EFFECT OF TRAINING STRATEGY ON SELF-CONTAINED SELF-RESCUER DONNING PERFORMANCE

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ABSTRACT

The purpose of this Bureau of Mines study was to assess the impact of three different instructional strategies upon trainee ability to don self-contained self-rescuers. The strategies, designed to deliver the same introductory content, were a live demonstration, a structured lecture, and a computer-based format. One hundred fifty-five subjects were randomly assigned to groups that had their initial donning instruction conveyed by one of the three strategies. The trainees performances were then assessed using a number of different measures. It was found that delivery strategy had a modest initial influence upon how well people did, but that this effect tended to disappear after one initial hands-on experience.. It was also noted that a significant amount of skill degradation occurred during the first 3 months following training.

INTRODUCTION

Since 1940, there have been over 18 major explosions and more than 1,000 fires in underground coal mines in the United States (McDonald and Baker (1),[4] and Richmond, Price, Sapko, and Kawenski (2)). In a majority of these incidents, loss of life and property were minimized by the exercise of good judgment and the effective use of mining skills on the part of workers in the situation (McDonald and Baker (1)). This conclusion is in agreement with much of the recent literature dealing with human actions in emergencies, which suggests that people do not necessarily panic and become incapable of taking effective action (Sime (3)). Rather, they engage in adaptive behavior based on choices made from among those perceived to be available at any particular time during the emergency. The variable factor is how well a person uses all available information to arrive at a choice. That is one of the elements of judgment and decision making. Once a decision is made to implement a specific corrective, the variable factor may become one's ability to carry out that course of action successfully. The problem of whether an individual has the necessary procedural skills involves the area of task competency. A case in point is provided by a series of recent studies undertaken by the University of Kentucky and the Bureau of Mines.

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BACKGROUND

In open-ended interviews with more than 50 mine safety experts, Cole (4) recorded several accounts of worker failure to use self-contained self-rescuers (SCSR's) to escape toxic mine atmospheres. The prevailing assumption among those respondents offering such accounts appeared to be that workers are generally proficient in donning SCSR's. All new miners are given training, which includes a demonstration of the respiratory devices used at their mine. In addition, each 8 h annual refresher class includes a course on the use, care, and maintenance of self-rescue and respiratory apparatus. In the absence of empirical evidence to the contrary, that instruction has been accepted as being sufficient. Reputed failures of workers to don the devices in situations calling for their use were most often attributed to poor judgment, panic, or both. Other evidence from the investigations, however, has cast doubt on the adequacy of current SCSR task training and suggests that lack of procedural skills may be an important consideration.

The researchers conducted an extensive review of existing training materials and found logical inconsistencies that suggest that a task analysis might not have been done prior to training material development. Task analysis would begin with the function of the apparatus—to enable a miner to isolate his or her lungs from the ambient air—and determine empirically the most effective sequence of actions for getting the SCSR into operation. The following problems, which are discussed in detail elsewhere (Vaught and Cole (5)), run counter to that protocol: First, the recommended donning position is difficult under most mining conditions, and impossible for miners working in low coal. Second, the donning sequence appears inefficient, placing nonessential and time-consuming tasks such as strap adjustment ahead of some of the steps necessary to isolate one's lungs from the ambient atmosphere. Third, the materials do not present a simplified, easy-to-remember set of procedural rules to help miners order the complex array of tasks needed to get the apparatus on in an emergency.

In the opinion of the investigators, those logical problems with instructional content were not the only indicators that generally available SCSR task training may be insufficient. Summary statistics from 15 mine trainer workshops supported the widely held notion that a majority of underground miners never have hands-on experience with the apparatus (Cole and Vaught (6)). This was a cause for concern in view of the evidence suggesting that infrequently used procedural skills must be overlearned if proficiency is to be maintained, and that the overlearning of procedures having a motor component requires hands-on training (Johnson (7) and Hagman and Rose (8)). Given the critical nature of SCSR donning as a corrective action, the industry tendency to rely upon films, slide-tape programs, or demonstrations by an instructor instead of upon performance trials by the trainees seemed less than optimal.

As part of their effort to show what an optimized SCSR training program might include, the researchers conducted a detailed task analysis using a controlled experiment in which 36 working miners who had recently gotten refresher training were videotaped in performance trials with the SCSR model in use at their mine. Assessment of the tapes allowed the investigators to target those steps in the procedure where most errors occurred and where most time was lost. It was found that individuals spent a majority of their time adjusting straps and locating goggles that had been dropped on the floor. In addition, many of the subjects became confused and omitted tasks such as putting on the nose clips. Only 22 individuals (61 pct) were able to complete the minimum of steps necessary to isolate their lungs, and approximately half of these required over a minute to do so.

