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Interactive Training Versus Reading to Teach Respiratory Protection

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A tenet of behavioral education is that interactive training produces superior retention compared with reading. However, this has not often been directly tested and never with practical occupational information in working adults. Adults from diverse occupational backgrounds learned the principles of proper respiratory protection presented (a) in a book, (b) on a computer monitor, (c) through interactive computerized training consisting of textual information and illustrative pictures followed by quizzes and feedback, or (d) passively viewing the information and quizzes in Condition c on a computer monitor. Interactive training produced significantly more correct test answers at immediate posttraining, 1 week, and 2 months. This study demonstrated the superiority of interactive training for teaching occupational safety and health information in working adults.

In work settings, skills and specialized knowledge are taught in many ways. This training constitutes a major institutional expense. U.S. corporations, for example, spend an estimated $55 to $60 billion per year to provide almost 2 billion hours of training to an estimated 60 million employees (National Institute for Occupational Safety and Health, 1999), including training in safe workplace behavior. However, when A. Cohen and Colligan (1998) reviewed over 2,000 publications (1980–1996) that described training methods, only 80 of those publications provided evidence of effectiveness (positive or negative) and met basic scientific requirements for evaluation. Of those 80 publications, the overwhelming majority (53) used the lecture format as the primary training method, 17 studies used extended interactions or discussion, 14 included on-the-job training or instruction, 9 used videotapes or movies, and 5 used written materials or posters (as some reports involved multiple methods, the total exceeds 80). Although there is a large literature evaluating methods for training managerial skills (e.g., Burke & Day, 1986), evaluations of occupational safety and health training methods are sorely needed.

Although many methods have their place in worker training, there is empirical (e.g., Merrill, Reiser, Merrill, & Landes, 1995) and consensus agreement that individual tutorials can be the most effective methods for teaching the cognitive knowledge required for good safety and health practice (A. Cohen & Colligan, 1998). This knowledge typically must be supplemented by hands-on training to develop specific procedural skills (as encouraged, for example, by Weinstock, 1994). Further, to improve worker compliance with standards of safe practice, additional changes must be put in place such as on-the-job monitoring (e.g., Burke & Day, 1986; Morrow, Jarrett, & Rupinski, 1997). Our specific focus in the present report is on methods for training the cognitive (i.e., nonprocedural) knowledge needed for worker safety and health.

Behavioral approaches to education provide effective individual instruction through active or interactive methods, perhaps the earliest example of which was Programmed Instruction (PI; e.g., Holland, 1960; Skinner, 1958). Although the early academic implementation of PI showed promise (Holland, 1967), clumsy implementation (teaching machines), too-small training steps, and failure to require the requisite active behavior (Vargas & Vargas, 1992) ultimately doomed this early implementation. The

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concepts were not without merit, however, and the fields of behavioral education and computer-based instruction or computer-assisted instruction grew in the wake of PI to become effective tools in many educational settings. Azevedo and Bernard (1995), Kulik and Kulik (1991), and Kulik (1994), for example, reviewed many studies in academic settings that demonstrate a superiority of computer-based instruction over traditional instruction. Although these approaches have been used to good effect in the occupational setting (e.g., Geller, 1999; Goldrick, 1989), their effectiveness in occupational safety training has not been widely tested.

Consensus behavioral education principles are as follows: (a) fully specify learning objectives, (b) focus attention on key elements, (c) carefully sequence training steps to assure competence at each point, (d) require learner to answer questions at each step to demonstrate learning, (e) provide clear feedback on correctness of answers, (f) require repetition of material following errors and correct answers before proceeding to the next step, (g) learner-paced progress through training steps, and (h) provide a precise record of accomplishments (e.g., Edgar & Sulzbacher, 1992). The goal of the present study was to test the hypothesis that an interactive training method rooted in these principles is superior to the presentation of the same information in a book.

Respiratory protection was the topic selected to exemplify basic occupational health information for this evaluation of interactive computer-based training. The Occupational Safety and Health Administration (OSHA) requires knowledge training prior to on-the-job use of respirators. An estimated 5 million U.S. workers are required to wear respiratory protection to prevent "hundreds of deaths and thousands of illnesses annually" (29 C.F.R. § 1910), and specific studies support this contention (e.g., Fuller & Suruda, 2000). There is ample evidence that respirators are effective (e.g., Dosman et al., 2000; Muller-Wening & Neuhauss, 1998), yet acceptance and compliance problems abound because of comfort, visibility, and fatigue factors (e.g., Salazar, Connon, Takaro, Beaudet, & Barnhart, 2001; Salazar et al., 1999). A computer-based training program based on the principles of behavioral education, and more specifically PI, served as the interactive training method. To evaluate the importance of interactivity (Principles d, e, f), the same material was presented in book form or on a computer monitor without quizzes (d), feedback (e), or required repetition of material following an error (f). In addition, to control for exposure to the full set of materials experienced by the active participants (viz., text, quizzes, answers, feedback repetition of missed information), the computer-based training program was passively shown to some participants (passive yoked controls). To examine the durability of the learning, we administered posttests to all groups immediately and at 1 week and 2 months after training.

