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Efficacy of a Computer-Based Hearing Test and Tailored Hearing Protection Intervention

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Advances in computer technology and accessibility enable researchers to provide individually tailored interventions for behavioral change. Using multimedia technology, this study developed and tested a computer-based hearing test and a tailored intervention. The purpose of this study was to evaluate, using a randomized experimental design, the efficacy of the intervention to increase workers' use of hearing protection. The tailored intervention developed by the research team showed more significant short-term effect measured immediately after the intervention than the control intervention. For the long-term effect measured 1 year after the intervention, both tailored and control groups showed significant increase in their reported use (7% vs. 6%) from preintervention to postintervention, but no significant difference between the two groups. The change accomplished in this study was small progress toward the desired level of 100% use of hearing protection to prevent noise-induced hearing loss. This finding showed that changing workers' hearing protection behavior is difficult.

Key words: tailored intervention, computer-based, hearing protection, construction worker

Occupational noise-induced hearing loss (NIHL) is hearing loss that develops slowly over several years as a result of exposure to loud noise (ACOEM, 2003). NIHL is considered to be totally preventable. The best way to prevent NIHL is to eliminate the noise hazard. While engineering controls of noise exposure are most desirable, they are often impractical, costly, or scientifically impossible to implement in a manner that eliminates all harmful noise. Because NIHL can be prevented by consistent use of hearing protection devices (HPDs) with proper fit (NIOSH, 1996; Sataloff & Sataloff, 1993), protective action by workers is necessary. In a study of airport workers exposed to high noise (≥85dBA 8-hr time-weighed average), Hong, Wilber, and Furner (1998) found that workers who used HPDs consistently had significantly lower hearing loss than those who did not. Failure to use them consistently and to ensure proper fit is probably the leading causes of occupational NIHL (Sweeney et al., 2000).

Factors unique to the construction industry, such as a mobile workforce, subcontracting, multiple employers and job sites, multiple sources of noise in job sites, difficulty in controlling noise through engineering efforts, and hearing conservation programs that are less comprehensive than those for manufacturing workers, all suggest the need for more responsibility by individual construction workers for protecting their hearing by using HPDs (Lusk, Ronis, & Hogan, 1997; Schneider & Susie, 1993).

Previous studies with various groups of workers found that workers did not consistently wear HPDs to prevent hearing loss (Hong, Chen, & Conrad, 1998; Hong, Wilbur, et al., 1998; Lusk, Hong, et al., 1999). According to a study by Lusk, Hong, et al., (1999), in particular, operating engineers, construction workers who operate heavy equipment such as bulldozers, graders, backhoes, asphalt road rollers, asphalt spreaders, and wheel loaders, reported mean use of HPDs 49% of the time they were in high noise. This rate falls far short of the 100% use needed to prevent NIHL (Berger, 2000; Dear, 1998), demonstrating the need for further behavior change in operating engineers, the target population of this study.

Computerized tailored interventions, relatively new health education approaches, are characterized by the fact that the content of the materials is adapted, with the assistance of computers, to the

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characteristics of a specific individual (de Vries & Brug, 1999). Greater accessibility of computer technology has facilitated addressing large segments of the population, who can now receive sophisticated tailoring of interventions that are not general but highly individualized. Tailoring to individuals allows health professionals to present only the health information most relevant to each individual. Computer technology can be especially useful for tailoring specific aspects of training aimed at behavioral change according to an individual's perceptions, beliefs, and attitudes that are most in need of alteration (Rhodes, Fishbein, & Reis, 1997). Thus tailored training provided by computer technology can address the most salient needs of workers relative to their hearing ability and hearing protection behaviors.

The effectiveness of computer-tailored interventions has been demonstrated in several studies (Campbell et al., 2002; de Vries & Brug, 1999; Skinner, Strecher, & Hospers, 1994; Velicer & Prochaska, 1999). These studies have found that tailored messages are more likely to be read, remembered, rated as attention catching, and perceived as personally relevant compared to nontailored messages (Brug, Campbell, & van Assema, 1999; Kreuter & Wray, 2003; Skinner, Campbell, Rimer, Curry, & Prochaska, 1999).

The purpose of this study was to test the efficacy of a tailored intervention combined with the self-administered hearing test in increasing use of HPDs in operating engineers.

Conceptual Framework

This study used the Predictors of Use of Hearing Protection Model shown in Figure 1 as the conceptual framework to identify the predictors of workers' use of HPDs and to guide the tailored intervention. The model includes three modifying factors (demographic/experiential/biological factors, interpersonal influences, situational factors) and three cognitive-perceptual factors (perceived benefits, barriers, self-efficacy) as predictors for use of HPDs, the dependent variable. In the model, all predictors have a direct effect on use of HPDs, and the modifying factors have an additional indirect effect on this behavior, exerting their influence through the cognitive-perceptual factors.

The model has been tested and demonstrated utility as a causal model for predicting hearing protection behaviors in different worker populations (Hong, Lusk, & Ronis, 2005; Kerr, Baer, & Arnold, 2002; Ronis, Hong, & Lusk, 2006). Multivariate analyses revealed that significant predictors of self-reported HPD use in the study population were perceived benefits, perceived barriers, perceived hearing ability, social models, supervisor climate, and daily noise exposure (see Figure 2).

