Miners' Rating of Exercise Validity and Quality (Frequency %)

Statistic	Likert Rating Scale				Mean (n=93)	SD
	Definitely yes			Definitely no		
	4	3	2	1		
Exercise is realistic and authentic	88.2	9.7	2.2	0.0	3.86	0.41
Helped me remember important things	64.5	34.4	1.1	0.0	3.63	0.51
Learned something new	46.7	37.0	16.3	0.0	3.30	0.74
Exercise too long	1.1	4.3	14.0	80.6	1.26	0.59
Liked working exercise	68.8	29.0	2.2	0.0	3.67	0.52
Instructor's directions clear	88.2	11.8	0.0	0.0	3.88	0.33
Written directions clear	74.2	23.7	2.2	0.0	3.72	0.50
Graphics easy to understand	68.8	26.9	4.3	0.0	3.65	0.56
Scoring easy to understand	67.7	23.7	6.5	2.2	3.57	0.71
Exercise easy to read	83.9	16.1	0.0	0.0	3.84	0.37

Does participation in the training exercise increase miners' knowledge of SCSRs?

Two versions of a 25 item true-false test were developed to assess trainees' knowledge of their SCSR's functional capabilities and proper procedures for use. Although the 25 questions were exactly the same in the two versions of the true-false tests, the order in which the questions were presented was different. The "I Can't Get Enough Air" training exercise was administered to two groups of experienced coal miners as part of their annual mine safety and health training class. One group served as the experimental group. They were given the first version of the true-false test, then they participated in the "I Can't Get Enough Air" training exercise, then they completed the second version of the true-false test. The second group of miners served as the control group. They were given version 1 of the true-false test, then after a two minute break, they took version 2 of the true-false test. Finally, they participated in the "I Can't Get Enough Air" training exercise.

The hypotheses are as follows: 1) The mean of the experimental group's version 2 (post-training) scores will be significantly higher than the mean of their version 1 (pre-training) scores; and 2) the mean gain in the experimental group's scores will be significantly higher than the mean gain in the control group's scores.

Table III shows the means and standard deviations for the experimental and control groups' scores on versions 1 and 2 of the test. Using a paired one-tailed t test, it was found that the mean of the experimental group's post-training scores was significantly higher than the mean of their pre-training scores ($t = 4.626$, $p < .001$). This strongly supports the first hypothesis.

In order to test hypothesis 2, a difference score for each participant was computed by subtracting the pre-training score from his or her post-training score. An independent samples one-tailed *t* test was performed to determine whether the mean of the difference scores for the experimental group was higher than the mean of the difference scores for the control group. The computed statistics are reported in Table III.

Table III. Summary of Test Scores on Versions 1 and 2 of the True-False Test by Test Group

Test Group	Number of Miners	Version 1 Test Scores Mean (SD)	Version 2 Test Scores Mean (SD)	Increase in Test Score Mean (SD)	t-value
Experimental	44	18.16 (2.20)	19.68 (1.84)	1.52 (2.18)	3.65*
Control	39	18.26 (2.07)	18.10 (2.20)	-0.15 (1.98)	

* $p < 0.001$

As expected, the mean gain in number of questions correctly answered by the experimental group (1.523) was significantly greater than the corresponding mean value for the control group (-0.154). This difference was highly significant ($t = 3.65$, $p < 0.001$). These results strongly suggest that the "I Can't Get Enough Air" training exercise helps to increase miners' knowledge of their SCSR breathing apparatus.

CONCLUSIONS

The "I Can't Get Enough Air" simulation was designed to let miners experience vicariously the problems that can arise from not knowing when and how to don their SCSR, what to do when breathing resistance increases, and how to know when the device is completely exhausted. It was thought embedding these issues in a problem-solving simulation would have a greater impact on workers than the rule-bound instruction they are usually given in training class along with their donning practice. That is because rule-bound instruction is passive and largely context free. On the other hand, simulations require a person to actively seek information and make judgments about what he or she has discovered. Therefore, "[t]o the extent that such simulations accurately reflect the dilemmas and decisions encountered in actual fires [and the "I Can't Get Enough Air" scenario is derived directly from real incidents], they provide better training for these non routine events than does the more traditional method of teaching facts, escape algorithms, and post-hoc analysis of case studies (Cole et al., 1998:161)." And, while there is no substitute for actual practice with an actual device, the vast majority of subjects thought the exercise scenario was realistic and over 80% reported learning something new. Finally, miners' perceptions that learning had taken place were supported by the results of the pre-test/post-test control group experiment.

REFERENCES

Brnich MJ, Vaught C, & Calhoun R. (1999) I can't get enough air! Proper self-contained self-rescuer usage. Washington, D.C.: U.S. Department of Health and Human Services.

Cole H, Vaught C, Wiehagen WJ, Haley JV, & Brnich MJ, Jr. (1998) Decision making during a simulated mine fire escape. IEEE Transactions on Engineering Management, 45(2), 153-162.

Cole HP, Moss J, Gohs FX, Lacefield WE, Barfield BJ, & Blythe DK. (1984) Measuring learning in continuing education for engineers and scientists. Phoenix: Oryx Press.

Flathers GW, Jr., Giffin WC, & Rockwell TH. (1982) A study of decision making behavior of pilots deviating from a planned flight. Aviation, Space, and Environmental Medicine, 53(10), 958-963.

Fotta B, Bockosh G, (2000) The aging workforce: An emerging issue in the mining industry. In Proceedings of the 31st Annual Mining Safety, Health and Research Conference. Virginia Tech, August. Blacksburg, VA.

Giffin WC, & Rockwell TH. (1984) Computer-aided testing of pilot response to critical in-flight events. Human Factors, 26(5), 579-581.

Halff HM, Holland JD, & Hutchins EL. (1986) Cognitive science and military training. American Psychologist, 41(10), 1131-1139.

Kowalski KM, Vaught C, Mallett L, & Brnich MJ. (1997) Worker responses to realistic evacuation training. In: Proceedings of The International Emergency Management and Engineering Society Conference (TIEMES '97), June 10-13, 1997, pp. 52-56.

Lacefield WE, & Cole HP. (1986) Principles and techniques for evaluating continuing education programs. The Military Engineer, 78(511), 594-600.

Schmidt RA. (1988) Motor control and learning: A behavioral emphasis. Champaign, IL: Human Kinetics Publishers, Inc.

Vaught C, Brnich MJ, Jr., Mallett LG, Cole HP, Wiehagen WJ, Conti RS, Kowalski KM, & Litton CD. (2000) Behavioral and organizational dimensions of underground mine fires. Washington, D.C.: U.S. Department of Health and Human Services, NIOSH IC 9450.

Vaught C, Brnich MJ Jr., Wiehagen WJ, Cole H.P, & Kellner HJ. (1993) An overview of research on self-contained self-rescuer training. Washington, D.C.: United States Department of the Interior, Bureau of Mines Bulletin 695.

Vaught C, Wiehagen WJ, & Brnich MJ Jr. (1991) Self-contained self-rescuer donning proficiency at eight eastern underground coal mines. Washington, D.C.: United States Department of the Interior, Bureau of Mines Report of Investigation 9383.