Method

Participants

A total of 123 adults (73 female, 50 male) were recruited through advertisements in local newspapers, the Web site of Oregon Health and Science University, and flyers distributed at a liberal arts university. They were paid $15, $75, and $35, respectively, for completing three sessions (participants were not initially informed about Session 3, so its payment was treated as a "one-session rate"). Participant occupations can be categorized as follows: clerical/accounting/sales/research aide/technician/computers/media/medical care/teacher (79), unemployed (18), student (16), laborer (7), and retired (3).

Setting and Apparatus

Up to 2 participants were seated facing a wall in front of a small table, and up to 4 participants were seated around a single 1.06 m × 3.04 m table. Panels (0.89 m × 0.89 m) on top of the large table blocked views of other participants.

For the two conditions involving computer presentation, training was administered on Apple G3 PowerBooks or iBook laptop computers. Participants responded on a user-developed "9BUTTON" response unit constructed of aluminum covered with a powder-coat finish. The face of the "9BUTTON" response units sloped from the screen toward the participant, covering the keyboard (pictured in Anger et al., 1996). Nine 20 × 15 mm buttons, with the numbers 1–9 on their face, were arranged in an arc near the screen and were back-lighted with incandescent lamps when a participant response could effect an action. For the passive viewing condition, participants viewed training over "slave" monitors (i.e., they had no unit on which to respond). Two conditions used spiral-bound booklets with text and pictures identical to that shown on the computer screens, one screen per page, or participants were shown the same information on a computer screen but without interactive features (quizzes and feedback).

Respiratory Protection and cTRAIN

Basic respiratory protection information compiled from the Occupational Safety and Health Administration (both federal and Oregon), addressed the following: uses (preventing symptoms), limitations (IDLH [immediately dangerous to life or health] conditions, seal, fit tests), and maintenance of air-purifying and supplied air respirators (SAR; valve, cartridge replacement); recognition of respiratory hazards (lead, solvents, carbon monoxide; acute and chronic effects); selection of proper respirators for different hazards (MSDS [material safety data sheets], product labels, PELs [permissible exposure limits]), and measurement of hazard levels.

The interactive condition used cTRAIN software (copyrighted by Oregon Health and Science University and Ronald R. Reed Consultants, Inc). The program consisted of information "screens" containing the content followed by quiz "screens" that contained four-item multiple-choice questions about the content in the preceding information screens, all in color. At the bottom of every screen was a navigation bar with icons and short words prompting the participant as to which action each button would produce. For noncomputer conditions, the same text and pictures were presented but without the navigation bar (Anger et al., 2001).

For the interactive training condition, the information for each topic was divided into information sets consisting of 2–6 information screens of text, illustrative pictures, or a movie (demonstrating SAR maintenance), followed by 2–10 four-answer multiple-choice questions on quiz screens. There were 58 information screens and 60 quiz screens. Procedurally, the participant could change his or her selection multiple times until he or she pressed the 9 button to indicate a final answer, which was followed by feedback. An error on a quiz screen returned the participant to the first information screen in the information set, which the participant was required to step through again until the missed question was answered correctly. The participant could not step back to a prior information set, nor could the participant step forward to the next set until correctly completing the question(s) for the current set. The program began with a two-screen explanation of "how to use the system" and an overall description of the program's structure (Anger et al., 2001).

Procedure and Conditions

Participants were randomly assigned to conditions when they arrived. Each completed a pretest consisting of the 60 quiz questions (with no feedback), followed by the four topics of information. This was accompanied by quiz questions in the interactive training program condition. Following each topic, participants completed a posttest consisting of the quiz questions for that topic. One training condition was presented in a booklet; the test for that condition was given in paper format. Correct responses served as the dependent variable.

PI-active. PI-active participants completed the cTRAIN respiratory protection program as described earlier, responding on the 9BUTTON apparatus to pace the program and answer questions that were followed by feedback. "PI" is the condition descriptor because the training used the principles in classic Programmed Instruction (e.g., Holland, 1967), and "active" was appended because the program required active or interactive participation to complete the training.

