COMPUTER BASED

HEARING TEST & TAILORED TRAINING

THE UNIVERSITY OF MICHIGAN SCHOOL OF NURSING

OISAENG HONG, PHD, RN
PRINCIPAL INVESTIGATOR

DIRECTOR OF OCCUPATIONAL HEALTH NURSING PROGRAM
NIOSH EDUCATION & RESEARCH CENTER
IN OCCUPATIONAL HEALTH & SAFETY ENGINEERING
&
ASSISTANT PROFESSOR
SCHOOL OF NURSING
UNIVERSITY OF MICHIGAN
400 N. INGALLS, RM. 3182
ANN ARBOR, MI 48109-0482

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Computer-based Hearing Test and Tailored Training

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Principal Investigator

OiSaeng Hong, PhD, RN
Director, Occupational Health Nursing
NIOSH Education & Research Center
in Occupational Health & Safety Engineering
&
Assistant Professor, School of Nursing
The University of Michigan
400 North Ingalls, Room 3182
Ann Arbor, Michigan 48109-0482

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Project Staff

Co-Investigator	Jan Brady, PhD (till December 2000)
Co-Investigator	Sally L. Lusk, PhD, RN, FAAN
Statistician	David L Ronis, PhD, MA
Research Associate (Data Analyst)	James Roll, MS
Research Associate (Data Analyst)	Kwang Sook Kee, MA
Research Associate (Data Analyst)	Guipeng Liu, MA
Research Associate (Data Analyst)	Anamaria Kazanis, MA
Graduate Research Assistant	Jamie Decker, MS
Consultant (Nursing)	Madeleine J. Kerr, PhD, RN
Consultant (Hearing Science)	Paul Kileny, PhD
Consultant (Causal Modeling)	Laura Klem, AB
Consultant (Hearing Conservation)	Julia Royster, PhD
Consultant (Computer Engineering)	Peter Csaszar, PhD
Data Collector	Gary Smith, MA
Data Collector	Naruemol Shinga-Dong, MA
Multimedia Technician	Vic Divecha, MSE
Research Administrative Staff	Alonzo LaGrone, BA
Post-Doctoral Fellow	Ae Suk Jeong, PhD
Doctoral Student	D. Martin Raymond, PhD
Undergraduate Research Opportunity Program Student	Sheena Thomas
Undergraduate Research Opportunity Program Student	Mark Fleming
Center of Health Promotion Scholar	Julie Wilner

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AT	Audiometric Test
ANSI	American National Standards Institute
CDC	Centers for Disease Control and Prevention
dB(A)	Decibel(A)
HAZMAT	Hazardous Material
HPDs	Hearing protection devices
NIOSH	National Institute for Occupational Safety and Health
NORA	National Occupational Research Agenda
NIHL	Noise-induced hearing loss
OEs	Operating Engineers
OSHA	Occupational Safety and Health Administration
PUHPM	Predictors of Use of Hearing Protection Model
RMSEA	Root Mean Square Error of Approximation
SAAT	Self-administered audiometric tests
USDHHS	Department of Health and Human Services
USDL	United States Department of Labor

LIST OF FIGURES

Figure 1. Predictors of Use of Hearing Protection Model

Figure 2. Significant paths from predictors to use of HPDs in Time 2.

ABSTRACT

The purpose of this project Is to prevent noise-induced hearing loss (NIHL) in operating engineers (OEs), construction workers who operate heavy equipment, by testing the effectiveness of an innovative tailored intervention, along with self-administered audiometric test (SAAT) and immediate feedback on the test results, to increase workers' attention to hearing abillty and use of hearing protection. The study has four specific aims: (1) design and test the effectiveness of an innovative intervention for OEs to increase their use of HPDs; (2) determine prevalence of hearing loss in OEs; (3) demonstrate the feasibility of providing computer-based SAAT and hearing protection interventions at a construction worker training center; and (4) test and refine the Predictors of Use of Hearing Protection Model (PUHPM), a causal model designed to explain use of HPDs by OEs.

