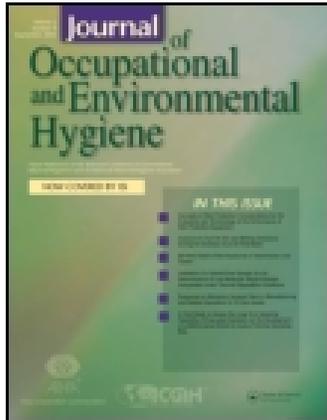


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Journal of Occupational and Environmental Hygiene

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/uoeh20>

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Accepted author version posted online: 21 May 2014. Published online: 30 Oct 2014.

To cite this article: Philip Harber, Jing Su & Cheng Cheng Hu (2014) Persistence of Respirator Use Learning, Journal of Occupational and Environmental Hygiene, 11:12, 826-832, DOI: [10.1080/15459624.2014.925115](https://doi.org/10.1080/15459624.2014.925115)

To link to this article: <http://dx.doi.org/10.1080/15459624.2014.925115>

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Persistence of Respirator Use Learning

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Although retraining and repeat fit-testing are needed for respirator users, the optimal frequency is uncertain. The persistence of proper respirator donning/doffing techniques and changes in quantitative fit factor over 6 months after initial training were measured in this study. Initial training was designed for rapid rollout situations in which direct contact with well-trained occupational health professionals may be infeasible. Subjects (n = 175) were assigned randomly to use either a filtering facepiece N95 (FFR) or dual cartridge half facemask (HFM) respirator. Each was assigned randomly to one of three training methods—printed brochure, video, or computer-based training. Soon after initial training, quantitative fit and measures of proper technique were determined. These measurements were repeated 6 months later. In the six-month followup, subjects were randomized to receive either a brief reminder card or a placebo card. Total performance score, major errors, and quantitative fit all became significantly worse at 6 months. An individual's result soon after training was the most important predictor of performance 6 months later. There was a marginal not statistically significant tendency for those initially trained by video to have better protection 6 months later. The study suggests that persons who use respirators intermittently should be thoroughly retrained and reevaluated periodically.

[Supplementary materials are available for this article. Go to the publisher's online edition of Journal of Occupational and Environmental Hygiene for the following free supplemental resource: Additional statistical analyses.

Keywords respirator, respiratory protection, training

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INTRODUCTION

The frequency with which respirators (respiratory personal protective equipment) are used varies considerably: In

some workplaces, workers use them on a daily basis, while in other occupational settings they are used very rarely. Sometimes, workers are trained to use respirators even though they will need them only in case of an unexpected event. Respirator use in many health care and human services facilities is often intermittent rather than continuous. In community settings, many persons may use a respirator (e.g., N95) only when there is a temporary concern about an epidemic, such as during the influenza season.

Workplace studies have shown that respirators are frequently used incorrectly.^(1–3) Improper use is particularly common when respirator utilization is intermittent,^(4–6) or in community settings.^(7,8) Studies by our group and others^(2,3,9–13) have shown that naïve users can be effectively trained by simple methods that do not depend upon immediate access to well-trained occupational health professionals.^(14,15) Such training may be effectively rolled out to provide protection when a new potential exposure of limited temporal duration occurs or when workers are trained to use respirators as a precaution in case an unusual event occurs. These situations are exemplified by temporary protection of human service workers or community members during an epidemic^(16–18) and making respiratory protection available for use only if an unlikely accidental spill event occurs.

The persistence of learned proper respirator use is, however, unknown. Particularly for persons who do not benefit by reinforcing their learning by regular use, the time span over which a trained user can be considered protected is undefined. This study therefore considers whether someone who has been effectively trained to use a respirator requires retraining 6 months later and if there is benefit from a very simple reminder card as an alternative to complete retraining.