PI-passive. PI-passive participants served as "yoked" controls. Each was yoked to a PI-active participant scheduled for the same time. The PI-passive participants viewed the information and quiz screens, quiz answers, and feedback on a "slave" monitor at the pace of the PI-active participant to whom they were yoked. When errors by the PI-active participant led to repetition of the information set, this process was visible to the PI-passive participant who was not able to control the process in any way. Thus, PI-passive participants viewed Programmed Instruction but did not receive (active) Programmed Instruction training.

Once the PI-passive participant had viewed the training as controlled by the PI-active participant, he or she turned to face a computer and 9BUTTON response unit to take the posttest. On finishing each posttest, the participant turned back to the "slave" monitor for the next topic. Examiners prevented yoked PI-active or PI-passive participants from beginning a topic until both had completed their posttest and were facing the monitor to begin the next topic. Yoked PI-active and PI-passive participants were unable to see each other because they were on opposite sides of a panel. PI-passive participants were given consent and demographic forms and preliminary instructions on their condition in a separate location from the PI-active participants, to enhance the sense of separation.

INFO-screen. INFO-screen participants stepped actively through the same information screens as PI-active and PI-passive participants by pressing the 9 button and also watched the movie and enlarged pictures if they chose those options. However, the quiz screens with feedback had been eliminated from the information sets. INFO-screen participants completed the same pre- and posttests in the same manner as the PI-active and PI-passive participants.

INFO-book. INFO-book participants were given a booklet with the information and color pictures in the exact same format as on the cTRAIN screens but without a navigation bar. The movie on respirator maintenance was set up for participants to view by pressing a single button on an adjacent computer. This group, like the INFO-screen group, did not receive quizzes or feedback. Participants took the same posttests as all other participants, although the tests were presented in paper format and the participants circled the correct answers with a pen.

Role of the Examiner

Examiners administered informed consent and initial oral instructions on testing procedures. In the challenging active/passive testing sessions, one examiner was assigned to the side of the table with 2 PI-active participants and the other to the side with 2 PI-passive participants. Examiners, who communicated by signs over the partitions, stopped continuation at the end of a topic or test until yoked active and passive participants were both ready to begin a topic. Otherwise the PI-active participants were self-paced.

Results

A total of 123 participants completed the pretest, posttest, and 1-week retest in the PI-active ($n = 32$), PI-passive ($n = 31$), INFO-book ($n = 28$), and INFO-screen ($n = 32$) conditions. There were more female than male participants in each condition, with the largest difference in the INFO-book group with only 29% male participants, compared with 44%, 42%, and 47% in the PI-active, PI-passive, and INFO-screen groups, respectively. The mean age varied between 34.1 and 37.5 years, and mean years of education completed varied between 14.9 and 15.9 years in the four conditions. Between 3 and 7 participants per group reported using a respirator in a job during their working life, and between 1 and 3 participants per group reported having had formal training in respirator use.

Pretest Versus Posttest Versus 1-Week Retest

PI-active participants had the highest mean performance on both the posttest and the 1-week retest, followed by PI-passive, INFO-book, and INFO-screen groups, in that order. Mean PI-active group performance was 55.9, only 4 questions below perfect (60) at the posttest, but declined sharply to 48.1 at the 1-week retest (see Table 1). As seen in Table 1, the PI-active change from pretest to posttest, when expressed as effect size (*d*) based on the mean as a fraction of the pooled standard deviation (Dunlap, Cortina, Vaslow, & Burke, 1996; Richardson, 1996), is a substantial 6.35, well above that for the other three groups (3.26–4.76). The mean performance of the PI-active and PI-passive participants (see Table 1) who viewed both the information and the quiz screens was superior to that of the participants who saw only the information (INFO-screen and INFO-book participants). PI-active performance was, expressed as effect size (*d*), 0.78 better than PI-passive, 1.92 better than INFO-book, and 2.35 better than INFO-screen (see Figure 1). However, the differences between the PI and INFO group means, which were a healthy 4 to 11 answers in the immediate posttest (see Table 1 and Figure 1) declined slightly to a spread of 2 to 7 questions by the 1-week retest (see Table 1). This is mirrored by lower effect size (differences) of 0.31 versus PI-passive, 0.64 versus INFO-book, and 1.14 versus INFO-screen (see Figure 1). J. Cohen (1969) characterized effect sizes larger than 0.5 as medium and those over 0.8 as large.

Individual scores at pretest, posttest, and 1-week retest of all 123 participants were compared by one-way analysis of variance (ANOVA) with a Fisher's protected least significant difference (PLSD) post hoc test for all pairwise comparisons (see Table 2). The overall F ratio was significant for the posttest, $F(3, 119) = 26.20$, $p < .0001$, and 1-week retest, $F(3, 119) = 6.61$, $p = .0004$, but not for the pretest, $F(3, 119) = 1.51$, $p = 0.217$. Because of the higher-than-chance pretest scores, these analyses were repeated after excluding the four questions on which 80% or more of participants were correct at all test points (pretest, posttest, and 1-week retest). The resulting shifts were trivial.