RESEARCH PROBLEM

Based on the experimental findings, an instructors manual and short videotape demonstration were prepared for field testing. This package presents a generic procedure for the four SCSR's in common use (CSE, Draeger, MSA, and Ocenco). It offers the following: (1) a donning position (kneeling) that is easy and efficient, (2) a donning sequence that moves critical steps (those tasks necessary to isolate one's lungs) ahead of the others, and (3) a set of "chunked" procedural rules that facilitate easy retention. The present study focuses upon two aspects of the effectiveness of training strategies used to deliver this new donning method. First, the effect of "front-end" complexity and feedback capability was investigated using three different treatments. Each of these treatments required differing levels of involvement on the part of the subjects. The second part of the study deals with the impact of the three treatment strategies upon trainee ability to retain and demonstrate procedural skills 90 days after initial training. It was expected that the type of involvement required to learn the procedure would affect the subject's proficiency with the motor tasks during initial performance trials, as well as his or her capacity to remember and do the procedure at a later date.

METHOD

During a 2-week period in July 1986, professional and technical employees at the Bureau's Pittsburgh Research Center, many of whom make regular visits to mine sites, were given 8 h of annual refresher training for underground miners. This training was performed according to a plan filed with the Mine Safety and Health Administration (MSHA), pursuant to title 30 Code of Federal Regulations, part 48. The classes were conducted by two MSHA approved instructors, and the curriculum conformed generally with that required of the industry. As part of the course of instruction, the students received task training in the new method of donning an SCSR.

TASK CONTENT

The actual training scheme involved having each subject put on a Draeger OXY-SR 60B as if he or she were trying to escape a fire or explosion. There are 19 discrete steps in this activity, and as might be inferred, it comprises a number of possible procedural sequences with an extensive motor component. Although there are necessary conditions for beginning certain steps, each step in any possible sequence is relatively simple from the standpoint that it does not have to mesh with other steps in order to be completed. The task itself is potentially confusing, however, because there are several sequences in which the complete procedure could be done. Nevertheless, as was stated earlier, there is a sequence which is most logical. For the present research the task was made exacting by the fact that it had to be performed without prompting, in the sequence that prior analysis had determined to be most efficient, and within a specific timeframe.

The new 3+3 (three critical and three secondary actions) donning method taught to the trainees contains a chunked sequence of actions that imposes a uniform structure upon the variable discrete steps that combined make up a particular action (depending upon the SCSR model being donned). For example, to fully activate oxygen on the Draeger one is required to (1) lift the opening lever, (2) remove the metal closing clamp, (3) grasp the lid and pull until the split pin is out of the chlorate starter, (4) insert the mouthpiece, and (5) exhale into the breathing bag to activate the bed of potassium superoxide. To fully activate oxygen on the Ocenco, a person would (1) pull the latch rod, (2) release the latches, (3) open the case, (4) open the oxygen valve, (5) inserting the mouthpiece and (6) inhale deeply to open the demand valve and fill the breathing bag. The structure that the generic method imposes upon the donning task not only presents the chunked actions in a logical sequence, but also constrains the discrete tasks to be performed in a consistent order.

INSTRUCTIONAL CONTENT

The core of information delivered to trainees learning the new method provides a two-stage approach to the donning task. First, it presents an efficient position and orientation of apparatus designed to make the chunked sequence possible. Directions for the first stage are as follows: (1) *Kneel.*—place the SCSR on the floor in front of you— lay your miner's cap on the floor and shine the lamp on the SCSR—work with both hands; and (2) *Loop.*—quickly loop the neckstrap over your head in order to position it and the case—leave the strap loose so you will have room to work—now you are ready to begin the 3+3 donning procedure. Directions for the second stage divide the chunked sequence into the three critical actions necessary to isolate one's lungs, and the three secondary actions needed to prepare an individual to escape: (1) activate the oxygen, (2) insert the mouthpiece, (3) put on the noseclips, (4) then put on the goggles, (5) adjust straps, and (6) replace miner's cap. The strategies for transmitting this message were varied for purposes of the present study, but the content remained the same.

CHARACTERISTICS OF THE THREE INSTRUCTIONAL STRATEGIES

Treatment A was a computer-based training program that presented the 3+3 method as sequential blocks of information, each block followed by a series of questions designed to determine whether the individual had learned and retained the material. Wrong answers were remediated by looping the respondent back through the block from which the question was taken. At the end, a short review exercise reiterated the critical and secondary donning actions. This approach required the most active involvement in terms of verbal learning, not only because of the amount of interaction necessary to obtain the front-end information, but also because the subjects were not cued by either the actual apparatus or the paper-and-pencil configuration. In order to reinforce what had been learned, instruction was followed by a videotape demonstration of a trainer putting on an SCSR as if he were in an actual emergency.

Treatment B was a structured lecture that utilized an advance organizer. Using overhead transparencies, the instructor presented the two stages of the new method and discussed the rationale behind each chunked action. Students were next familiarized with an evaluation form that utilized a connect-the-dots configuration and was designed to help individuals reproduce the procedure on paper. Trainees were then given copies of the form and prepared to watch videotaped demonstrations of two trainers donning the apparatus in real time. Active participation was required in that the students were asked to evaluate the first performance by drawing a line to each dot in succession as the trainer completed the action that particular dot represented. In a sense, this activity competed with the visual stimuli, although it had the desired goal of involving the students. At the conclusion of the first demonstration the tape was stopped and feedback given by the instructor, who accompanied his discussion with an overhead transparency depicting an accurately completed evaluation form. The trainees were offered another opportunity to practice the sequence by following the actions in the second performance. Feedback was again provided. The instructor closed the lecture with an overhead transparency representing a hypothetical evaluation of a poor donning trial, and stressed the consequences of doing the critical actions incorrectly.