Survey Questionnaire

Content of the survey was based on prior research that determined the predictors of HPD use among factory and construction workers (Hong et al., 2005; Lusk, Hong, et al., 1999; Lusk, Kerr, Ronis, & Eakin, 1999; Ronis et al., 2006). A detailed description of questionnaire items has been reported in a previous publication (Hong et al., 2005). The scales in the questionnaire had demonstrated good reliability in previous studies (Hong et al., 2005; Kerr et al., 2002; Lusk, Hong, et al., 1999; Lusk, Kerr, et al., 1999; Ronis et al.,

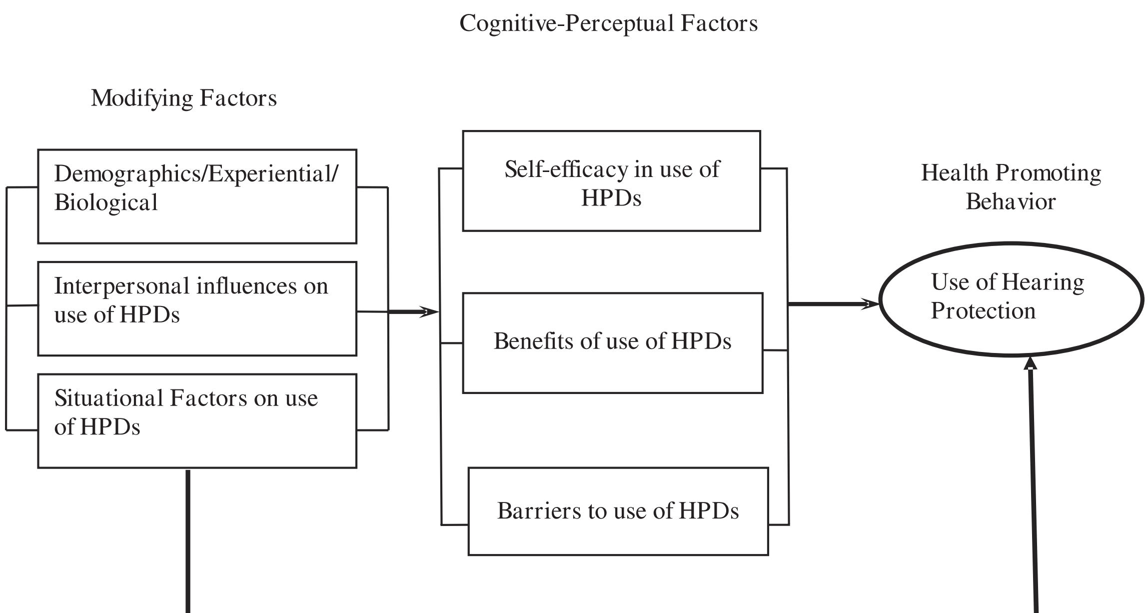

Figure 1. Predictors of use of hearing protection model.

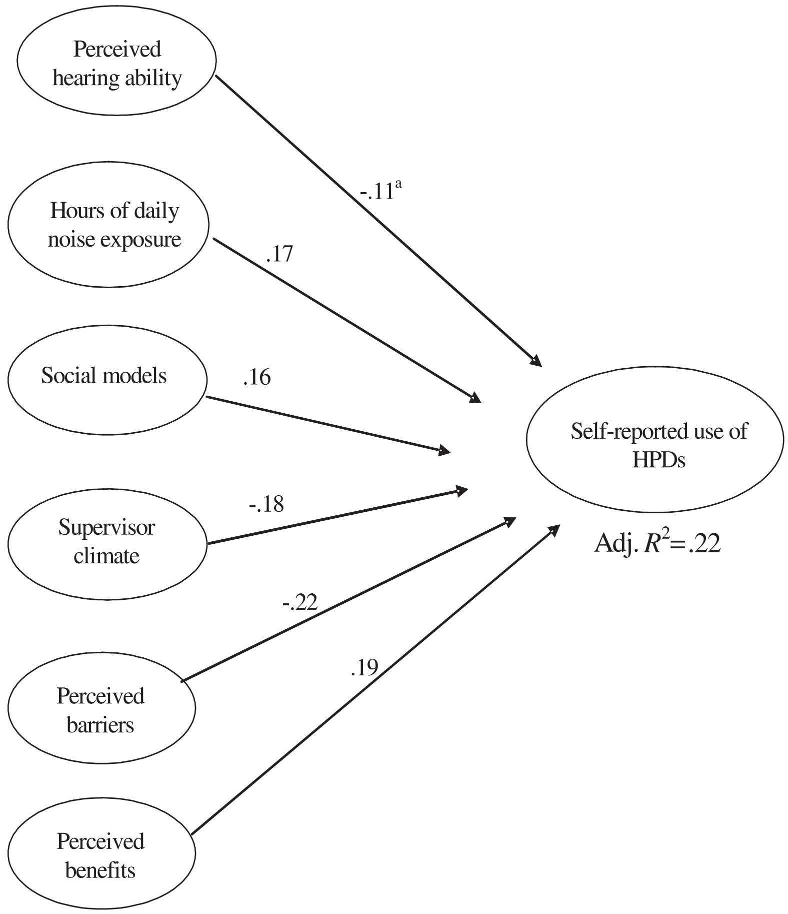

Figure 2. Significant predictors of hearing protection. ***Note*. [a]Standarized regression coefficients**

in press). Reliability coefficients for all scales, with the number of items and range of scales (e.g., 1–6), for the current sample are presented in Table 1.

Method

Study Design

To test the effectiveness of the intervention, this study used an experimental pretest–posttest control group design (Campbell & Stanley, 1968). Random assignment of the study participants to the experimental and control groups was performed by the computer. The design contrasts the effects of the experimental intervention with a control intervention on operating engineers' use of HPDs as shown in Table 2.

Hypotheses

To examine both short- and long-term effects of interventions, two hypotheses were considered. First, immediately after the intervention, the tailored intervention group will report a higher intention of HPD use in the future than the control group. Second, at one year after the intervention, participants in the tailored training will report a significantly greater increase in their use of HPDs than the control group.