Although group results are the primary basis for comparison, each individual worker must learn all the critical information to meet a goal of universal occupational health. From the perspective of individual performance, results at pretest, posttest, and 1-week retest are shown in Figure 2. Pretest distributions were approximately comparable between the participants in each condition, with performance ranging between 12 and 37 correct of 60 questions. Because chance performance on 60 questions with four possible answers would be 15 correct, participants apparently entered the study with some knowledge of respiratory protection or with sophistication regarding answer selection on multiple-choice items. On the posttest, PI-active participants had 25 of the 34 highest scores (56–59), including the five highest scores (59 of 60). Conversely, on the pretest, PI-active participants had only 9 of the 35 best scores (30–37). On the pretest, the INFO-screen and INFO-book conditions each had 10 of the 35 scores of 30 or above, including the two highest scores (37 and 38). The su-

Table 1
Mean (SD) Performance on Pretest, Posttest, and 1-Week Retest (Out of 60 Questions), and Effect Size and Pearson Correlations of Changes Between Pretest to Posttest and Pretest to 1-Week Retest

Group	Pretest	Posttest	1-week retest	Pretest to posttest		Pretest to 1-week retest	
				d	*r*	*d*	*r*
PI-active	26.7 (5.1)	55.9 (3.8)	48.1 (5.8)	6.35	.583	3.79	.596
PI-passive	24.9 (4.3)	51.7 (6.6)	46.0 (7.4)	4.76	.385	3.50	.357
INFO-book	27.3 (5.3)	46.4 (5.9)	43.9 (7.1)	3.27	.528	2.57	.580
INFO-screen	27.2 (5.4)	45.2 (5.0)	41.1 (6.2)	3.36	.400	2.32	.625

Note. PI = Programmed Instruction.

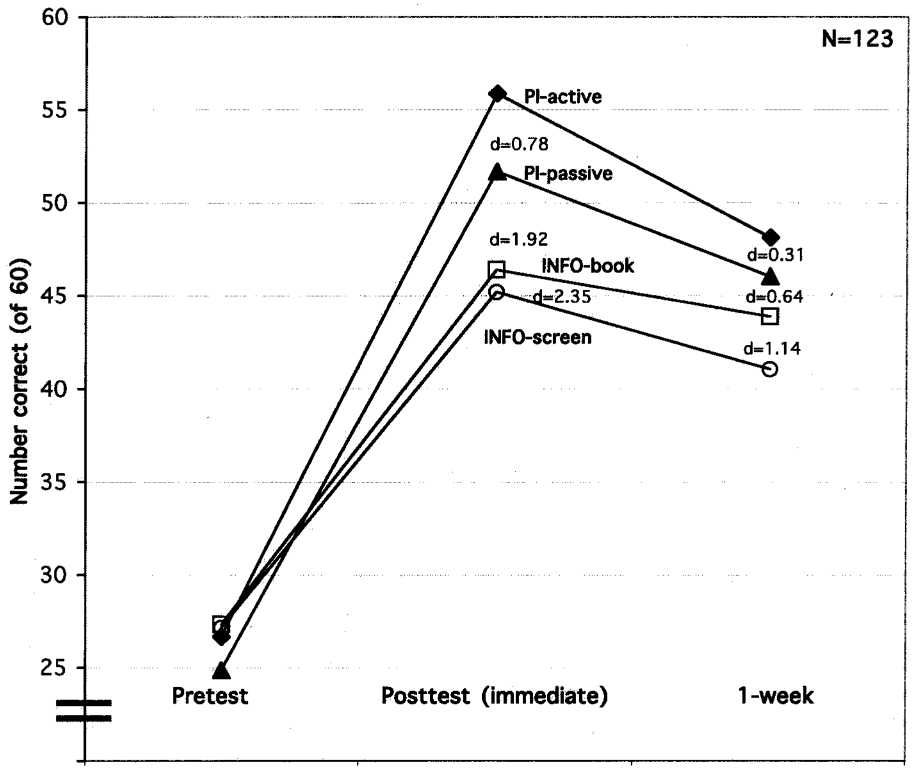


Figure 1. Mean performance of the PI-active ($n = 32$), PI-passive ($n = 31$), INFO-book ($n = 28$), and INFO-screen ($n = 32$) groups at pretest, posttest and 1-week retest. The effect size (d) of each difference between the PI-active mean and the other group means is listed above each group mean. PI = Programmed Instruction.

periority of the PI-active participants was far less marked at the 1-week retest. Although 82% of the four highest scores (57–59 of 60) at the posttest were made by the PI-active participants, their performance fell to 44% of those scoring 50 or better at 1-week retest.