To achieve these aims, this project was conducted in three phases, (1) Phase I: pre-study development of intervention, (2) Phase II: intervention study, and (3) Phase III: post-study evaluation of intervention. In Phase I, qualitative data on OEs' perceptions, opinions, and attitudes on use of HPDs were obtained through focus groups to guide development and refinement of an intervention. This intervention and the SAAT was pilot tested and revised as needed. Phase II tested the effectiveness of an individually tailored, interactive, multimedia intervention combined with the SAAT, delivered by computer and contrasted with a control intervention. The experimental group received the tailored intervention based upon the participants' audiometric test results, their responses to questions on current use of HPDs and the theoretically derived predictors of HPD use from the PUHPM. The control group was shown the commercial video on use of HPDs selected for the research team's previous project. The study used an experimental pretest-posttest control group design, with post intervention measures one year following the intervention. Phase III obtained workers' feedback on the SAAT and the tailored intervention.

A total of 403 participants who completed both pretest and posttest were included in the analyses to determine efficacy of the intervention. The study found significant short-term (immediately after) and limited long-term (a year later) effects of the tailored intervention in increasing use of HPDs in workers. The study also identified limitations that might have contributed to the limited long-term effectiveness of the interventions including frequency of interventions (one-shot with 50% chance of one booster), frequency and timing of follow up (F/U) (one F/U at one year, i.e., long delay from intervention to posttest), and frequency and format of boosters (one-time mailed one-page letter).

Clearly findings from this study have added insights about the seriousness of the NIHL problem, the importance of the interventions to promote workers' use of HPDs to protect hearing, application of e-learning modality for training worker population, and will inform our continued efforts to develop the most effective behavioral interventions to prevent NIHL in noise exposed workers.

SIGNIFICANT FINDINGS

1. Multimedia computer technology was successfully incorporated with a self-administered audiometric test (SAAT) with hearing protection training and using audiometric test results for tailoring based on each individual worker's need for information and motivation.

2. Hearing protection devices (HPDs) demonstrated protective effect on NIHL. Workers who used HPDs consistently showed significantly lower hearing loss than those who did not and the continuous use of HPDs was one of the strongest predictors for reduced hearing loss.

3. Identified the magnitude and severity of the NIHL problem among construction workers, specifically, operating engineers (OEs).

4. Applied a behavioral theory to determine significant factors to explain workers' hearing protection behavior and to develop interventions to promote workers' use of HPDs.

5. Interventions were tailored to provide information most relevant to individual workers. The study demonstrated significant short-term (immediately after) and limited long-term (one year later) effects of the tailored intervention in increasing workers' use of HPDs.

6. Identified several limitations that might have contributed to the limited long-term effects of the interventions: frequency of interventions (one-shot with 50% chance of one booster), frequency and timing of follow up (one follow up at one year, i.e., long delay from intervention to posttest), and frequency and format of boosters (one time mailed one-page letter), informed the design of the future studies.

7. Workers' high satisfaction level with interactive computer program demonstrated that a computer-based screening and training is a promising modality for training in the worker population.

8. Provided an exemplary collaboration among a committed team representing a university, a worker labor union, and workers. In particular, through both worker and union involvement in the development and implementation of the program, this study provided a model for worker/union participatory safety and health training.

USEFULNESS OF FINDINGS

This study was the first project to use the novel approach of combining computer-based SAAT with tailored hearing protection intervention and using audiometric test results for tailoring. The multimedia technology this study developed and tested will serve as the basis for future studies.

With proven feasibility and workers' high satisfaction, the innovative multimedia program developed in the study is expected to be greatly beneficial for millions of workers who are at risk of NIHL. The program can be disseminated in a cost-effective manner through the internet-enabled version (web) to the entire construction worker population in the country. This will greatly aid in reducing NIHL. Particularly, this centralized hearing test and training with record-keeping system at a union training center would allow even employees of smaller contractors to have hearing tests and education when they are at a union training center for their various job-related training sessions. Even if a small fee is required by the training center, this could be an efficient and cost-effective system.