One of the simplest ways to introduce a procedural task is to have a competent person demonstrate the routine. Indeed, much SCSR instruction, especially in the context of hazard training, consists of just that. Accordingly, treatment C involved having the trainer who had helped perfect the 3+3 method talk groups of subjects through the task, step-by-step, as he slowly donned the apparatus. This live demonstration was followed by a videotape performance of the same individual putting on an SCSR as if he were preparing to escape a mine fire or explosion. The purpose of the videotape was to give the trainees a sense of how a proficient donning execution appeared in real time. As is evident, this approach offered nothing but the basics. First, it did not require the active participation of the trainee in obtaining the front-end knowledge necessary to carry out the procedural task. Second, it did not provide any type of advance organizer to help cue the person's memory when it came time for his or her performance trial. Third, there was no feedback in terms of reiteration of correct steps, or additional information about the consequences of doing a step incorrectly.

PERFORMANCE CRITERION

Ultimately, the act of donning an SCSR is a motor task. Therefore, it was determined that the subjects must demonstrate proficiency by donning the apparatus. In the real world, whether or not one would be considered competent might actually be decided by whether one could use the SCSR to escape a toxic mine atmosphere. The experimental corollary to this practical criterion would probably entail checking to see if an individual could isolate his or her lungs and secure the SCSR adequately within an acceptable length of time, regardless of the sequence of discrete steps. There were two problems with using this sort of indicator in the present study. First, an important part of the research focuses upon skill retention. It would be very difficult to suggest forgetting as a cause of sequencing change or errors if it could not be shown that the subject had at least one systematic and error-free performance. Second, and just as important, it is known that large skill decrements exist with seldom-used procedural tasks (Hagman and Rose (8)). It seemed advisable, within the constraints of the training situation, to allow as much learning to take place as possible. The proficiency level established for the annual refresher trainees was a perfect sequence to be completed in 90 s or less, with the critical part of the sequence to take no more than 45 s. The first trial in which the subject recorded a perfect sequence within the acceptable time was designated the criterion. It was against this criterion that all subsequent performance would be measured.

EXPERIMENTAL PROTOCOL

One hundred fifty-five subjects are included in the ongoing training experiment of which this study is a part. None had extensive prior experience with any type of self-contained breathing apparatus and had never received hands-on SCSR training. In this respect, at least, they were considered to be somewhat like working coal miners; there was no preexisting procedural knowledge that might influence their performance.

At the beginning of each training class individuals were given serial numbers that were to be used to identify them for various purposes throughout the course of the research. The first use of the serial numbers was to enable the trainers to draw lots for random assignment of subjects to groups that would have their initial donning instruction conveyed by different delivery strategies. Following instruction on general hazards, mine maps and escapeways, checkin and checkout procedures, and personal protective equipment, class members were randomly divided into two groups and sent to separate classrooms. There, they were rotated through three assignments: a first aid simulation using either computer-based training or a paper-and-pencil format; roof and rib hazard identification utilizing stereoscopic viewers and three-dimensional slides; and one of the three instructional treatments for SCSR donning. Each classroom was the site of a different delivery strategy.

An alternating protocol had been designed that would enable the trainers to present any two of the three treatments to each training class. The treatments being given on a particular day depended upon the rotation plan in effect. For instance, plan A, which was implemented on the first day, specified that the structured lecture would be used in one room and the computer-based training presentation would be used in the other. Plan B, in effect on the second day of classes, offered the computer-based training and the live demonstration. Plan C, the strategy for the third day, made provision for the live demonstration and the structured lecture. On the fourth day the rotation was repeated.

Immediately following instruction the subjects were taken, one at a time, to an isolated room for a donning trial.

This performance was to serve three purposes. First, an analysis of initial attempts would permit an evaluation of the effectiveness of the strategy used to deliver the front-end donning instruction. Second, the donning trial would provide the motor component, which was considered to be crucial for proficiency at the procedural task. Third, by requiring each person to perform to criterion, the researchers were establishing a baseline from which to assess the magnitude of forgetting over time.

Prior to the performance trial, each individual was equipped with a miner's belt, cap, and caplamp. An SCSR, with its neck strap adjusted all the way out, was placed on the floor approximately four case lengths in front of the subject. The trainee was requested to await a signal from the trainer, and at this signal to put the SCSR on as if he or she were in an actual mine emergency. No questions were answered or information given at this stage of the process. During the donning trial, which was performed with no prompts, the trainer evaluated the subject's proficiency by means of a specially designed connect-the-dots evaluation form intended to show sequencing errors and actions that were done incorrectly (fig. 1). A helper recorded times for both the critical actions and the secondary actions. At the end of the trial, if an error had been made, the instructor pointed it out and explained how to do that particular step correctly. The apparatus was repacked and the student was asked to try again. This procedure was repeated until each individual reached the criterion of a perfect sequence within the specified times.