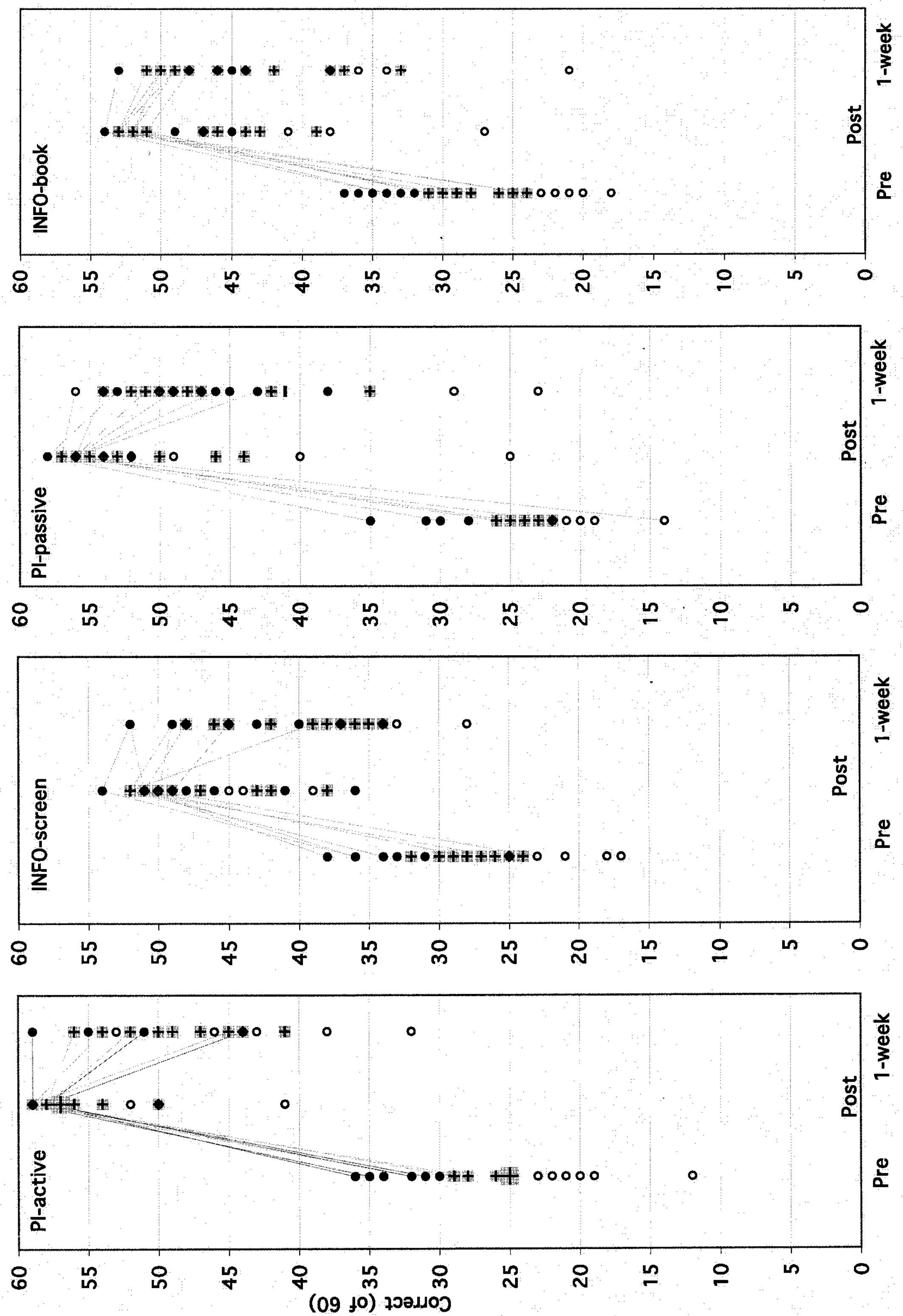
Table 2
Effect Size and Pearson Correlations of Changes Between Pretest to Posttest and Pretest to 1-Week Retest

Group	Pretest to posttest		Pretest to 1-week retest	
	d	*r*	*d*	*r*
PI-active	6.35	.583	3.79	.596
PI-passive	4.76	.385	3.50	.357
INFO-book	3.27	.528	2.57	.580
INFO-screen	3.36	.400	2.32	.625

Note. PI = Programmed Instruction.