Outcome Variables

To test the study hypotheses, the study had two outcome variables: *intention of HPD use in the future* and *mean use of HPDs*. Intention of HPD use in the future was measured by asking the participant what percentage of time (0–100%) they would use HPDs when in loud noise in the future, with data collected before and immediately after intervention to evaluate an immediate effect of intervention. Mean use of HPDs was calculated using workers' reported use of HPDs in percentage of the time (0–100%) when in loud noise in the two job sites (the past 12 months and the most recent) and measured at preintervention and at 12-month postintervention. As the two scores for the job sites showed a strong correlation (r = .91, p = .001), the mean of two scores was used as the outcome variable. Both measures were self-reported. Appropriateness of workers' self-reported measure was validated in a prior study of factory workers that showed a strong correla-

Table 1. *Predictors of Use of Hearing Protection Model Components and Scales*

Model Components	Instrument	# of Items[a]	Range	*M*	Alpha
Modifying factors					
Demographic/experiential/ biologic factors	Age	1	20–67	43	n/a
	Gender (91% men)	1	M/F	n/a	n/a
	Ethnicity (91% white)	1	1–6	n/a	n/a
	Years in construction	1	0–51	18	n/a
	Noise exposure	1	0–15	7	n/a
	Perceived hearing ability	1	1 to 5	3	n/a
	Hearing status (Worst loss at 4k or 6k)	4	0–95	38	n/a
Interpersonal influences	Social Models + Interpersonal support	5[b]	1–3	2	n/a[c]
Situational factors	Availability of HPDs	3	1–6	4	.71
	Worksite climate	6	1–6	4	.86
Cognitive-perceptual factors					
Perceived barriers	Barriers of HPD use	9	1 to 6	3	.77
Perceived benefits	Benefits to HPD use	5	1 to 6	5	.60
Perceived self-efficacy	Self-efficacy in HPD use	2	1 to 6	5	.73
Dependent variable					
Health-related behavior	Intention of HPD use	1[d]	0–100%	71	n/a
	Use of HPDs	2[d]	0–100%	50	.95

Note. HPD = hearing protection devices.
[a]All items, except where noted, use a 6-point Likert response scale. [b]Items measured on a 3-point scale ranging from 1(*never*),to 2 (*sometimes*), to 3 (*often*). [c]Formative scale. [d]Measured by percentage (0–100%) of the time.

Table 2. *Study Design*

Random Assignment	Time 1 Jan.–April 2002			Time 2 Jan–April 2003		
Experimental group	O	Xt	M_I	O	X[a]	M_I
Control group	O	Xc	M_I	O	X[a]	M_I

Note. Xt = tailored intervention; Xc = control intervention; O = hearing test + data collection via computerized survey; M_I = measure of intention immediately after intervention.
[a]Repeated interventions (either tailored or control) in Year 2 but their effectiveness at subsequent year (Year 3) was not assessed, as the study ended in Year 2.

tion (r = .89, $p < .01$) between workers' self-reported HPD use and data obtained by observation (Lusk, Ronis, & Baer, 1995).

Study Site and Target Population

The study was conducted at a trade Union Training Center in a midwestern state in the United States. Approximately 900–1,000 operating engineers from the entire state coming to the training center for the 8-hr Hazardous Material (HAZMAT) refresher course were invited to participate in the study. An estimated 70 trainees attending a 3-year apprenticeship program were also included in the study. Because the same individuals attended an 8-hr HAZMAT refresher annually to meet federal requirements, postintervention evaluation was obtained with the same subjects 1 year later during the HAZMAT course. Trainees in the apprenticeship program could also participate in the postintervention assessment, because they returned a year later for the initial HAZMAT courses.

Interventions

Tailored intervention. The content of tailored intervention was developed based on the participants' hearing test results, their responses to questions on current use of HPDs, and the theoretically derived predictors of HPD use. In particular, the study considered providing meaningful feedback to the workers about their hearing test results as an important factor for educating and motivating the workers to protect their hearing. Generally, for most individuals, feedback about their own hearing is inherently interesting. Praise for good hearing will reinforce the worker's continued use of HPDs; warnings to workers with hearing loss will help to motivate them to use HPDs to prevent further loss (Royster, 1985; Royster & Royster, 1991).

An example of information tailored to responses on their current use follows. If the participants reported that they use HPDs 100% when in loud noise, then they received the following information. "Earlier you said you use earplugs or muffs 100% of the time they should be used when in loud noise. That's great! You already know, then, that wearing hearing protection all the time is the best way to prevent hearing loss."

An example of intervention content tailored to take account of workers' hearing ability based on their audiogram follows. If the participants showed moderate hearing loss on their hearing test, then they received the following information. "Your hearing test results showed that you have a moderate hearing loss. Remember, this test is only a screening of your hearing and cannot be used as a diagnosis. Please see your physician or audiologist for further diagnostic testing. You know, it's important to protect the hearing you still have whenever you're exposed to loud noise."

An example of information tailored to responses on a predictor (perceived self-efficacy) item follows. If responses were *strongly disagree* or *moderately disagree* with the statement, "I can use earplugs or muffs properly," then the participant received the following information: "Earlier you said you're not sure you can use earplugs or muffs properly. This is a big concern for a lot of people, like it is for you. So, our nurse offered some thoughts on this topic …" Training continued with demonstrations and a directed practice on how to use HPDs properly. The participants controlled the pace of the training and practice session. On average, participants in tailored groups spent about 32 sec for hands-on practice. Practice was not part of the control intervention.

Control intervention. For the control intervention, the study used the same commercial video on use of HPDs selected for the research team's previous project for factory workers (Lusk et al., 2003). The research team reviewed a number of videos highly rated by the National Hearing Conservation Association (Kerst & Langman, 2000) and selected one that met the Occupational Safety and Health Administration's required information on hearing conservation. The research team made sure that the selected commercial program had not been developed based on theoretically specified predictors used for the experimental intervention and not previously been shown to the study population. The video was already digitized, after written permission was obtained from the publisher, for the factory worker project (Lusk et al., 2003).