At the conclusion of the 1986 annual refresher training period, individuals' serial numbers were again randomly drawn (by treatment) to designate subjects who would get followup training and a 90-day retention evaluation. The training, given to half the subjects in each treatment group who had been selected for the 90-day recall, consisted of a quick and simple refresher. The refresher was administered 30 days before the recipient was to have his or her 90-day evaluation. People who had originally received the computer-based format were brought to a training room where they worked through an abbreviated version of their original instruction. Individuals who had gone through the structured lecture were visited in their workplaces by a trainer who gave each person a copy of the evaluation form and asked him or her to reproduce the procedure on paper. After the subject had connected the dots to indicate the order of actions he or she believed to be the correct sequence to follow, the trainer pointed out any sequencing errors and reiterated the correct procedure. For those who had originally gotten the talk-through and live demonstration, the refresher entailed having a trainer visit each person's workplace and do the live demonstration once again.

Seventy-two subjects were chosen to participate in the 90-day retention evaluation. There were 24 individuals for each of the three treatment conditions: 12 who had been refreshed and 12 who had not. Each person in the sample was scheduled to be recalled on or about the 90th day following the date on which he or she had been initially trained. At the determined time, the subject was taken to a laboratory room which contained a videocamera. The purpose of the study was explained briefly, and a one-page interview schedule was administered by a researcher (fig. 2). Following completion of the interview, the subject was outfitted with a miner's belt, cap, and caplamp. An SCSR, with its neck strap adjusted all the way out, was placed on the floor approximately four case lengths in front of the trainee. The individual was instructed to await a signal from the trainer, and then to put the SCSR on as if he or she were in a mine fire or explosion. During the performance trial, which was done with no prompts, one trainer evaluated the process while another trainer recorded critical and secondary times and videotaped the activity. Following the donning trial, the subject reviewed the evaluation form and then watched his or her videotaped performance. A trainer pointed out any errors and suggested ways to correct them. The trial was not repeated.

PROFICIENCY MEASURES

There were three means of evaluating the performance trials. Taken together, they provide a good assessment of the effectiveness of those training strategies used to deliver the initial donning instruction. First, it was possible to record both the number and types of errors committed. This includes sequencing errors, omissions, and incorrect execution of particular steps. Second, there were two measures of time: the number of seconds a subject required to isolate his or her lungs, and the amount of time he or she took to complete the entire procedural task. Third, the number of trials necessary for each individual to reach criterion were recorded. For purposes of this study, data on these variables were obtained for the initial donning trials and the 90-day evaluation. Data management techniques are discussed in the following section.

DATA MANAGEMENT

During the initial phase of the SCSR donning study, 262 records were obtained for the 155 subjects included in the ongoing training experiment. The reason there are more data records than subjects is that some trainees required more than one trial to reach criterion. In addition to these initial records, the project staff planned to collect further information on the performance of the trainees at predetermined dates during the course of the experiment. For this reason the person-oriented information system for educators (POISE) data management software was chosen. POISE permits ready expansion so that additional data may be added, and is flexible enough to allow easy interfacing with a statistical package for the social sciences (SPSSx), the statistical package selected for use in the analysis. Three files are needed to make use of the POISE data management system: a description file, a data file, and a screen format file. For the present experiment, however, it

Performance Evaluation for ______________________ Date __________

1. Did the miner answer the following?

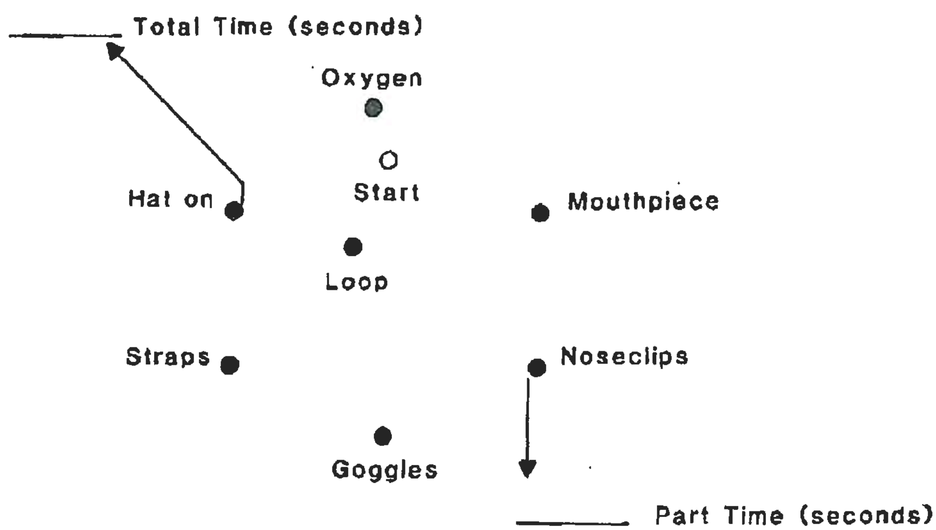
   A. Name the exact place where you started working last shift.

   ______ Yes ______ No

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

   ______ Yes ______ No

2. Connect the dots in the diagram below to show the steps the miner took in donning the SCSR. DO NOT TOUCH THE DOT IF HE OR SHE DID THE STEP INCORRECTLY.



