Effectiveness of a Tailored Intervention to Increase Factory Workers' Use of Hearing Protection

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► ***Background:*** In the United States it is estimated that more than 30 million workers are exposed to harmful levels of noise on the job. When engineering or administrative controls cannot be used to reduce noise, workers should always use hearing protection devices (HPDs) when exposed to loud noise to prevent noise-induced hearing loss (NIHL). Previous research has shown that workers do not always use HPDs when required; therefore, it is essential that workers assume personal responsibility for preventing NIHL by increasing their use of HPDs.

► ***Objectives:*** This study tested the effectiveness of an individually tailored multimedia intervention to increase use of HPDs by factory workers.

► ***Methods:*** A randomized controlled design was used to compare the effects of a tailored intervention (n = 446) with two other interventions (a nontailored predictor-based intervention (n = 447) and a control intervention (n = 432)) on workers' self-reported use of HPDs 6 to 18 months following the intervention.

► ***Results:*** Only those workers receiving the tailored intervention significantly increased their use of HPDs from pretest to posttest. However, this increase significantly differed from the nontailored group but not from the control group.

► ***Conclusions:*** Individually-tailored interventions offer promise for changing behavior. In light of the similarity between the results for the tailored intervention and the control intervention groups, further research is needed to understand barriers to HPD use and how to maximize the benefits of individually tailored interventions in this setting.

► ***Key Words:*** health education · hearing protection · noise-induced hearing loss · occupational health · tailored intervention

In the United States it is estimated that more than 30 million workers are exposed to harmful levels of noise on the job (National Institute for Occupational Safety and Health [NIOSH], 1996), thus making it one of the most common occupational health hazards today. Industrial or agricultural processes and machinery account for much of the noise exposure (U.S. Department of Health and Human Services [USDHHS], 1988). Significant harmful effects of loud noise include noise-induced hearing loss (NIHL); tinnitus (noises or ringing in the ears); psychological effects such as anxiety, depression, job stress, and decreased job satisfaction (Bhattacharga, Aparna, Tripathi, & Chatterjee, 1985; Melamed, Luz, & Green, 1992); and physiologic effects such as changes in heart rate, blood pressure, and increases in accidents/illnesses (Melamed et al., 1992; Johsson & Hansson, 1997; Lusk, Haggerty, Gillespie, & Caruso, 2002).

Because of this significant occupational health hazard, the Occupational Safety and Health Administration (OSHA) has mandated workplace Hearing Conservation Programs for industrial worksites (U.S. Department of Labor [USDL], 1983). As a part of these programs, engineering or administrative controls should be used as the first line of defense to reduce noise. However, implementation of these types of controls may not always be feasible or practical or may be insufficient to reduce noise to a safe level. When this occurs, hearing protection devices (HPDs) should always be used by workers (when exposed to loud noise) to prevent NIHL (Berger, 2000; Dear, 1998; Savell & Toothman, 1987). Although there is no comprehensive database available regarding the extent of HPD use, previ-

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ous research has shown that construction and factory workers use HPDs only a fraction of the time (18% to 70%) when they should be worn (Lusk, Kerr, & Kauffman, 1998; Lusk, Ronis, & Kerr, 1995). Therefore, it is essential that workers increase their use of HPDs, thus assuming personal responsibility for preventing NIHL. As health professionals, occupational health nurses conduct audiometric screening tests, provide education to workers regarding the dangers of loud noise, and assist them in preventing NIHL.

Although prior research has shown that there is a strong need to change worker behavior regarding use of HPDs, the research base regarding occupational behavior change programs is sparse. In a review of 36 intervention research studies in occupational health and safety, Goldenhar and Schulte (1994) noted a number of methodological problems including lack of a theoretical basis, small sample size, and inadequate intensity to cause the desired change. They also noted that most studies were either quasi-experimental (including nonrandom assignment) or nonexperimental (lack of a control group). Only one study was found that investigated hearing protection using a behavioral intervention (Ewigman, Kivlahan, Hosokawa, & Horman, 1990). While this intervention did result in changes in knowledge, attitudes, beliefs, and behaviors toward use of hearing protection, it lacked a control group to assess the effect of the intervention. Fishbein and associates (1991) have noted that theory-based research has the best potential to enhance the development of successful new interventions and underscored the need for all behavioral intervention programs to be guided by a theoretical framework. However, prior reviews of studies involving changes in workplace practices (Goldenhar & Schulte, 1994; McAfee & Winn, 1989) have noted that few of the behaviorally focused intervention studies had a theoretical basis.