Data Collection Procedure

All trainees in the apprenticeship program and operating engineers who enrolled in initial HAZMAT training and their annual HAZMAT refresher courses at the training center were invited to participate in the study. Staff at the center introduced the project and recruited volunteers during the orientation before the course started each day. The study had been reviewed and approved by the University Institutional Review Board. The sequence of activities involved in delivery of the hearing test and the intervention is shown in Figure 3. The computer-based program began with an introduction to the program and the equipment to be used by the study participant. Prior to the delivery of the intervention, a hearing test was completed by all study participants. The hearing test was conducted using a microprocessor pure-tone audiometer for both ears tested at the frequencies 0.5 through 8 kHz, followed by a computer-based survey. The computerized survey was presented in text on the computer screen and with narrated audio for participants' clearer understanding. Considering the fact that many construction workers did not use computers in everyday life (34% of study participants had never used a computer), a specially designed keypad similar to a telephone keypad was used in this study. The keypad had numbers (0–9) and "YES" and "NO" buttons for participants to answer multiple-choice questions and enter required data, such as percentage of their use of HPDs, date of birth, and union identification numbers.

Once the computerized survey was completed, the computer randomly assigned participants into one of two interventions, tailored or control. Although both groups were offered a hearing test, the computer provided interpretation of audiogram and immediate feedback on their hearing test results on the screen for tailored group only. The control group did not get feedback on their hearing test results as a part of the intervention, but both groups received printed handouts with information regarding their hearing status when they finished the program and had the opportunity to ask the staff for clarification. Details about the two interventions used in this study are provided in the next section.

On average, participants in tailored and control groups spent a total of 43 min and 33 min in the booths, respectively. Both groups spent the same amount of time for the introduction (6 min), hearing test (6 min), and the survey (9 min). Length of the training for the tailored and control groups were 22 min and 12 min, respectively. As workers completed the interactive program, they received a hard copy of their hearing test with an explanation of the results and the pertinent points covered in their intervention.

The computer-based hearing test and the intervention were delivered in one of eight soundproof booths. Each booth was equipped with a computer, flat display monitor, keypad, microprocessor audiometer, earphones, and response button (hand-switch). All computers were hooked to a local area network at the training center in order to communicate with the networked central printer for producing handouts and to upload data to the main computer for future data analysis. In addition to intervention in Year 1, some workers (50% of participants in each intervention group) received a single-page printed letter (booster)

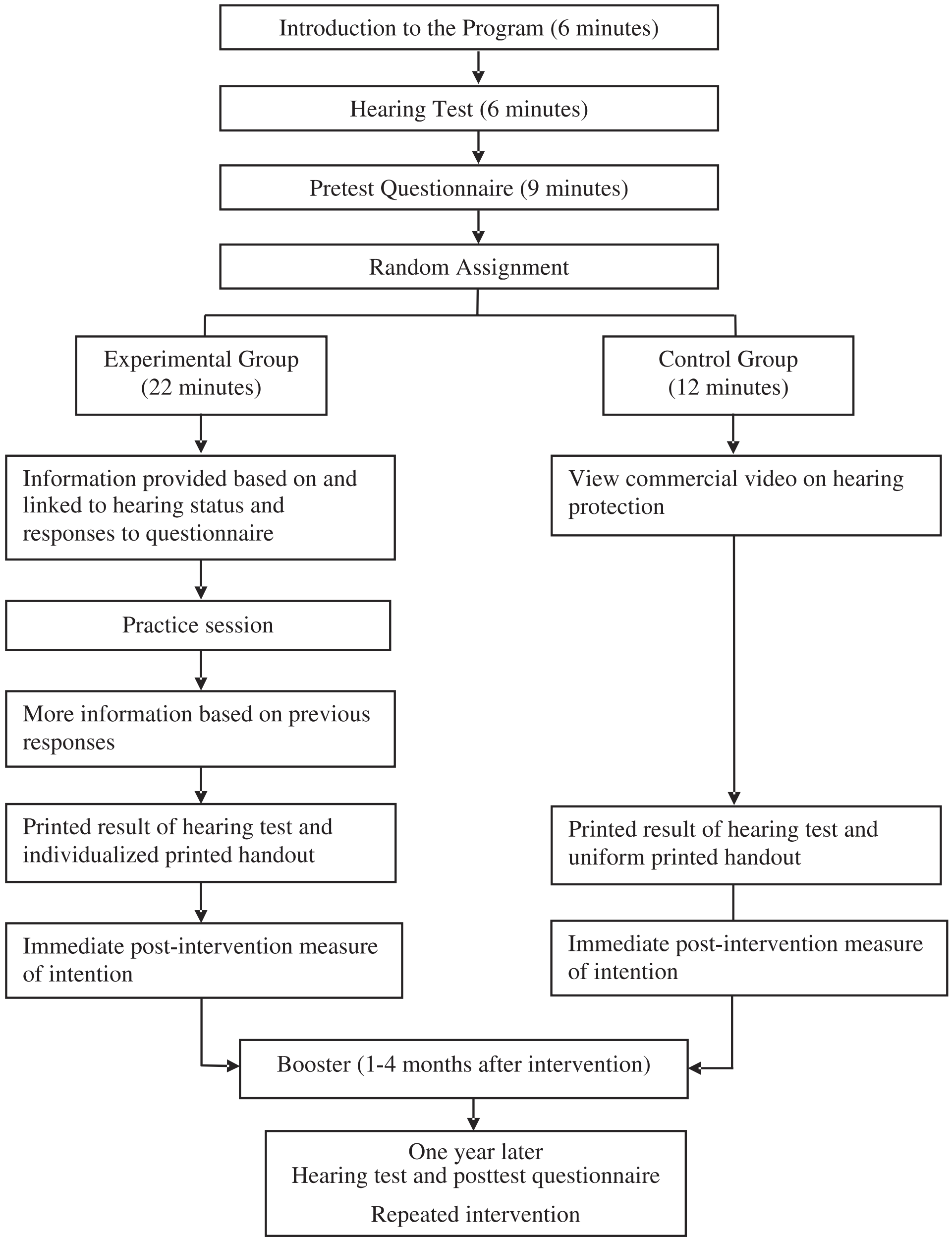

Figure 3. Sequence of computer-based self-administered hearing tests and interventions.

mailed to their homes in early May (1 to 4 months following the original inter vention) when they generally would go back to work at construction sites. The content of the letter for both groups was similar in covering common noise levels and importance of using HPDs, with additional comments on hearing status based on results of their hearing test, for tailored group only. Approximately 1 year later, when the workers returned to the training center for their annual HAZMAT refresher or continuation of apprentice certification course, they received the second hearing test and completed a computerized survey to assess the effects of the interventions. The survey data were obtained in the same manner as in Year 1. Interventions were repeated after completion of postintervention surveys.