While this study focuses on persons who do not regularly use respirators after initial training, analogous questions relate to persons who use respirators more regularly. The need for and optimal frequency of reevaluating respirator users (e.g., by fit-testing) and retraining users are not fully defined. Selection of an annual frequency is arbitrary in most cases.

METHODS

Subjects participated in a study approved by the University of Arizona Institutional Review Board. Participants were recruited from community settings targeted to include individuals with none or minimal prior respirator experience. They were randomly assigned to either a dual cartridge half facemask respirator (MSA ComfoClassic with P99 cartridges, SOFTFEEL, MSA, Pittsburgh, Pa.) or to a filtering facepiece N95 (1860 series, 3M, St. Paul, Minn.) device. For each, subjects were randomly assigned to a single training method—printed brochure, video, or computer-based training. Details of the methods are described in other publications.^(12,19)

Subjects were invited to a repeat session approximately 6 months after the initial training evaluation. Each was randomized to receive either a brief refresher card or a placebo containing general information about health in the followup session. These cards were very short (including 171 and 127 words for the N95 and HFM, respectively).

In both the initial and 6-month followup sessions, subjects donned and doffed the respirator several times. Research staff members carefully avoided providing any direct guidance about proper technique or about adequacy of the subjects' approaches. Two primary outcome measures were utilized—proper performance of placing and removing the respirator and quantitative fit factor. The analyses are based upon the second cycle on each of the experimental days.

Video recordings of the placement and removal of the respirator were coded by staff members with a four point scale ranging from perfect to seriously/definitely deficient for a series of specific performance items (10 for N95 and 14 for the HFM).⁽¹⁹⁾ These codes were integrated into two summary indices: The total performance score (TP) was the sum of the scores for each of the behavioral items and was scaled to a 100 unit range. The major errors (ME) score was the number of serious errors committed by the subject.

Quantitative fit factor (FF) was determined using the Portacount condensation nucleus method. Measures were obtained using the standard aerosol measurement protocol. Each measurement was conducted with four subject maneuvers (quiet breathing, head movement, reading the rainbow passage, and labored breathing). Methods are described in detail elsewhere.⁽¹⁹⁾ For analysis purposes, the geometric mean of the fit factor with the maneuvers is employed.

Data were maintained in a relational database (Microsoft Access, Microsoft, Redmond, Wash.) with additional Visual Basic programming. Statistical analyses were conducted using SAS for PC (SAS version 9.3, SAS Institute, Cary, N.C.).

Comparisons of subjects allocated to each of the three training methods and comparison of subjects who completed both sessions versus those who completed only session 1 were tested using Fisher's exact. Hypothesis tests to compare results for the first session and the second session were evaluated with the Wilcoxon signed rank test. The Kruskal-Wallis was used to determine if there were statistically significant

differences in session 2 results according to training method employed in session 1.

Several additional statistical approaches using general linear model methods were used to evaluate the effects of initial training mode (print, video, CBT), the performance or FF achieved at session 1, and the use of the brief reminder card upon outcomes at 6-month followup (session 2) when considering possible confounders. The proper donning/doffing methods scores were used as raw scores and the fit factors were transformed using a cubic root because of non-normality of the raw results. Three sets of analyses were conducted: Set A was univariate analyses of a single variable (either initial training type or the result in session 1). Set B analyses were multivariable analyses including both the session 1 result and the training method.

Set C addresses the possibility that differences in subject personal characteristics among those who participated in session 2 and those lost to followup might affect the results. Additional variables were selected based upon whether they were differentially distributed between the those in session 2 and those lost to followup; these additional variables were added to the pool of potential confounders if $P > 0.2$ in the test for difference between the two subgroups. Then a backward elimination process was performed with 0.05 as the threshold of p-values.