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

Trainer's Signature ______________________

FIGURE 1.—Evaluation form for use in teaching and assessing the 3 + 3 donning method.

Interviewer ____________ Date ________ Time ____________

Subject Name ____________ Serial No. ____________

Treatment ________ Refresher (if yes, date from records) ________

1. Person's Age ______ 2. Gender ______ 3. Education (yr) ______

4. Person's Job Classification ____________

5. How many times have you put an SCSR on.......

   a. Like this model? ________

   b. Another model? ________ (specify all) ________

6. Explain the circumstances under which it was donned (emergency, training, etc.)

7. Have you ever used any other type of oxygen or compressed air breathing apparatus such as.........

   a. Mine rescue gear? ____________
   b. Firefighting gear? ____________
   c. Scuba gear? ____________
   d. Other (explain) ____________

8. If yes to the above, please explain the circumstance.

9. Have you ever put on and breathed through a FSR? (include no. of time) ______

10. If yes to the above, please give model ________ and explain circumstances

11. Date of last donning (from records) ______ 12. No. of days ago ______

FIGURE 2.—Interview schedule designed to elicit information about trainee background and prior experience with breathing apparatus.

was necessary to have a way to identify individual records. As a result, field 1 of the data file was designated a key field, and each record was assigned a key number. A key file was then created in the add option of the describe program. This file made it possible to identify each student and the corresponding trial number for a particular treatment.

When the POISE files were created, 31 data fields were delineated to accommodate the information collected. The described fields occupied columns 1 through 438 in the data file. Major fields originally defined include those allocated for student name, identification number, date of training, treatment, trial number, donning sequence, and errors made. Fields for recording critical times, escape times, and narrative comment were also included. An additional 37 fields were added later in order to provide for data gathered during subsequent phases of the study. Included are fields for demographic information, whether or not the subject had followup training, the number of days since his or her last donning performance, and numerous flags to indicate any other types of breathing apparatus the trainee might have been familiar with.

ANALYSIS

It was originally expected that delivery strategy would have an impact upon the subjects first donning trials, but that the act of putting on an SCSR would override and confound the effects of the front- end strategy. It was further expected that the method of giving the brief refresher would influence trainees' performances on the 90-day trials. Specifically, the live demonstration was hypothesized to have the greatest short-term benefit, because that approach, although the same in content as the other approaches, was the only one that offerded the students a live view of the internal components of the case as they were talked through the procedure. Also, it was the only condition that did not have a competing task associated with it. In the area of retention, however, the computer-based training treatment was hypothesized to have the most impact, since it required the highest degree of involvement in getting the necessary verbal information and was followed by a motor performance. Ideally, involvement is expected to foster retention (Johnson (7)). Additionally, it was expected that the computer-based training refresher, being the most thorough, would have a significant influence on subjects performances at their 90-day trials.

INITIAL PERFORMANCE

In order to begin an exploration of the results, subjects performances on the initial trials following instruction were divided into three categories: (1) failures—those who did not get their lungs isolated from the ambient atmosphere, (2) survivors—those who succeeded in getting their lungs isolated, but who did not record a perfect sequence (the criterion), and (3) criterion performers—those who had a perfect sequence on the first trial. Table 1 is a contingency table that presents the observed (or actual) and expected frequencies of performances by each delivery system. The expected frequencies are those that one would expect to occur by chance, given the number of people exposed to each treatment and the number of performances that fall into each of the three categories.

It is instructive to examine the data in the table. Essentially, there were more perfect sequences than expected for the live demonstration, more survivors than expected for the lecture format, and more failures than would be expected for the computer-based treatment. Conversely, there were fewer than the expected number of failures among those who had received the live demonstration, and greater than the expected number of failures among performances following the computer- based delivery. It should be noted that this phenomenon lies in the expected direction: individuals receiving the live demonstration were hypothesized to do somewhat better initially, while those who were more involved would be less likely to forget what they had learned.

A chi-square (X^2) test for independence was applied to performance by treatment condition in order to test the null hypothesis of no association between delivery system and how well subjects did on their initial donning trials. The chi-square value of 13.88 is sufficiently large to enable rejection

TABLE 1. - Chi-square test of performance by delivery ($X^2 = 13.88$, $P < 0.01$, Cramer's V = 0.212)

Performance	Computer-based		Lecture		Demonstration		Total
	Observed	Expected	Observed	Expected	Observed	Expected	observed
Failure	17	11.9	7	8.7	9	12.3	33
Survivor	20	18.1	18	13.2	12	18.7	50
Criterion	19	26.0	16	19.0	37	26.9	72
Totals	56	NAp	41	NAp	58	NAp	155

NAp Not applicable.

of this hypothesis at the 0.01 level of significance and conclude that there is, in fact, a relationship between the variables which is not due to chance. The magnitude of evidence for the existence of a relationship does not indicate anything about the strength of that relationship, however. Accordingly, Cramer's V, a measure of association suitable for nominal level data, was computed in order to assess how strongly the variables are interrelated. The coefficient, 0.212, represents approximately a 5 pct association. Thus, although chi-square was found to be highly significant, there is only a very weak association between the way in which the 3+3 method was presented to the subjects and how they fared in their initial hands-on attempts.