Subsequent to these reviews, Lusk and colleagues (1999) tested the effectiveness of a theory-based intervention delivered to groups of workers working in three trades. Plumber/pipefitters and their trainers showed significant increases in use of HPDs at the 1-year posttest, while operating engineers and carpenters did not. However, mean rate of use was considerably less than the necessary use (100%) to prevent hearing loss, demonstrating the need for further behavior change. Building on the intervention for construction workers, the project described in this paper developed and tested a tailored theory-based intervention and a nontailored theory-based intervention delivered to individuals via computer to increase factory workers' use of HPDs. With increasing accessibility and recent advances in technology, computer-based programs offer a promising method of presenting behavior change messages to large groups of workers. Programs can be produced that combine interesting and relevant video and graphics with the database capabilities and processing power of a desktop computer to provide a feasible and cost-effective approach for behavior-change interventions to individuals and groups (Eakin, Brady, & Lusk, 2001).

Prior studies using a variety of approaches have shown the beneficial effects of tailoring behavior change messages to the individual (Bull, Krueter, & Scharff, 1999; Krueter, Bull, Clark, & Oswald, 1999; Prochaska, DiClemente, Velicer, & Rossi, 1993; Strecher, 1999). In the research project presented here, the intervention was tailored to:

(a) workers' responses to survey questionnaire items (perceptions of benefits, barriers, self-efficacy, interpersonal, and situational factors)
(b) self-reported type of HPD used
(c) perceived hearing ability
(d) self-reported use of HPDs,

thus determining the information they would receive and making it relevant to them

Program content was based on prior research using the Health Promotion Model (Pender, 1987) that identified predictors of hearing protection use among factory and construction workers (Lusk et al., 1995; Lusk, Kerr, Ronis, & Eakin, 1999). In addition, Pender's (1987) Health Promotion Model and Bandura's (1986) Social Cognitive Theory provided the theoretical foundation and guided the process for creating an individually-tailored, multimedia program to change workers' behavior regarding use of HPDs.

Methods

Design

This study used an experimental design, randomly assigning subjects in a pretest-posttest control group design (Campbell & Stanley, 1963) to contrast the effects of three interventions on factory workers' use of HPDs. The interventions were:

1. a tailored intervention, in which workers received information based on the predictors of HPD use from the causal model obtained in the original study of a large group of factory workers (Lusk et al., 1995), but tailored to each individual's specific responses to the survey items
2. a nontailored predictor-based intervention
3. a control intervention

Setting and Subjects

The study site for this program was an automotive factory in the Midwest. All workers included in the plant's longstanding Hearing Conservation Program were invited to participate. Following their annual audiometric test, workers (N = 2831) participated in pretest data collection over a 32-month period. Posttest data were obtained when workers returned to the plant's medical clinic for their next annual audiometric test. Only those workers whose annual exam occurred between 6 and 18 months following the pretest were included.

Complete pretest and posttest data were available for less than one-half of the workers (n = 1325). There were no significant differences in gender, ethnicity, type of HPDs used, or perceived hearing ability between those who returned for the posttest and those who did not. A significantly larger proportion of those with bachelor's degrees failed to return for the posttest. This is presumed to be due to workers in professional positions who were not required to be part of the plant's Hearing Conservation Program, but participated in the pretest out of curiosity. There was also a slight, albeit significant, difference in noise exposure with lower levels for the pretest-only group as compared to those who provided both pretest and posttest data (90.2 dB vs. 90.7dB, respectively). The professionals who were likely to have lower noise exposures may have contributed to this result. In addition, the group that did not participate in the posttest contained significantly more older workers and workers who had more years of service at the plant. This would be expected because most workers who were no longer employed at the plant had most likely retired.

Reasons for incomplete data included:

- audiometric test and return visit training <6 months or >18 months since pretest (*n* = 389)
- data recorded for only one intervention and corresponding audiogram for workers who were presumed to have left employment at the plant before posttest data collection had been completed (*n* = 335)
- pretest data collected during the last 5 months of the study, which did not allow sufficient time to return for posttest within the minimum 6-month time frame (*n* = 223)
- unknown reasons for no return visit (*n* = 559)

Dependent Variable

The dependent variable examined in this study was self-reported frequency of use of HPDs. The mean score for two questions regarding workers' use of HPDs in percentage of time when in high noise at the plant for the past week and the past month was used. A prior study of factory workers (Lusk, Ronis, & Baer, 1995) found that observations of use and workers' self-reported use correlated at .89. This suggests that worker self-report is an appropriate measure. Based on the range of scores, workers clearly felt free to report nonuse of HPDs (range 0%-100%).