Results

Characteristics of Study Participants

A total of 612 and 535 operating engineers participated in the study in Year 1 and Year 2, respectively. About 66% (403/612) of the Year 1 participants completed the Year 2 postintervention. In order to determine if there were any differences between Year 1 participants who did ($n = 403$) and did not return ($n = 209$)

to complete the postintervention survey in Year 2, their characteristics were compared. The results showed no significant differences in their demographic characteristics. Return rates were not different by either training type (tailored vs. control groups = 67% vs. 65%) or receiving a mailed one-page printed letter (booster vs. no booster = 67% vs. 64%). However, preintervention mean use between the returns and the no-returns was significantly different (49% vs. 41%, $p = .008$).

A total of 403 participants who completed both the preintervention and the postintervention surveys were included in the analysis. A summary of the demographic characteristics of the participants at preintervention in Year 1 is presented in Table 3. Participants were predominantly middle-aged (mean age = 43 years), men (91%), and white (91%). The majority (94%) of them had at least a high school education. They reported high noise exposures (7 hr/day), and their use of HPDs was low (50% of the time needed). More than 70% of the participants showed hearing loss in at least one ear for either 4 or 6 kHz, the noise-sensitive frequencies.

Characteristics of the study participants were compared for the tailored ($n = 221$) and control ($n = 182$) groups. As shown in Table 3, the two groups did not show significant differences in mean use of HPD and key demographic characteristics, except for age (F[1, 397] = 3.96, $p = .047$). The control group was older than the intervention group (44 years vs. 42 years), but their years in construction industry were not significantly different (18 years vs. 19 years). As age and years in construction were highly correlated ($r = .77$, $p < .001$), and years in construction seemed more directly relevant than age to behavior at work, the age difference between two groups was not considered a problem.

Effects of Intervention on Changes in Workers' Intention of HPD Use in the Future

To determine the immediate effect of intervention, *intentions of HPD use in the future* measured before and right after intervention in Year 1 and Year 2 were compared. The two groups showed no significant difference in their changes in intention of HPD use in the future at preintervention in Year 1 (F[1, 401] = .25, $p = .62$) and Year 2 (F[1, 401] = .67, $p = .41$). But two-sided paired t tests showed that the changes from before the intervention to right after the intervention in Year 1 and Year 2 were significant for both the tailored (Year 1: $t = 7.30$, $p = .001$, and Year 2: $t = 6.47$, $p = .001$) and the control (Year 1: $t = 3.16$, $p = .002$, and Year 2: $t = 2.57$, $p = .011$) groups (see Table 4).

A repeated measures ANOVA examining changes in intention of HPD use in the future from before to

Table 3. *Characteristics of Study Participants*

	Total[a]		Tailored[b]		Control[c]		
Variable	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F* statistic, *p* value**
Age (year)*	43	9	42	10	44	8	$F(1, 397) = 3.96$, $p = .05$
Years in construction	18	10	18	11	19	10	$F(1, 392) = 1.35$, $p = .25$
Hours of noise exposure a day	7	3	7	3	7	3	$F(1, 401) = .01$, $p = .91$
Pretraining use of HPDs (%)[d]	50	34	50	34	50	34	$F(1, 401) = .01$, $p = .93$
Pretraining intention of use (%)[d]	71	26	71	28	72	25	$F(1, 401) = .25$, $p = .62$
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	**χ^2, *p* value**
Gender (men)	364	91	201	92	163	91	$\chi^2(1) = .19$, $p = .67$
Ethnicity (White)	366	91	204	93	162	90	$\chi^2(1) = .25$, $p = 1.30$
Education (High school or above)	378	94	205	93	173	95	$\chi^2(1) = .43$, $p = .62$
Perceived hearing (poor)	93	23	52	24	41	23	$\chi^2(1) = .06$, $p = .81$
Measured hearing (loss)[e]	269	71	141	68	128	76	$\chi^2(1) = 2.88$, $p = .09$

[a]$N = 403$. [b]$n = 221$. [c]$n = 182$. [d]Measured in % of time (0–100). [e]Loss was defined as hearing thresholds of higher than 25dB using the highest level among four thresholds measured at 4 and 6 kHz for right and left ears.
*Significantly different between tailored and control groups.

Table 4. *Changes in Intention of Use (%) in the Future—Paired t Test (two sided)*

		Before Training		Right After Training		Change			
	Intervention Group	***M***	***SD***	***M***	***SD***	***M***	***SD***	***t***	***p* value**
Year 1	Tailored	70	28	78	24	8	15	7.30	.001
	Control	72	25	75	24	2	10	3.16	.002
Year 2	Tailored	74	24	80	22	6	13	6.47	.001
	Control	72	27	74	27	2	10	2.57	.011

Table 5. *Changes in Intention of Use in the Future—Repeated Measures Anova*

	ANOVA	*df*	*F* Statistic	*p* Value
Year 1	Time[a]	1,382	56.06	.001
	Training type[b]	1,382	.12	.730
	Time × training type	1,382	16.37	.001
Year 2	Time[a]	1,387	44.90	.001
	Training type[b]	1,387	2.26	.134
	Time × training type	1,387	12.43	.001

Note. Anova = analysis of variance.
[a]Preintervention and postintervention. [b]Tailored and control interventions.

right after the interventions by the two types of interventions was conducted, and results are summarized in Table 5. The test of time (before the intervention and right after the intervention) by the intervention type interaction was significant for both Year 1 (F[1, 382] = 16.37, p = .001) and Year 2 (F[1, 387] = 12.43, p = .001), indicating significant differences in the amount of change between the two intervention groups. Changes in the tailored group were significantly greater than in the control group for both years. The improvement in intention of use over baseline in Year 1 for the tailored and control groups were 11% and 3%, respectively. In Year 2, the same trend, greater improvement in intended use in tailored versus control group (8% vs. 3%) was shown.