A second measure of performance immediately following treatment is the amount of time it takes individuals to get the apparatus on. Given what is known about human behavior in fires (Marchant (9)), it is quite likely that most of the time available to don an SCSR in an emergency will be spent in deciding to take action. When one actually begins the task, therefore, he or she should be able to do it rapidly. The most important, or critical, steps are those that are necessary to isolate one's lungs from the ambient atmosphere. Table 2 provides information about how quickly these critical steps were performed by those who were able to do them on the first trial. It should be remembered that those who were not able to complete the three critical steps do not enter into this part of the discussion.

A preliminary analysis of the time data was conducted in order to test the homogeneity of variance assumption. In analyses using the real times, it was found that the null hypothesis of equal variances could be rejected. For this reason, the time measures were transformed into reciprocals (1/X). There is evidence to suggest that reciprocal transformation of time measures is inherently good procedure, because for some subjects the time taken to complete a task might be overly long. A few extreme measures in any one group would increase the variance for a particular treatment, while the variance for the other treatments would not be affected. Transforming the times to reciprocals would tend to make the variances more homogeneous (Edwards (10)). Table 2 includes transformations below the actual means and standard deviations.

As can be seen, those in the live demonstration group required approximately 3 s less (on average) to get their lungs isolated than did those in the other two treatments. An analysis of variance (ANOVA) test for differences between means was performed in order to determine if there was a statistically significant difference in times. The ANOVA model essentially allows a comparison of the magnitude of heterogeneity within samples to the heterogeneity between samples. The rationale is that if subjects are given a treatment that is the same for everyone in their group, but that this treatment is different from the treatment given others, subjects within groups will be more alike on that variable than subjects between groups (Loether and McTavish (11)). All this assumes, of course, that the treatments make a difference in the first place.

The F-ratio (table 3), which indicates the region of a theoretical sampling distribution in which two sample variances would reside, is calculated by dividing the between-group variances by the within-group variances. The larger the F-ratio, the farther out on the tail of a particular F-distribution an

TABLE 2. - Basic statistical data for critical task donning times

	Computer-based	Lecture	Demonstration
Total observations	56	41	58
Students successfully completing critical tasks	39	34	49
Mean critical time, s:			
Actual	18.13	19.12	15.23
Transformation	0.0595	0.0590	0.0705
Standard deviation, s:			
Actual	5.67	8.69	4.74
Transformation	0.015	0.0168	0.0175

TABLE 3. - Summary ANOVA for critical task donning times on transformed scores

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	F-probability
Between	20	.0037	0.019	6.854	0.0015
Within	119	.0325	.003	NAp	NAp
Total	121	.0362	NAp	NAp	NAp

NAp Not applicable.

occurrence would fall. At a certain point in the critical region of the distribution's tail, one is justified in rejecting the null hypothesis that two sample variances estimate a common population variance. At this stage, one may conclude that some type of difference exists between some pairs of groups in the study. As with the chi-square test, however, the existence of a significant F- score does not indicate the reason for that score. A second analysis must be done in order to determine which pairs of group means are significantly different from each other. For the present research, Fisher's LSD (least significant difference) test was used, because it is the most sensitive to small differences between means. Table 2 reveals that two of the possible pairs of means are the cause of the significant F. The pairs are computer-based and demonstration, and lecture and demonstration. Computer-based and lecture were not significantly different from each other.

Tables 4 and 5 present the same information for escape times (the number of seconds trainees required to complete all six tasks in the donning procedure) that table 2 and 3 contain

TABLE 4. - Basic statistical data for escape times

	Computer-based	Lecture	Demonstration
Total observations	56	41	58
Students successfully escaping	25	23	41
Mean critical time, s:			
Actual	65.28	63.94	53.49
Transformation	0.0170	0.0166	0.0203
Standard deviation, s:			
Actual	24.88	18.52	15.76
Transformation	0.0052	0.0037	0.0059

for critical times. These tables are self-explanatory and will not be discussed in detail. It should be noted, however, that the degrees of freedom for the within- subjects source of variation is 86 rather than 119, as given in table 3. Degrees of freedom for within-subjects variation are calculated by taking the number of subjects minus the number of groups. The difference in degrees of freedom, then, reflects the fact that fewer people were able to complete all the procedural tasks than were able to complete just the critical steps. It might also be noticed that the total number of criterion performances listed in table 1 is different from the total number of people recorded as successfully escaping in table 4. This is because a different logic was used in compiling the data. The criterion was a perfect performance. However, some subjects completed all six tasks, thereby receiving an escape time, but did some of the tasks out of order. Hence, their initial performance was not their last, or criterion performance, although they were considered to have escaped.