RESULTS

Participant Characteristics

The second session was held approximately 6 months after the initial training. As shown in Table I, 75% of subjects from session 1 participated in the second session as well. The characteristics of subjects in both sessions and those who participated only in session 1 are summarized in Table II. There were small but statistically significant differences for smoking status, occupational status, education level, and any prior use of respirators. In comparison to subjects who participated only in the initial session, the subjects who were present for both sessions were more likely to be female (58% versus 43%, $P = 0.05$), more likely to be never smokers (75% versus 48%, $P < 0.01$), and tended to have more students and fewer with only high school education. Additional detail is provided in the online supplement Table S1.

Comparison of Session 1 and Session 2 results

Figure 1 compares overall results obtained soon after training and 6 months later (i.e., session 1 versus session 2). The analysis is limited to persons who participated in both sessions. For all measures, there were significant declines in the respirator effectiveness measures over the 6 months. The median fit factor declined from 63.5 to 44.5 for FFR, and from 722 to 167 for HFM. Both the measures of proper utilization technique and the fit factors became worse over time. More detailed description of the session 2 results is included in the online supplemental material Table S2.

TABLE I. Subject Assignments^A

	Session 1		Session 2 Participation		
	FFR		Yes	No	%
Brochure	39	->	26	13	67%
Video	38	->	28	10	74%
Computer-based training	41	->	30	11	73%
	HFM				
Brochure	40	->	31	9	78%
Video	36	->	28	8	78%
Computer-based training	40	->	32	8	80%
	234		175		75%

Note: FFR = filtering facepiece respirator, HFM = half facemask dual cartridge respirator. P-values using the Fischer Exact test for difference of followup by training type were 0.7 and 1.0 for FFR and HFM, respectively.

^AThe table summarizes followup of subjects participating in initial training session according to training modality. The percentage refers to the proportion of session 1 participants who were present for the followup 6 months later. followup

Impact of Initial Training on Performance and fit Factor Six Months Later

Performance was measured using a performance total score and a major errors score (see Methods). The unadjusted effect of training type on effective respirator use 6 months later is shown in Table III.

For both the FFR and the HFM, neither the fit factor nor the behavioral performance scores were statistically significantly different according to the training modality 6 months previously. However, the unadjusted analyses (set A1 in the table) suggest there was a tendency for both fit factor in performance in session 2 to be better for those who had received video training during the initial session. This effect diminished when adjusted for results achieved in the first session (model set B). A post hoc analysis of the unadjusted results showed that the quantitative fit factor for HFM with video training was statistically significantly better than the fit factor for those who had been trained with the other methods ($p = 0.026$, not adjusted for multiple comparisons).

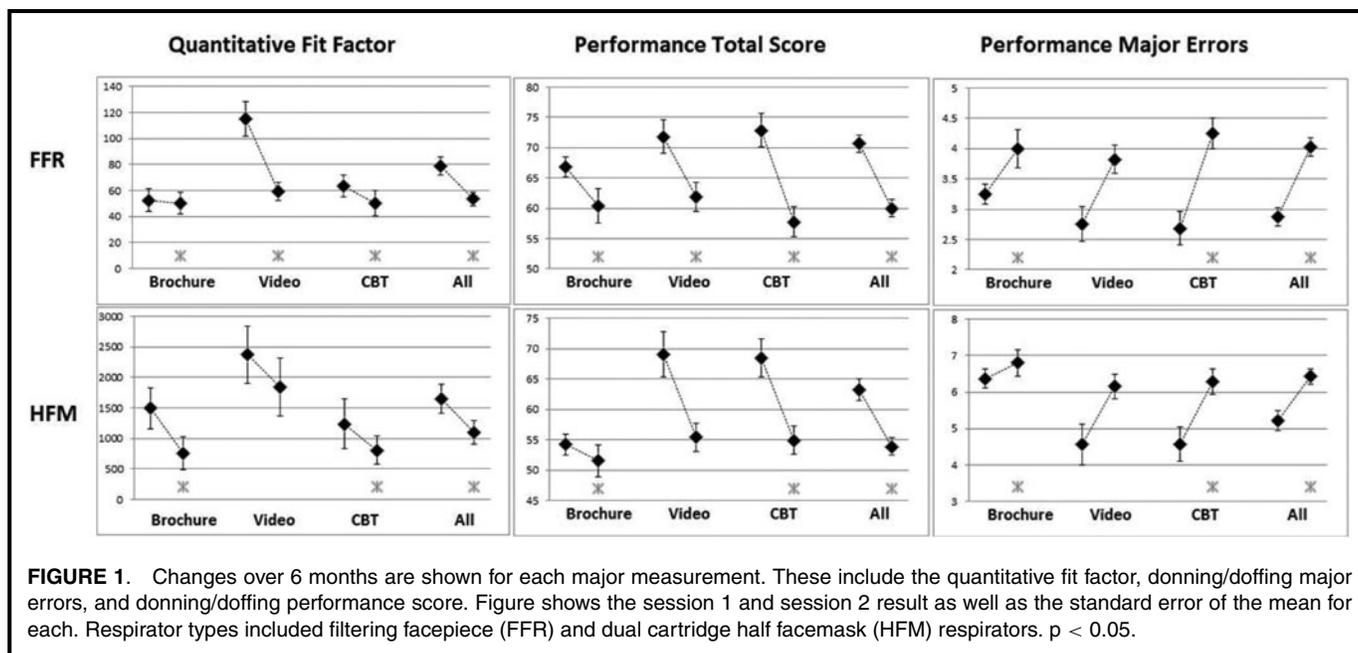
TABLE II. Characteristics of Participants^A