Scores on the dependent measure had a moderate negative skew (-1.40). The analyses make the assumption that the residuals are normally distributed. However, given that the size of all subgroups in the analyses were more than 300, the Central Limit Theorem implies that the sampling distribution of the means is close to normal and that the assumption is irrelevant (Hays, 1994). Thus, no transformations were used to normalize the data.

Delivery of Interventions

The study interventions were delivered via computer in two soundproof booths. This arrangement assured worker privacy and provided insulation from the surrounding factory noise. The interventions were designed to be worker-initiated and available 24 hours a day, 7 days a week, thus allowing participation of workers from all shifts in the training program. Each booth contained a computer (as well as speakers and a printer) to collect data, deliver the intervention, and provide a handout containing information from the intervention and a hard copy of the consent information.

Permission was granted from the Institutional Review Board of a large Midwestern university to obtain workers' consent electronically via computer. Permission was also obtained from workers to include the results of their annual audiometric tests in the data collection. Workers began the training program by:

- providing information regarding their current use of HPDs, type of HPD used most often, and perceived hearing ability
- answering questions measuring predictors of use of HPDs

Following the data collection, participants were randomly assigned by computer to receive one of three interventions (tailored [*n* = 933], nontailored predictor-based [*n* = 945], control [*n* = 953]). Workers in all three intervention groups received OSHA-mandated content for worker training regarding hearing protection that included:

- use of HPDs
- the effects of noise on hearing
- the meaning of audiometric testing (USDL, 1983)

Because the factory could allow only a limited amount of worker time to complete the intervention, the entire program (introduction, informed consent, data collection by survey questionnaire, and the intervention) could not exceed 30 minutes.

Survey Questionnaire

Content of the questionnaire was based on prior research that determined the predictors of hearing protection use among factory and construction workers (Lusk, Ronis, Kerr, & Attwood, 1994; Lusk, Kerr, et al., 1999). The most important predictors from the Health Promotion Model (Pender, 1987) were:

- perceived benefits and perceived barriers to use of hearing protection
- perceived self-efficacy in the use of hearing protection
- situational factors and interpersonal support for use of hearing protection

Scales measuring predictor items were examined closely for validity and reliability (Lusk et al., 1994). With input from consultants, the research team developed three criteria for selection of content for the intervention. The items were those that (a) correlated with use (.20 or higher); (b) with room for improvement in scores (i.e., not already at ceiling) and; (c) potentially amenable to change (Lusk, Kerr, et al., 1999). Items that best met the inclusion criteria provided the survey content and the majority of the bases for the intervention. Detailed information regarding scale items and reliability measures has been reported in previous publications (Lusk et al., 1994; Lusk, Hong, et al., 1999). Questions were simultaneously presented in print form on the computer screen and by video-recorded voice. Workers responded by using a specially designed keypad similar to a telephone keypad.

Interventions

Tailored Intervention Information contained in the tailored intervention was derived from the theoretically specified predictors of use of HPDs, but was tailored to:

- individuals' responses to survey questionnaire items
- reported type of HPD used
- perceived hearing ability
- self-reported use of HPDs.

In addition, positive feedback was given for high reported use of HPDs and for optimal perceptions in relation to items measuring components of the model (e.g., a "strongly agree" response to "Using hearing protection prevents hearing loss").

Nontailored Intervention As in the tailored intervention, information contained in the nontailored intervention was derived from the theoretically specified predictors of use of HPDs. However, the nontailored intervention was not related to the individual's reported use of HPDs or responses on the survey questions. Rather, intervention content was delivered in a uniform manner to all participants in the group, with each worker receiving the same information in the same sequence.

Both the nontailored predictor-based and tailored interventions used factual, cognitive approaches, as well as demonstration, directed practice, vicarious experience, persuasion, and role-modeling techniques. The demonstrations and testimonials were presented in an interactive format by persons from various gender and ethnic groups.

Control Intervention A commercially available video on use of hearing protection was used as the control intervention. The research team reviewed a number of videos highly rated by the National Hearing Conservation Association (Kerst & Langman, 2000). Criteria set for selecting the video required that it

- provide required OSHA-mandated information on hearing protection
- had not previously been used in the factory
- did not emphasize the theoretically specified predictors used for the experimental interventions

Written permission was obtained from the publisher to digitize the video so that it would be delivered in the same manner on computer as the experimental interventions.