2-Month Retest

Without prior warning, all of the participants were contacted by phone 5–6 weeks after training and were invited to return for another session 2 months after initial training (in the 8th week following but not necessarily on the same day as initial training). Seventy-nine participants returned for testing. Pretest, posttest, 1-week test, and 2-month test performance of those returning at 2 months after training is depicted in Figure 3 (thus, 44 participants in Figures 1 and 2 are not in Figure 3). Performance continued to decline in all groups. Although mean performance of the PI-active ($n = 19$) group (44.1 correct) remained significantly above performance in all other


PI-active
INFO-screen
PI-passive
INFO-book
Pre
Post
1-week
Correct (of 60)
60
55
50
45
40
35
30
25
20
15
10
5
0

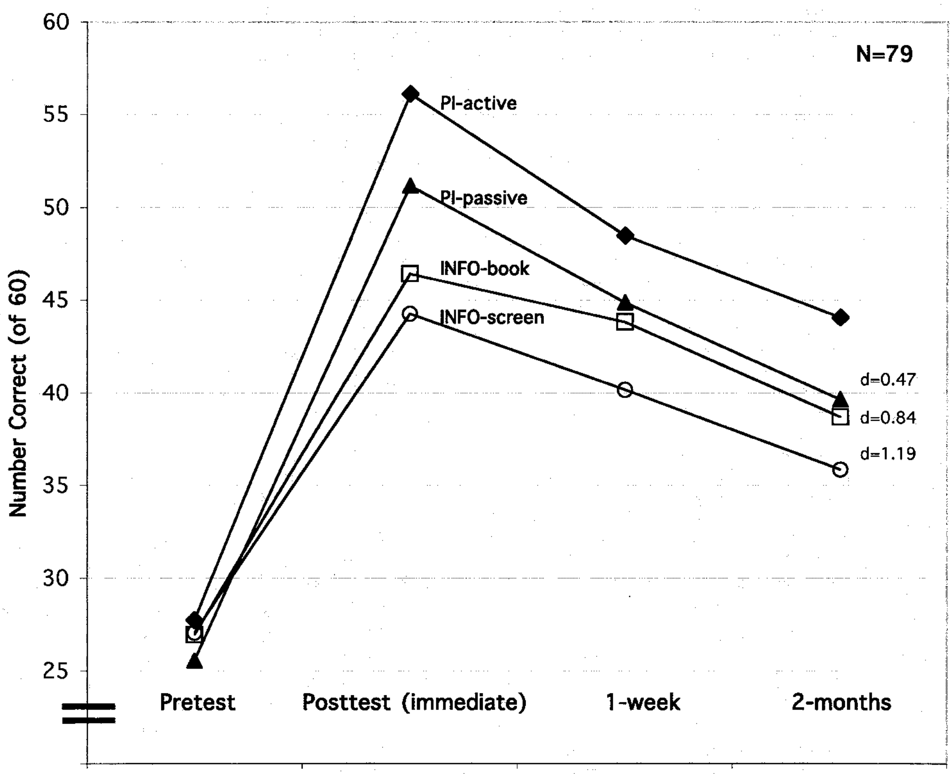


Figure 3. Performance of those PI-active (n = 19), PI-passive (n = 20), INFO-book (n = 20), and INFO-screen (n = 20) participants who returned at 2 months for a retest. PI = Programmed Instruction.

conditions, mean performance of the PI-passive (n = 20), INFO-screen (n = 20), and INFO-book (n = 20) groups reached a similar level, between 36 and 40 correct. A one-way ANOVA with a Fisher's PLSD post hoc test for all pairwise comparisons was applied, as above, with the smaller number of participants and the added 2-month test period. The overall F ratio remained statistically significant at the posttest, $F(3, 75) = 17.37$, $p < .0001$, and 1-week retest, $F(3, 75) = 5.31$, $p = .002$. It was also statistically significant at the 2-month retest, $F(3, 75) = 5.00$, $p = .003$. PLSD probabilities are listed in Table 3. Effect size is included in Figure 3 at the 2-month retest between PI-active and the other conditions.

Figure 2 (opposite). Distributions of the PI-active, INFO-screen, PI-passive, and INFO-book groups at the pretest, posttest, and 1-week retest. The lowest quartile of respondents on the pretest are represented by open circles, the highest quartile are represented by filled circles, and the remaining participants are represented by pluses surrounded by gray. The lines connect the scores from the participants in the highest quartile of the distribution on the posttest with their respective pretest and 1-week retest scores. A quartile consisted of 8 participants, though tied scores sometimes inflated this number. In the INFO-screen graph, 7 people tied at 23, so they were superimposed on the same physical location. There were other ties as well. PI = Programmed Instruction.