Intervention Effect on Increasing Reported Mean Use of HPDS

To determine the long-term effect of the interventions, the second outcome variable (*mean use of HPDs*) was examined approximately 1 year after the intervention. Change in reported mean use of HPDs between preintervention and postintervention for the tailored group was 7% (from 50% to 57%), representing 14% improvement over baseline ([57–50]/50*100). Change in reported mean use of HPDs between preintervention and postintervention for the control groups was 6% (from 50% to 56%), representing 12% improvement over baseline ([56–50]/50*100).

Findings from paired t tests (two-sided) showed that changes from preintervention to postintervention were significant for both the tailored (t[220] = 4.47, p = .001) and control (t[181] = 2.96, p = .004) groups. Repeated measures ANOVA was used to examine if changes in mean use of HPDs from preintervention to postintervention differed by the type of intervention. The test of the intervention type by time (preintervention and postintervention) interaction was not significant (F[1, 401] = .24, p = .627), indicating no significant difference in the amount of change in mean use of HPDs between the two intervention groups.

Relationship of Intention to Use in Year 1 and Reported Use in Year 2

Since training type significantly affected the participant's intention of HPD use in the future, the relation-

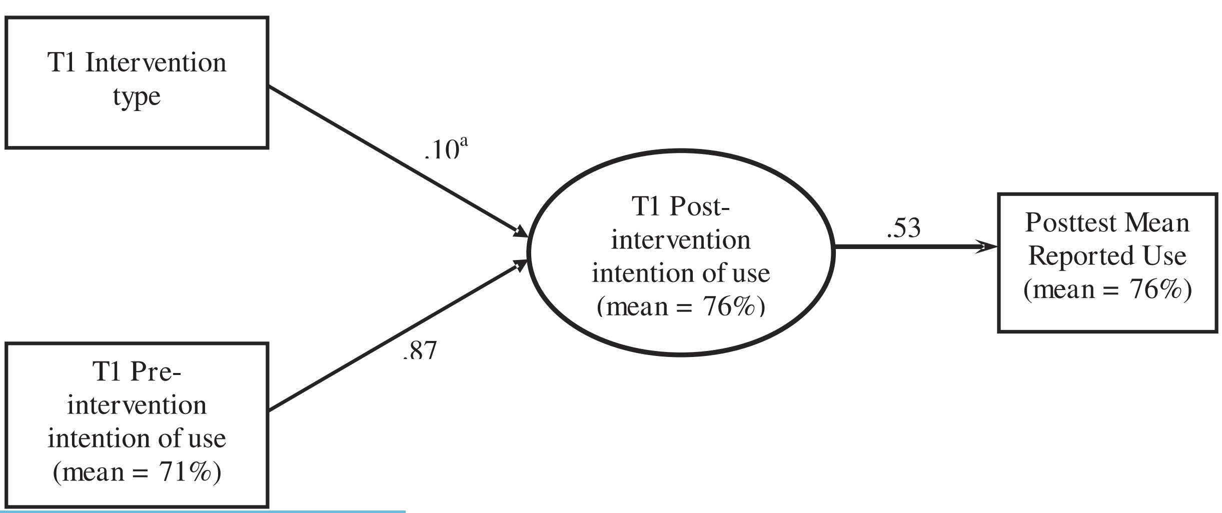

Figure 4. **Path model for intervention effect on posttest mean reported use through changes in intention.** ***Note*****.** **[a]Path coefficients**

ship between training types, intention before and after intervention in Year 1, and HPD use at Year 2 were examined using a path analysis. As shown in a path model in Figure 4, Year 1 intervention type (.10, tailored intervention was more effective) and Year 1 preintervention intention of use (.87, $p = <.001$) were significant factors to increase Year 1 postintervention intention of use, which subsequently affected HPD use (.53, $p = <.001$) in Year 2.

Discussion

Two hypotheses were tested in this study:

- H1: Immediately after the intervention, the tailored intervention group would report a higher intention of HPD use in the future than the control group
- H2: 1 year after the intervention, the tailored intervention group would report a significantly greater increase in their use of HPDs than the control group.

The first hypothesis was supported, with the tailored group reporting a significantly greater increase in intention of HPD use in the future than the control group in both Year 1 (11% vs. 3% improvement over baseline) and Year 2 (8% vs. 3% improvement over baseline). This immediate difference may have been due to the fact that the tailored intervention group, as part of their training, received an interpretation of their hearing tests with audiogram on the computer screen while the control group did not. However, the effect of this visualized interpretation was likely diluted by the fact that every participant could obtain personalized feedback following the training session from the staff present, just by asking questions.

While both interventions significantly increased HPD use 1 year following the intervention, the second hypothesis was not supported by the data, as their effects did not significantly differ. Workers who received the tailored intervention increased their use of HPDs slightly more (actual increase: 7% vs. 6%; improvement over baseline: 14% vs. 12%), but not significantly more than workers in the control group. This insignificant difference between the two intervention groups may be viewed as somewhat disappointing, as other research studies have generally found tailored interventions to be more effective. Plausible reasons for the similar results shown by the two groups include the hearing test provided to both groups and the highly rated commercial control program with more entertaining actors. Hearing test results not only provide the concrete evidence to workers that their daily HPD use can affect hearing ability but also provide the best opportunity to educate and motivate workers' attitudes and behaviors regarding hearing protection (Royster, 1985; Royster & Royster, 1991).