Results

Characteristics of Subjects

Workers who returned between 6 and 18 months after pretest for their annual audiometric test and hearing protection intervention were included in the posttest sample (n = 1,325). A summary of the demographic characteristics of study participants is presented in Table 1. There were no significant differences between workers in the three training groups in demographic characteristics or mean use of HPDs. The majority of workers in the plant were male (87%), White (74%), and middle-aged (m = 44 years of age). More than 95% of the total worker population was routinely exposed to noise levels at or above 85 dB, the standard set by OSHA for inclusion in an Hearing Conservation Program (USDL, 1983). According to data provided by the plant, the mean noise exposure for workers was 92 dB.

Effectiveness of Tailored Intervention

Total Sample Use of HPDs was recorded as a percentage of time where 0% equaled "no use" and 100% equaled "use of HPDs whenever they were required." Paired t tests (two-sided) determined the significance of pretest to posttest changes in mean use. Repeated measures analysis of variance (ANOVA) established whether change from pretest to posttest mean use differed by the three types of intervention (tailored [n = 446], nontailored predictor-based [n = 447], and control [n = 432]). The dependent variable (mean use of HPDs), was calculated as the mean of self-reported use during the past week and the past month.

Various assumptions of the analyses were examined. The data had a moderate negative skew (-1.40) but because of the large sample size and the Central Limit Theorem, this was not a problem. Variances were similar in the three groups. Finally, because there were only two measurement points (pre and post) the sphericity assumption

TABLE 1. Demographic Characteristics of Study Participants (n = 1,325)

Characteristic	n	%
Sex		
Male	1,147	87
Female	178	13
Ethnicity		
White	986	74
African-American	152	12
Hispanic	115	9
Other	68	5
Education		
< High school or GED	118	9
High school or higher	1,206	91
Type of HPD used		
Ear plugs	1,232	93
Ear muffs	54	4
Perceived hearing quality		
Excellent or good	1,031	78
Fair or poor	293	22
		Mean (*SD*)
Age (years)		44 (9.6)
Years worked at plant		15.7 (12)
Noise exposure (dB)		91.3 (4.7)

Note. GED = graduate equivalency degree; HPD = hearing protective device; dB = decibels.

TABLE 2. Mean Percent Use of HPDs (*N* = 1,325)

	n	Pretest % Use Mean (*SD*)	Posttest % Use Mean (*SD*)	Mean Change in Use Percent (*SD*)
Tailored	446	79.1 (29.8)	82.6 (26.8)	3.5* (22.6)
Predictor	447	78.1 (31.0)	76.9 (32.5)	−1.2 (23.6)
Control	432	74.6 (34.0)	76.2 (33.0)	1.6 (22.7)

Note. HPDs = hearing protective device.
*p = .001.

of repeated measures ANOVA was perfectly fulfilled (Mauchley's W = 1.00).

Workers randomized into the nontailored intervention slightly decreased their use from pretest to posttest. Participants in the control and tailored groups showed an overall trend of greater use at posttest, with those in the tailored group showing the greatest increase (Table 2). Paired t tests (two-sided) indicated that the change from pretest to posttest was significant for the tailored intervention group (t [445] = 3.244, p = .001) but not for the nontailored predictor-based group (t [446] = 1.120, p = .264) or for the control group (t [431] = 1.487, p = .138).

The test of the intervention type by time (pretest and posttest) interaction from the repeated measures ANOVA was significant, F (2, 1322) = 4.791, p = .008, indicating significant changes from pretest to posttest by intervention group (Table 3). Though not directly related to the research questions of this study, the main effects of time and intervention type were also statistically significant (p <.05). Posthoc comparisons using the Scheffé procedure (Hays, 1994) indicated that the change in the tailored group differed significantly from the change in the predictor group (p = .009). Changes in the control group did not significantly differ from changes in either the tailored group (p = .491) or the nontailored group (p = .180).

Subsample This study occurred in an industrial setting that employed an OSHA-mandated Hearing Conservation Program (USDL, 1983) requiring workers to use HPDs at all times while in high noise at the work place. Therefore, it would not be unexpected to find workers reporting total use (100%) of HPDs at pretest. More than one-third of the workers (n = 480) completing the study reported using HPDs the entire time they were needed at pretest. Obviously, these workers could not increase their HPD use beyond 100% at posttest. However, exclusion of these workers from the analyses based on pretest use (100%) could result in an induced regression artifact.

To reduce the ceiling effect due to 100% users, while not inducing a regression artifact, participants who reported 100% HPD use at *both* pretest and posttest were removed for reanalysis. This approach does not induce a regression artifact because the subsample selection is based equally on pretest and posttest use. This method uses a theoretically consistent approach to effectively exclude in this analysis participants who would not normally be included in a behavior change program.