Table 3
PLSD Adjusted Post Hoc Comparison Probabilities of All Pairwise Comparisons for Participants Completing Post- and 1-Week Tests Only

Comparison	Post	1 week
PI-active vs. PI-passive	.003*	.21
PI-active vs. INFO-book	<.0001*	.015*
PI-active vs. INFO-screen	<.0001*	<.0001*
PI-passive vs. INFO-book	.0003*	.22
PI-passive vs. INFO-screen	<.0001*	.004*
INFO-book vs. INFO-screen	.402	.10

Note. $N = 123$. PLSD = Fisher's protected least significant difference; PI = Programmed Instruction.
* $p < .05$ (adjusted by PLSD).

Pretest Performance

Test performance may reflect both knowledge of respiratory protection and information acquired during the training. The impact of pretest score on subsequent performance was addressed by analysis of covariance regression techniques with pretest performance as the covariate. Interactions between pretest performance and performance at other test periods could also be assessed. Pretest was a significant factor at both posttest, $F(1, 115) = 30.16$, $p < .0001$, and 1-week retest, $F(1, 115) = 43.68$, $p < .0001$. That is, those with higher pretest scores continued to have the highest scores thereafter. The interaction terms, however, were not significant at posttest, $F(3, 115) = 0.34$, $p = .76$, or 1-week retest, $F(3, 115) = 0.08$, $p = .97$. Those with higher pretest performance profited from the training about equally with those who scored poorly. A similar trend was seen for the 79 participants completing the 2-month retest. Pretest was a significant overall factor at posttest, $F(1, 71) = 18.41$, $p < .0001$; 1-week retest, $F(1, 71) = 31.60$, $p < .0001$; and 2-month retest, $F(1, 71) = 39.04$, $p < .0001$, but there were no significant interactions, $F(3, 71) = 0.90$, $p = 0.45$ at posttest; $F(3, 71) = 0.36$, $p = .79$ at 1-week retest; and $F(3, 71) = 1.73$, $p = .17$ at 2-month retest. The post hoc comparisons revealed a similar pattern of significant differences, as did the ANOVA comparisons. However, at the 2-month retest, PI-active was significantly superior to all three other conditions (see Table 4), rather than only INFO-book and INFO-screen (*p* levels in Figure 3; $p = .04$ was not significant).

Discussion

Four methods were evaluated for training individuals in the appropriate use of respiratory protection. Of these, interactive training (PI-active) was consistently superior. Two methods that involved reading the same material but without the interactive requirements (INFO-screen and INFO-book) were consis-

Table 4
PLSD Pairwise Comparisons Among All Conditions for Those Completing Only Two and Those Completing All Three Retests, Following Analysis of Covariance Using Pretest Performance as the Covariate

Comparison	Posttest	1-week retest	2-month retest
Posttest and 1-week test only ($N = 123$)			
PI-active vs. PI-passive	.0009*	.15	
PI-active vs. INFO-book	<.0001*	.005*	
PI-active vs. INFO-screen	<.0001*	<.0001*	
PI-passive vs. INFO-book	<.0001*	.15	
PI-passive vs. INFO-screen	<.0001*	.0008*	
INFO-book vs. INFO-screen	.35	.06	
All three retests ($N = 79$)			
PI-active vs. PI-passive	.003*	.05*	.01*
PI-active vs. INFO-book	<.0001*	.01*	.003*
PI-active vs. INFO-screen	<.0001*	<.0001*	<.0001*
PI-passive vs. INFO-book	.004*	.55	.58
PI-passive vs. INFO-screen	<.0001*	.01*	.03*
INFO-book vs. INFO-screen	.18	.04*	.10

Note. PLSD = Fisher's protected least significant difference; PI = Programmed Instruction.
* $p < .05$ (adjusted by PLSD).

tently inferior. The interactive training condition (PI-active) differed by having frequent quiz questions, requiring an active response to those questions, and providing feedback regarding the accuracy of the response. In the event of an error, the PI-active participant repeated the information on which the question was based and repeated the quiz question until he or she selected the correct response. In the fourth condition, PI-passive, each participant was yoked to a participant in the PI-active condition. A PI-passive participant's monitor showed each screen that their PI-active "partner" saw at the same time. Therefore, in addition to the information seen by the INFO groups, PI-passive participants also saw each quiz question, each response that was given, the feedback for that response, and the subsequent repeated material that followed an incorrect response by the PI-active "partner." This condition thus provided a control for the PI-active group's additional exposure to the quiz questions and correct answers, as well as repetition of information following errors. PI-passive performance was superior to INFO-screen and INFO-book but was below the PI-active group in all comparisons. This outcome supports the benefits of interactive training—active responding, frequent testing of understanding and retention, and feedback—specifically following a PI format.