		Session 2	Session 1 Only	p
Number subjects		175	57	
Age	Mean (SD)	34.2 (14.28)	34.77 (13.58)	0.64
	Range	18–70	18–68	
Gender	Female	100 (58%)	25 (43%)	0.05
Smoking	Never	129 (75%)	28 (48%)	<0.01
	Current	11 (6%)	14 (24%)	
	Former	32 (19%)	16 (28%)	
Occupational status	Not working	17 (10%)	15 (27%)	<0.01
	Working	93 (54%)	27 (48%)	
	Student	51 (29%)	7 (13%)	
	Other	12 (7%)	7 (13%)	
Education	High school or less	24 (14%)	17 (30%)	0.02
	Some college	76 (44%)	26 (46%)	
	College graduate	31 (18%)	8 (14%)	
	Postgraduate	41 (24%)	6 (11%)	
Language	Primarily English	129 (74%)	46 (79%)	0.6
	Other	45 (26%)	12 (21%)	
Respirator Experience				
Current user	Yes	26 (15.2%)	9 (16%)	0.83
	No	145 (84.8%)	49 (84%)	
Current frequency	Often	6 (16%)	1 (13%)	0.85
	Occasional	11 (30%)	1 (13%)	
	Never	20 (54%)	6 (75%)	
Ever used	Yes	29 (18%)	12 (24%)	0.02
	No	131 (82%)	39 (76%)	
Respirator user		38 (22%)	15 (26%)	0.18

TABLE III. Effects of Session 1 and Training Type on 6-Month Followup (Session 2)