Along with previous studies (Lusk, Hong, et al., 1999; Lusk et al., 2003), this investigation again demonstrated that changing and sustaining worker behaviors in regard to use of HPDs is not easy. Difficulties in modifying human behaviors have also been shown in other behavioral intervention studies. Cochrane database systematic reviews for other types of behavior change (e.g., smoking, weight loss, and exercise) found from –1% to 9% improvements over baseline (Hillsdon, Foster, & Thorogood, 2005; Mulrow, Chiquette, Angel, Cornell, & Summerbell, 1998; Secker-Walker, Gnich, Platt, & Lancaster, 2002). Workers are less apt to adopt hearing loss preventive behaviors because hearing loss is insidious, occurring over a long period of time, without symptoms such as pain or bleeding to induce change. This certainly makes it much more difficult to change workers' hearing protection behavior.

Although statistically significant, the change seen in this study was small progress toward the desired level of 100% use of HPDs. Because at preintervention participants in this study reported less than 50% use when they were exposed to high noise at their work, the level of change accomplished in this project, increasing use to nearly 60% of the time, is far less than the 100% HPD use necessary to prevent NIHL. However, the fact that a one-shot intervention for fewer than 45 min, including survey and hearing test delivered a year earlier (plus 50% chance of being sent a booster message) had a significant effect on increasing workers' use of HPDs is remarkable.

No other reports have been found of projects that utilized multimedia computer technology to deliver a hearing test combined with a tailored intervention. As reported elsewhere (Hong & Csaszar, 2005), the analysis of participants' quantitative and qualitative feedback clearly indicated that this computer-based interactive program was well received by these construction workers, many of whom did not use a computer regularly or had never used one. It certainly provided a novel experience for construction workers at that time. Also, the hearing test was seen as valuable and of great interest.

Although no literature clearly recommends the ideal timing and frequency of interventions and boosters, it is reasonable to expect limited behavioral changes from a one-shot intervention for a limited length of time over the 1-year time interval and a mailed one-page booster. In fact, this is a reflection of reality, because most worksites provide a short training (less than 1 hr) once a year. Ideally, short ongoing motivational messages should be provided to remind workers about hearing protection throughout the entire year to increase their use of HPDs. Because of the numerous health and safety issues, it is not possible for worksites to spend a lot of time throughout the year on preventing NIHL, but signs, a 30-sec announcement, or distribution of bumper stickers would require little time and could help to promote behavior change.

Future studies should address the dose and frequency of interventions required to achieve greater behavior change, the relationship between intention and behavior, and the optimum time period for assessing effects of interventions on use of HPDs. Future hearing protection intervention studies should also consider individual workers' readiness to change, with different content and approaches depending on their current stages of changes (precontemplation, contemplation, preparation, action, and maintenance) as distinguished in the Transtheoretical Model (Prochaska, DiClemente, & Norcross, 1992). Interventions tailored to individuals' stages of change have been demonstrated as more effective in promoting health behaviors (Bock, Marcus, Pinto, & Forsyth, 2001; Marcus et al., 1998; Oldenburg, Glanz, & Ffrench, 1999; Peterson & Aldana, 1999; Prochaska et al., 2001; Velicer & Prochaska, 1999). But to date, no reports were found of reported hearing protection interventions that were matched to individual workers' stages of changes.

It is important to find effective means of changing HPD use behavior, as NIHL is a serious problem with significant monetary and personal costs, but is preventable through consistent use of HPDs. Unfortunately, limited training on hearing conservation has been provided for construction workers due to less comprehensive Occupational Safety and Health Administration standards regarding hearing conservation for construction versus industrial settings. Occupational NIHL affects not only those workers who have lost their hearing but also their family members and society as a whole. In fact, "preventing NIHL would probably do more to reduce the societal burden of hearing loss than medical and surgical treatment of all other ear diseases combined" (Dobie, 1993, p. 1). Increasing use of HPD through effective training is essential to prevent NIHL among construction workers.

References

American College of Occupational and Environmental Medicine (ACOEM). (2003). ACOEM evidence-based statement: Noise-induced hearing loss. *Journal of Occupational Environmental Medicine, 45*(6), 579–581.

Berger, E. H. (2000). Hearing protection: Dual protection. *Occupational Health and Safety, 69*(10), 98–102.

Bock, B. C., Marcus, B. H., Pinto, B. M., & Forsyth, L. H. (2001). Maintenance of physical activity following an individualized motivationally tailored intervention. *Annals of Behavioral Medicine, 23,* 79–87.

Brug, J., Campbell, M., & van Assema, P. (1999). The application and impact of computer-generated personalized nutrition education: A review of literature. *Patient Education and Counseling, 36,* 145–156.

Campbell, D. T., & Stanley, J. C. (1968). *Experimental and quasi-experimental designs for research*. Chicago: Rand McNally & Company.

Campbell, M. K., Tessaro, I., DeVellis, B., Benedict, S., Kelsey, K., Belton, L., et al. (2002). Effects of a tailored health promotion program for female blue-collar workers: Health Works for Women. *Preventive Medicine, 34,* 313–323.

Dear, T. A. (1998). Updating damage risk criteria to include performance under workplace noise regulations. *Journal of Occupational Hearing Loss, 1,* 61–66.

de Vries, H., & Brug, J. (1999). Computer-tailored interventions motivating people to adopt health promoting behaviors: Introduction to a new approach [Special issue: Computer-tailored education]. *Patient Education & Counseling, 36,* 99–195.

Dobie, R. A. (1993). *Medical-legal evaluation of hearing loss*. New York: Van No strand Reinhold.

Hillsdon, M., Foster, C., & Thorogood, M. (2005) Interventions for promoting physical activity. The *Cochrane Database of Systematic Review*, Issue 1. Art. no. CD003180. DOI: 10.1002/14651858. CD003180.pub2.

Hong, O., Chen, S. C., & Conrad, K. M. (1998). Noise-induced hearing loss among male airport workers in Korea. *American Association of Occupational Health Nurses Journal, 46*(2), 67–75.

Hong, O., & Csaszar, P. (2005). Audiometric testing and hearing protection training through multimedia technology. *International Journal of Audiology, 44*(9), 522–530.

Hong, O., Lusk, S. L., & Ronis, D. L. (2005). Ethnicity differences in predictors for hearing protection behavior in black and white workers. *Research & Theory for Nursing Practice: An International Journal, 19*(1), 61–74.