The superiority of the PI-active condition answered the principle question addressed in the study, and at the posttest effect size (*d*) differed from the INFO-only conditions by 1.92–2.35 and the PI-passive condition by 0.79 standard deviation (see Figure 1), which J. Cohen (1969) characterized as medium (PI-passive) or large (INFO conditions). Interactive training produced better knowledge retention than did merely reading the same material. (Examiners reported that all INFO participants spent enough time looking at the pages or screens to be reading them, a supposition borne out by the test results.) This superiority was seen both immediately after the training and 1 week and 2 months later (although effect sizes declined to small for PI-passive, others remained large). This finding thus extends the literature supporting the superiority of interactive computer-based Programmed Instruction in academic settings (Azevedo & Bernard, 1995; Dube, McDonald, McIlvane, & Mackay, 1991; Geller, 1999; Kritch & Bostow, 1998; Kritch, Bostow, & Dedrick, 1995; Kumar, Bostow, Schapira, & Kritch, 1993; Miller & Mallot, 1997; Thomas & Bostow, 1991; Tudor & Bostow, 1991) to adult workers learning occupational health and safety information.

The constant difference over time (immediate, 1 week, and 2 months) among interactive training, passive viewing, and reading the same information is consistent with early PI research in the educational setting (reviewed in Anderson, 1967). Although some early studies did not detect differences (e.g., Goldbeck & Campbell, 1962; Krumboltz and Kiesler, 1965), these early programmed learning experiments presented information in book form with the correct answer readily available to mostly unmonitored students. In a telling query, Anderson (1970) reported asking students in a 1969 experiment if they had, despite explicit and repeated directives to the contrary, copied down the answer from the following page. In response, 40% said they did so on difficult questions and 20% said they did so regularly. This should not condemn all of the early PI research, but it does suggest caution in interpreting negative findings contradicted by contemporary, or especially more recent research, in which such potential "cheating" is monitored and prevented. Careful monitoring and the nature of the computerized training prevented cheating in the present study. PI, now that more capable technology permits effective implementation of its principles, deserves reconsideration as an effective form of behavioral education and computer-based training. More to the point of occupational health, in which the implications of poor learning are potentially very serious and irreversible, is the decline in recall over 2 months. Of course, this sample did not have occasion to use the information on their job, as would workers who use respirators in their trade, a factor that should act to increase retention.

The PI-passive condition was intermediate between active PI and reading. This condition did not allow the participants to actively respond to the quiz questions or receive direct feedback for their reactions. However, the passive condition increased the number of times participants were exposed to the quiz screens and the repeated information following a quiz error. That PI-passive was superior to the two INFO conditions suggests that these shared elements may be partially responsible for the success of PI. "Suggests" is used deliberately as the PI-passive condition had additional characteristics that might be involved in the training it produced. That each yoked participant was involved "au vivo" in the life of a partner, celebrating their successes and suffering their failures, gave this condition a bit of a soap opera quality that may, in fact, have engaged the yoked PI-passive participant in more active learning than the name for the condition implies. To the extent that the PI-passive condition was more engaging than another "passive" condition would be, the size of the contribution by the active responding would be underestimated.

This study has practical implications. The primary benefit of interactive computer-based training may be when documented training is essential, instructors are expensive, and large numbers of trainees do not appear simultaneously for training. In addition, self-pacing and requisite accurate performance should benefit people with a wider range of learning skills than traditional training approaches. Of course, the relative benefit of this interactive computer-based training in a well-educated population such as sampled here, notwithstanding J. Cohen's (1969) characterization of such effect sizes as medium to large, amounted to only a 10%–20% improvement over reading the same material in a booklet.

Although the present study affirms the success of interactive computer-based training, it provides only a starting point in the analysis of the factors that allow this success. Does separating quiz questions from the information, a technique rarely seen in PI, improve or decrease their impact? Are multiple-choice questions as effective as fill-in or other active response formats typically used in PI? In this study, quiz questions followed, on average, every 3.9 information screens. Was this an optimal frequency? These complex questions require further study. Nonetheless, the present report demonstrates the effectiveness of behavioral education principles and specifically interactive Programmed Instruction for teaching one topic in occupational health: respiratory protection. From a practical perspective, cTRAIN provides a flexible software program that makes this powerful behavioral technology readily available to trainers who might otherwise dismiss such methods as too complicated or expensive to implement. Although computer-based training is not a comprehensive solution for skills such as fit testing that require experience, nor does it demonstrate that the learned knowledge also changes behavior in the field, it can effectively (and ever-more cost-effectively with each repetition) teach the requisite knowledge so that a trainer (who is ever-more costly with each repetition) is needed only to teach the skills.

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