A third measure of performance is errors. Table 6 provides an accounting of errors made on each task by treatment condition. An examination of the table shows that the two areas where people seemed to have the most trouble

TABLE 6. - Portion of each group making errors in initial donning trial by delivery, percent

Error	Computer based	Lecture	Demonstration	X^2	P
Loop	1.8	9.8	3.4	3.73	0.155
Activate	19.6	14.6	10.3	1.95	.377
Mouthpiece	5.4	12.2	5.2	2.19	.333
Noseclip	7.1	9.8	1.7	3.12	.210
Goggle	21.4	26.8	19.0	.88	.644
Strap	12.5	22.0	5.2	6.29	.043[1]
Hat	7.1	14.6	8.6	1.64	.441

[1]Significant at or below $P < 0.05$.

were in activating the oxygen and in donning the goggles correctly. Both of these omissions are relatively serious. Failure to activate the chlorate candle on the Draeger means that the apparatus does not provide an initial burst of oxygen that the miner uses while activating the bed of potassium superoxide with his or her breath. The bed of potassium superoxide must then be activated by breathing in and out of the air bag several times without the benefit of a fresh oxygen supply. Rebreathing one's own air while waiting for the bed of potassium superoxide to begin delivering oxygen presents the danger of oxygen depletion, which would lead to unconsciousness. In the same vein, failure to put the goggles on properly would result in eye irritation in heavy smoke, and might impair a person's ability to escape. A series of significance tests were performed on the errors reflected in table 6 in order to ascertain if there were any differences in proportions of errors by treatment. As can be seen, the only chi-square score large enough to justify rejection of the null hypothesis of independence was in the number of errors made in trying to adjust the neck and waist straps.

TABLE 5. - Summary ANOVA for escape times on transformed scores

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	F-probability
Between	2	0.0003	0.0001	4.973	0.0090
Within	86	.0023	.0000	NAp	NAp
Total	88	.0026	NAp	NAp	NAp

NAp Not applicable.

NINETY-DAY TRIALS

As with the initial trials, subjects performances 90 days after having received their hands-on training were divided into failures, survivors, and those recording criterion sequences. Table 7 presents the observed and expected frequencies of performances by delivery strategy. The effect of front-end treatment was expected to disappear following the trainees hands-on experiences. The chi-square test for independence suggests that this is what happened. An unexpected finding is that the brief refresher given 30 days before the students were brought back in had minimal impact upon those who received it. As can be seen in table 8, there is almost no difference between observed and expected performance in any of the categories. Although not anticipated, the absence of a refresher effect on performance has a straightforward explanation: (1) the researchers deliberately kept the refresher presentation at the level one might reasonably expect to be given at a monthly safety meeting, (2) the refresher was administered to allow a long period of forgetting under the assumption that if workers received these presentations monthly, the worst case would be a disaster just before the next scheduled refresher, and (3) everyone in the sample had gotten the best hands-on training possible just 90-days before these trials. Therefore, most people did relatively well, refresher or not.

Time is the second indicator of training effectiveness examined in this section. Table 9 shows comparisons between how rapidly subjects were able to complete their criterion trials and how they did when they were recalled 3 months later. As the left half of the table indicates, 58 of the 72 trainees were able to complete the tasks necessary to isolate their lungs. The standard deviation for their 90-day trials reveals that not only had their average critical time increased, but that they were much more variable in the amount of time taken to complete the tasks. This finding was expected, and reflects what is known about skill degradation: forgetting invariably takes place over time, especially the forgetting of nonroutine tasks. A repeated-measure ANOVA test for differences between the two means resulted in a significant F ratio.

The right half of table 9 follows a different logic in the compilation of data, and must be interpreted cautiously. The mean times and standard deviations denote how all 72 subjects in the sample did from the time their hands touched the case of the SCSR until they signalled that they were ready to escape. Since the comparisons are being made between criterion trials and 90-day performances, the numbers under the heading original are derived from a complete and perfect sequence achieved by each trainee. The numbers under the heading 90-day are, with the exception of 13 individuals, obtained from incomplete and imperfect sequences. The difference between the two means in this case is not statistically significant, but it is qualitatively significant.

TABLE 7. - Chi-square test of 90 day trial performance by delivery ($X^2 = 6.40$, $P = 0.1712$, Cramer's $V = 0.218$)

Performance	Computer-based		Lecture		Demonstration		Total
	Observed	Expected	Observed	Expected	Observed	Expected	observed
Failure	8	4.7	4	4.7	2	4.7	14
Survivor	14	15.0	14	15.0	17	15.0	45
Criterion	2	4.3	6	4.3	5	4.3	13
Totals	24	NAp	24	NAp	24	NAp	72

NAp Not applicable.

TABLE 8. - Chi-square test of 90 day trial performance by comparing refreshed and nonrefreshed subjects ($X^2 = 0.892$, $P = 0.6401$, Cramer's $V = 0.1113$)

Performance	Refreshed		Nonrefreshed		Total
	Observed	Expected	Observed	Expected	observed
Failure	7	7.0	7	7.0	14
Survivor.	21	22.5	24	22.5	45
Criterion	8	5.6	5	5.6	13
Totals	36	NAp	36	NAp	72

NAp Not applicable.

TABLE 9. - Repeated measures of critical and secondary donning times

	Critical Original	Critical 90-day	Secondary Original	Secondary 90-day
Observations	58	58	72	72
Mean, s:				
Actual	15.22	23.76	54.68	66.20
Transformation	0.069	0.015	0.020	0.018
Standard deviation, s:				
Actual.	3.690	15.56	16.48	33.95
Transformation.	0.052	0.020	0.005	0.007
F ratio:				
Actual	20.14	NAp	10.77	NAp
Transformation.	49.97	NAp	2.24	NAp
Probability.	NAp	<0.01	NAp	<0.05

NAp Not applicable.