Hong, O., Wilber, L. A., & Furner, S. (1998). Use of hearing protection and hearing threshold levels among noise-exposed Korean airport workers. *Journal of Occupational Hearing Loss, 1*(4), 271–279.

Kerr, M. J., Baer, L. M., & Arnold, M. L. (2002). A computer game approach to construction worker hearing loss prevention. *Proceeding of the Hearing Conservation Conference* (pp. 160–163). National Hearing Conservation Association.

Kerst, K., & Langman, I. B. (2000). At the media. *NHCA Spectrum, 17*(3), 5.

Kreuter, M. W., & Wray, R. J. (2003). Tailored and targeted health communication: Strategies for enhancing information relevance. *American Journal of Health Behavior, 27*(Suppl. 3), 227–232.

Lusk, S. L., Hong, O., Ronis, D. L., Eakin, B. L., Kerr, M. J., & Early, M. R. (1999). Effectiveness of an intervention to increase construction workers' use of hearing protection. *Human Factor, 41*(3), 487–494.

Lusk, S. L., Kerr, M. J., Ronis, D. L., & Eakin, B. L. (1999). Applying the health promotion model to development of a worksite intervention. *American Journal of Health Promotion, 13*(4), 219–227.

Lusk, S. L., Ronis, D. L., & Baer, L. M. (1995). A comparison of multiple indicators. *Evaluations & the Health Professions, 18*(1), 51–63.

Lusk, S. L., Ronis, D. L., & Hogan, M. M. (1997). Test of the health promotion model as a causal model of construction workers use of hearing protection. *Research in Nursing & Health 20*(3), 183–194.

Lusk, S. L., Ronis, D. L., Kazanis, A. S., Akin, B. L., Hong, O., & Raymond, D. M. (2003). Effectiveness of a tailored intervention to increase factory workers' use of hearing protection. *Nursing Research, 52*(5), 289–295.

Marcus, B. H., Bock, B. C., Pinto, B. M., Forsyth, L. H., Roberts, M. B., & Traficante, R. M. (1998). Efficacy of an individualized, motivationally-tailored physical activity intervention. *Annals of Behavioral Medicine, 23,* 79–87.

Mulrow, C. D., Chiquette, E., Angel, L., Cornell, J., & Summerbell, C. (1998) Dieting to reduce body weight for controlling hypertension in adults. *The Cochrane Database of Systematic Review*, Issue 4. Art. no. CD000484. DOI: 10.1002/14651858.CD000484.

National Institute for Occupational Safety and Health (NIOSH). (1996). *Preventing occupational hearing loss: A practical guide*. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control and Prevention. *Agenda (NORA), Hearing loss*. Retrieved from http://www.cdc.gov/niosh/nrhear.html

Oldenburg, B., Glanz, K., & Ffrench, M. (1999). The application of staging models to the understanding of health behavior change and the promotion of health. *Psychology and Health, 14,* 503–516.

Peterson, T. R., & Aldana, S. G. (1999). Improving exercise behavior: An application of the stages of change model in a worksite setting. *American Journal of Health Promotion, 13,* 229–232.

Prochaska, J. O., DiClemente, C. C., & Norcross, J. C. (1992). In search of how people change: Applications to addictive behaviors. *American Psychologist, 47,* 1102–1114.

Prochaska, J. O., Velicer, W. F., Fava, J. L., Ruggiero, L., Laforge, R. G., Rossi, J. S., et al. (2001). Counselor and stimulus control enhancements of a stage-matched expert system intervention for smokers in a managed care setting. *Preventive Medicine, 32*, 23–32.

Rhodes, F., Fishbein, M., & Reis, J. (1997). Using behavioral theory in computer-based health promotion and appraisal. *Health and Educational Behavior, 24,* 20–34.

Ronis, D. L., Hong, O., & Lusk, S. L. (2006). Comparison of the original and revised structures of the health promotion model in predicting construction workers' use of hearing protection. *Research in Nursing and Health, 29,* 3–17.

Royster, J. D. (1985, May). Audiometric evaluation for industrial hearing conservation. *Sound Vibe,* 24–29.

Royster, L. H., & Royster, J. D. (1991). Education and motivation. In E. H. Berger, W. D. Ward, J. C. Morrill, & L. H. Royster (Eds.), *Noise and hearing conservation manual* (4th ed., pp. 383–416). Akron, OH: American.

Sataloff, R. T., & Sataloff, J. (1993). Occupational hearing loss. In R. T. Sataloff & J. Sataloff (Eds.), *Hearing loss* (3rd ed., pp. 371–402). New York: Marcel Dekker.

Schneider, S., & Susie, P. (1993). *Final report: An investigation of health hazards on a new construction project* [Report OSH 1–93]. Washington, DC: Center to Protect Workers' Rights.

Secker-Walker, R. H., Gnich, W., Platt, S., & Lancaster, T. (2002) Community interventions for reducing smoking among adults. *The Cochrane Database of Systematic Review*, Issue 2. Art. no. CD001745. DOI: 10.1002/14651858.CD001745.

Skinner, C. S., Campbell, M. K., Rimer, B. K., Curry, S., & Prochaska, J. O. (1999). How effective is tailored print communication? *Annals of Behavioral Medicine, 21*(4), 290–298.

Skinner, C. S., Strecher, V. J., & Hospers, H. (1994). Physician's recommendations for mammography: Do tailored messages make a difference? *American Journal of Public Health, 84*(1), 43–49.

Sweeney, M. N., Fosbroke, D., Goldenhar, L., Jackson, L., Linch, K., Lushniak, B., et al. (2000). Health consequences of working in construction. In R. Coble (Ed.), *Occupational health and safety in the U.S. construction industry* [M. E. Rinker, Sr., Lecture Series]. Philadelphia: Taylor and Francis.

Velicer, W. F., & Prochaska, J. O. (1999). An expert system intervention for smoking cessation. *Patient Education and Counseling, 36,* 119–129.