	A1. Univariate Models-Training Type Effect			A2. Univariate Models- Session 1 Effect			B. Multivariate Models		
	Parameter	Coefficient	p	Parameter	Coefficient	p	Parameter	Coefficient	p
N95 Performance Total Score	Brochure	2.66 (3.66)	0.50	Session 1	0.37 (0.11)	<.001	Session 1	0.4 (0.11)	<.001
	Video	4.17 (3.56)					Brochure	5.54 (3.5)	0.23
	CBT	0.00					Video	4.6 (3.3)	
	Video vs. Others		0.37				CBT	0.00	
N95 Performance major errors	Brochure	-0.25 (0.38)	0.51	Session 1	0.40 (0.11)	<.002	Session 1	0.43 (0.11)	<.001
	Video	-0.43 (0.37)					Brochure	-0.54 (0.36)	0.26
	CBT	0.00					Video	-0.46 (0.34)	
	Video vs. Others		0.35				CBT	0.00	
N95 Quantitative fit factor	Brochure	0.07 (0.33)	0.46	Session 1	0.57 (0.09)	<.001	Session 1	0.61 (0.1)	<.001
	Video	0.37 (0.31)					Brochure	0.22 (0.27)	0.47
	CBT	0.00					Video	-0.13 (0.26)	
	Video vs. Others		0.23				CBT	0.00	
HFM Performance Total Score	Brochure	-3.41 (3.38)	0.47	Session 1	0.43 (0.08)	<.001	Session 1	0.47 (0.09)	<.001
	Video	0.49 (3.51)					Brochure	3.42 (3.3)	0.57
	CBT	0.00					Video	0.64 (3.39)	
	Video vs. Others		0.48				CBT	0.00	
HFM Performance major errors	Brochure	0.51 (0.49)	0.40	Session 1	0.40 (0.08)	<.001	Session 1	0.42 (0.09)	<.001
	Video	-0.14 (0.51)					Brochure	-0.32 (0.47)	0.75
	CBT	0.00					Video	-0.28 (0.47)	
	Video vs. Others		0.38				CBT	0.00	
HFM Quantitative fit factor	Brochure	-0.67 (1.32)	0.07	Session 1	0.27 (0.10)	0.01	Session 1	0.26 (0.1)	0.01
	Video	2.45 (1.40)					Brochure	-1.18 (1.27)	0.42
	CBT	0.00					Video	0.51 (1.39)	
	Video vs. Others		0.03				CBT	0.00	

Note: HFM = half facemask dual cartridge respirator. CBT = computer-based training.



Effect of Initial Performance and Fit Factor Upon Results 6 Months Later

The results achieved at session 1 were highly significant predictors of results 6 months later. This was observed with all three statistical approaches. Model A2 (univariate effect of session 1 result) and model B (adjusted for training type) are shown in Table III. Model C (adjusted for both training type and potential confounders) did not differ from model B.

The analyses with extensive adjustment showed that the effect of training type on protection 6 months after training is probably mediated by its immediate benefit at the time of the training. This is illustrated by the coefficients in the multivariable adjusted models; when session 1 results are included in the models, the effect of video alone is reduced. This implies that video training is still preferable, but that the differences among the training modalities are reduced over time.

The online supplemental tables include the Kruskal-Wallis hypothesis testing results. They also demonstrate that training method per se did not have an effect. The analyses were repeated including interaction terms between session 1 result and training type. No significant interactions were noted.

Effect of Reminder

In session 2, participants were randomized to receive a very brief reminder card about proper use or a sham card with general information only. The analysis summarized in Table IV describes the impact of the brief reminder upon session 2 performances, adjusting for the subject's session 1 performance and the type of training administered. The brief reminder effectively improved proper placement and removal of the respirator for the FFR type. There was a minor, not statistically significant increase in the fit factor among those

FFR users who received the reminder. The reminder had no effect upon HFM users.

DISCUSSION

The study leads to several respirator policy suggestions for persons who only use respirators intermittently. In many workplaces, respirators are used only rarely, so there may be long gaps between utilizations, and widespread community use situations are generally intermittent (e.g., concern about influenza epidemic followed many months later by a natural disaster leading to respirator use).

Training Method

Stand-alone respirator training can be effective when direct contact with fully trained occupational health professionals is infeasible, such as during rapid rollout situations. This study of fit factor achieved soon after initial training showed that video training outperformed either computer-based training or printed brochure use.⁽¹²⁾ The current analysis of the 6-month followup results (session 2) appears to suggest that video training still has a possible advantage. There was a trend for those trained with video to have more effective protection, although not statistically significant, respirator use.

This persistent benefit of video training is probably mediated through its immediate effect soon after training. As shown in Table IV, the apparent benefit of initial video training at 6 months followup largely disappeared when adjusted for results soon after training (session 1).