A series of ANOVA tests were run to determine the net effect of the treatment and refresher factors on both critical and secondary donning times. The proportion of variation explained by the additive effects of training strategy and whether or not subjects had received a refresher presentation was negligible, and will not be discussed further.

The third variable of interest from the 90-day trials is the percent of each group making at least one error. Table 10 shows that, as with the initial attempts after instruction (see table 6), the trainees consistently had difficulty activating the oxygen and donning their goggles. Strap adjustment was also a problem at the 3-month interval, especially for the computer-based training subjects, and resulted in the only significant chi-square score in the table. Adequate strap adjustment is important, because the SCSR must be secured in order to allow the maneuverability necessary to enable a miner to escape once he or she has succeeded in isolating his or her lungs from the ambient atmosphere.

TABLE 10. - Portion of each group making errors in 90 day donning trial by delivery, percent

Error	Computer based	Lecture	Demon- stration	X^2	P
Loop	16.7	0.0	8.3	4.36	0.113
Activate	20.8	16.7	8.3	1.50	.472
Mouthpiece	12.5	16.5	4.2	1.27	.531
Noseclip	4.2	0.0	0.0	2.03	.363
Goggle	25.0	20.8	20.8	.16	.963
Strap	66.5	12.5	20.8	15.84	.0004[1]
Hat	20.8	12.5	0.0	5.34	.069

[1]Significant at or below $P<0.05$.

DISCUSSION

This paper has dealt with one of the most critical and nonroutine of all mine health and safety skills: the ability to put on an SCSR in the event of an emergency. The results clearly illustrate that donning an SCSR is not easy, and that miners must have hands-on training if the apparatus is to be of any benefit when circumstances dictate its use. What the content of this training should be has been resolved through extensive field testing: the new 3+3 method has shown itself to be an efficient and highly effective procedure. The question of how the 3+3 method should be delivered has been addressed here: it seems to make little difference (Zsiray (12)) as long as the content is presented thoroughly and systematically, and followed up with hands-on experience. The problem of how often, and at what level, miners should be refreshed is still open to exploration.

As was mentioned in the "Experimental Protocol" section, there was no overlearning involved in the initial training. Once a subject had reached criterion, he or she was dismissed. There is evidence that overlearning increases retention, and that had the subjects in this study been required to repeat their criterion (or perfect) performances several times, there would have been fewer failures and fewer errors on the 90-day trials (Hagman and Rose (8)). What is not so evident is whether anything short of relearning the task, in the same way it was learned the first time (by hands-on training), would have resulted in significant differences between refreshed and nonrefreshed trainees on any of the performance measures used here (Johnson (7)).

There are some interesting implications in both of these observations. First, if overlearning is the key to proficiency in SCSR donning, there must be a substantial front-end investment of both time and effort on the part of trainers and trainees alike. With the time constraints of annual refresher training, and the scarcity of either training models or real SCSR's used for training, the logistics of making this investment become challenging. A hands-on session, with remedial instruction following the trial, takes from 5 to 10 min per trainee, and requires the participation of at least one trainer. Cleaning, sanitizing, and repacking the apparatus in order to get it ready for the next student entails another 5 min or more (depending upon the model being used). When the overtraining factor is added in, this time cost increases significantly. Second, if hands-on relearning is the key to skill maintenance, it may have to be done more often than once a year. Almost 20 pct of those recalled for their 90-day trials failed by not completing one or another of the critical tasks. The encouraging note is that almost 20 pct were still able to do a perfect sequence. In a mine fire or explosion, however, a trainer undoubtedly wants no failures, and many more people in the perfect category. This goal may well require giving at least some of the workforce additional training during the year.

Given the findings of this series of studies to date, there are some obvious areas for further research. First, of course, the forgetting curve needs to be charted in order to assess the magnitude of skill degradation between one annual refresher class and the next. Second, the benefits of overtraining must be investigated. Third, a determination should be made as to what kind of interim refresher, up to and including hands-on relearning, would be effective in helping miners retain their proficiency in donning the SCSR. Fourth, and most important, a device should be developed that would allow some of the training burden to be assumed outside the traditional 8-h annual refresher session (if that is needed). There are at least two components to this device: (1) an instructional package (perhaps a videotape and short computer-based training program) that would enable miners to take self-paced remediation; and (2) a simple, durable, hygienic, inexpensive dummy SCSR that would have the adaptability to be practiced with in situations ranging from annual refresher training classes to preshift safety talks.

In the coming months, the Bureau will be addressing each of these problems. The aim is to discover a training regimen that will allow miners to achieve and retain proficiency in donning SCSR's while not intruding unduly upon a mine's production activities. It is expected that a major focus of this future research will be on the development of a means for integrating certain aspects of SCSR training with established practices such as scheduled fire drills and walking the escapeways. In this way, not only will SCSR training be strengthened, but the routine preparation for emergency escape procedures will take on an added dimension.

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