The reanalyses produced the same results as the original analyses. The same effects were statistically significant, directions of effects were the same, and effect sizes were similar but slightly higher (e.g., a difference of 4.8% in the tailored group in the reanalysis compared to 3.5% in the original analysis). Results of posthoc comparisons were similar as well.

TABLE 3. Training Type by Time ANOVA (*n* = 1,325)

	Df	F	*p*
Training type[a]	2,1322	3.898	.021
Time[b]	1,1322	4.133	.042
Training type x time	2,1322	4.791	.008

Note. ANOVA = analysis of variance; HPDs = hearing protective devices.
[a]Tailored, nontailored predictor-based, or control intervention.
[b]Pretest and posttest use of HPDs.

Discussion

All of the workers included in this study were part of the Hearing Conservation Program in their plant, an indication that they should be using hearing protection 100% of the time. Although HPD use in this plant was higher than in a previous study of factory workers (Lusk et al., 1995), (76% vs. 70% mean use), the constant use necessary to prevent noise-induced hearing loss was not achieved for all workers.

Because these studies relied on self-report of hearing protection use, questions may be raised about its accuracy. A prior study of factory workers assessed the usefulness of three indicators of hearing protection use (Lusk, Ronis, & Baer, 1995). Results showed that observations of use and workers' self-reported use correlated at .89. Little evidence was seen for a social desirability effect with mean self-reported use higher than observed use (7.9%). Thus, there is reasonable confidence in the accuracy of these workers' self-reports.

Workers who received the tailored intervention reported significant posttest increases in their use of hearing protection. Differences were not significant in the nontailored predictor-based or control groups. The pre- to posttest changes also significantly differed by training type; in posthoc comparisons the tailored group significantly differed from the nontailored predictor-based group, but not the control group. Because the tailored and nontailored interventions had similar content (differing by content presented in the tailored version which was specific to the individual's reported use of HPDs and responses to the survey) it is reasonable to conclude that tailoring made this intervention more effective than the nontailored intervention.

The findings regarding the comparisons between tailored, nontailored, and control are not inconsistent with the literature. A meta-analysis of 20 studies testing the efficacy of tailored interventions conducted by Ryan & Lauver (2002) assessed both process and outcomes. While they found that participants showed a positive perception of tailored interventions and remembered and discussed the content more than that of standard interventions, in terms of outcomes, tailored interventions were more effective in promoting health behavior than standard interventions in 50% of the studies.

This study provided a rigorous test of newly developed interventions with a control intervention that was a highly rated, commercially produced program that may have been more entertaining. That the taillored intervention was not significantly more effective than the control intervention was disappointing. However, it should be noted that the control intervention did result in a smaller increase in HPD use than the tailored intervention and that the tailored intervention was more effective than the nontailored.

When the results were analyzed for only those workers who did not report use at all times prior to and following the intervention, the results were essentially the same. The tailored intervention was the only one resulting in significantly increased use of hearing protection and in posthoc comparisons the changes in the tailored group significantly differed only from the nontailored predictor-based intervention group. Procedures were used to assure that there was no induced regression artifact. The fact that effect size remained essentially identical for the two samples suggests that the procedures were successful.

Prior to this project, workers had received information regarding hearing protection through short annual "toolbox talks." In this project, all three programs were delivered via computer (a novel experience for workers at that time). While there are many advantages to presenting the training via computer (e.g., continuous availability, accessible to workers on all shifts), it is important to note that the computer made it possible to tailor the intervention to the individual, and it was this tailored intervention that had the greatest effect. Only in the tailored version did the computer recognize individual responses and provide information specific to them. When workers are allowed some choice in the information provided, with information specific to each worker's reported behavior, attitudes, and beliefs, it is logical and consistent with educational principles that this type of program would be more effective (Caffarella, 1994; Merriam, 1993). Further research is needed to maximize the effects of individually tailored interventions in this setting.

Based on previous research results and anecdotal information, it is difficult to change worker behavior in regard to use of personal protective equipment. The annual training provided by the plant had not resulted in constant use of HPDs. Although statistically significant, the increase seen in this study was small progress toward achieving total use of HPDs. However, the fact that a 30-minute intervention delivered 6 to 18 months prior had an effect on this difficult-to-influence behavior is significant.

The number of workers exposed to noise, the importance of preserving hearing ability, and the impact of hearing loss on personal and work lives justifies the effort to develop useful interventions. To provide the best protection for workers, it is essential that the most effective interventions be used to promote use of HPDs to protect hearing.

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