Need for Retraining

Results of this laboratory study show that the effective protection declines when there has been a long gap (6 months) between training and subsequent use. Therefore,

TABLE IV. Effects of Reminder (Session 2)^A

	A. Univariate Models			B. Multivariate Models			
	Parameter	Coefficient	p	Parameter	Coefficient	p	
N95	Performance Total Score	Reminder Yes	15.08 (4.5)	0.00	Session 1	0.50 (0.18)	0.01
					Brochure	-0.89(5.9)	0.89
					Video	1.79(5.56)	
					CBT	0.00	
N95	Performance major errors	Reminder Yes	-1.38 (0.48)	0.01	Reminder Yes	14.60 (4.77)	0.00
					Session 1	0.54(0.18)	0.00
					Brochure	0.25(0.62)	0.74
					Video	-0.21(0.58)	
N95	Quantitative fit factor	Reminder Yes	0.25 (0.36)	0.48	CBT	0.00	
					Reminder Yes	-1.29(0.5)	0.01
					Session 1	0.57(0.15)	0.00
					Brochure	0.03(0.42)	0.65
HFM	Performance Total Score	Reminder Yes	5.15 (4.41)	0.25	Video	-0.35(0.45)	
					CBT	0.00	
					Reminder Yes	0.45(0.38)	0.24
					Session 1	0.34(0.16)	0.04
HFM	Performance major errors	Reminder Yes	-0.78 (0.65)	0.24	Brochure	3.38(5.36)	0.81
					Video	1.96(6.11)	
					CBT	0.00	
					Reminder Yes	3.47(4.52)	0.45
HFM	Quantitative fit factor	Reminder Yes	-0.55 (1.47)	0.71	Session 1	0.27(0.15)	0.08
					Brochure	-0.22(0.77)	0.78
					Video	-0.59(0.84)	
					CBT	0.00	
HFM	Performance major errors	Reminder Yes	-0.71(0.64)	0.27	Reminder Yes	-0.71(0.64)	0.27
					Session 1	0.19(0.17)	0.26
					Brochure	-0.8(1.79)	0.90
					Video	-0.17(2.09)	
HFM	Quantitative fit factor	Reminder Yes	-0.16(1.68)	0.93	CBT	0.00	
					Reminder Yes	-0.16(1.68)	0.93

^AThe table describes the effect of a short reminder in comparison to a sham reminder. Model C (adjusted also for potential personal factor confounders) gave similar results.

individuals should be retrained to use respirators rather than assuming they would still remember the proper technique. Also, facial features affecting fit factor may change over time.

Reminder Cards

The study also evaluated the potential utility of a brief reminder card. Unlike more extensive training methods, a small card can be easily distributed with respirators. Providing a brief reminder card may be beneficial for N95 (FFR) users. The brief reminder card affected the behavioral component (proper donning/doffing) but did not have a significant effect on the measured fit factor.

However, use of a reminder card showed no benefit for uses of the more complex HFM devices. These results suggest that use of a simple reminder card cannot substitute for actual retraining, particularly among HFM users.

CONCLUSION AND RECOMMENDATIONS

This series of studies has shown that rapid training without direct occupational health professional involvement is capable of enabling many naïve users to effectively use both N95 and HFM dual cartridge devices. This approach is particularly important when conditions such as epidemics, natural disasters, or terrorism concern require rapid surge in the number of respirator users. Video-based training appears preferable to either brochure or CBT approaches. Retraining is necessary rather than assuming that an episode of training 6-months previously is sufficient. While a simple reminder about proper technique has some potential utility for FFR users, it is not a substitute for proper retraining.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Robert J. Boumis in data collection and Julie Millet in preparing the manuscript. This work was supported by grant R01-8119 from the National Institute for Occupational Safety and Health/Centers for Disease Control and Prevention.

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