This was our first attempt to test the intervention effects immediately after and one year later to examine whether workers' behavioral change can be maintained for an extended period. Significant short-term and limited long-term effects demonstrated hearing protection efforts should be an ongoing concern.

The Predictors of Use of Hearing Protection Model (PUHPM) proved to be a useful conceptual model for explaining use of HPDs in operating engineers. The Model will be used to determine significant predictors of use of HPDs in other groups of workers, which will subsequently be used for developing the content of hearing protection intervention relevant to a specific target worker population.

The study demonstrated an exemplary collaboration among university researchers, a worker labor union and workers, and a model for worker/union participatory safety and health training which can be transferred to other worker groups.

SCIENTIFIC REPORT

BACKGROUND

NIHL is the most common occupational disease in the U. S. (National Institute for Occupational Safety and Health [NIOSH], 1996a). NIHL is an irreversible hearing impairment, causing significant monetary costs and human suffering, including emotional depression, a sense of being cut off from the rest of the world, a negatively affected quality of life, and a reduction in the personal safety of workers. Occupational NIHL affects not only those workers who have lost their hearing but also their co-workers, family members and society as a whole. Thus, prevention of NIHL is important.

While it is preferable to reduce hazardous noise exposure through engineering controls, it is often impractical, costly, or scientifically impossible to eliminate all harmful noise. Because this condition can be prevented by consistent use of HPDs (Sataloff & Sataloff, 1993), protective action by the workers is necessary. Consistent use of hearing protective devices (HPDs) reduces noise exposure and subsequent NIHL.

Factors unique to the construction industry, such as a mobile work force, 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. However, previous studies found that construction workers did not consistently use HPDs (Lusk, Hong, et al, 1999). Attention needs to be directed toward identifying the most effective ways to assist workers in adopting the use of HPDs.

Various levels of theory-based and individually tailored behavior change interventions have been described in the literature. Computer-tailored interventions are characterized by the fact that the content of the materials is adapted, with the assistance of computers, to the characteristics of a specific individual (de Vries & Brug, 1999). Tailored training provided by computer technology can address the most salient needs of workers relative to their hearing ability and hearing protection behaviors.

Both the U.S. Department of Health and Human Services, through Healthy People 2010 (U. S. Department of Health and Human Services (USDHHS, 2000), and NIOSH (1996b), through its National Occupational Research Agenda (NORA), has set national priorities aiming to prevent NIHL. Healthy People 2010 set a goal (Objective 20-11) to reduce new cases of work-related NIHL. NORA, set by NIOSH in conjunction with the occupational safety and health community, identified NIHL as one of eight target injuries and diseases for research. About 25% of all workers are exposed to hazardous noise, indicating a continued need for research into ways of reducing NIHL.

Most fundamental to reducing NIHL, would be the introduction of a comprehensive hearing conservation program for workers at risk. Such a program would include periodic audiometric tests for early detection of hearing loss, as well as worker education to promote workers' use of hearing protective devices. However, due to the inherently dangerous nature of construction work and the difficulty involved in performing health surveillance on a transient workforce, chronic construction health hazards such as noise have received little attention historically. The federal occupational noise standards have been notoriously weaker and less-stringently

enforced in construction than in manufacturing, so the majority of construction workers have not been given essential health services for preventing NIHL. Considering the significance of these two essential components of hearing conservation (use of HPDs and regular audiometric tests), this study developed and implemented computer-based audiometric tests and tailored intervention designed to provide construction workers with audiometric tests and promote their use of HPDs, ultimately, to prevent NIHL.

PURPOSE

The purpose of this project is to prevent NIHL in OEs through identifying an effective intervention. Along with SAAT and immediate feedback on the test results, this project designed and tested a new intervention program tailored to the trade as well as to individual workers' hearing ability and their HPD use. Tailored interventions, which consider the particular characteristics of the work situation and the individual worker, are expected to be more effective than the previous group intervention in changing OEs' hearing protection behavior. The project utilized a new hearing screening method, SAAT, and a new training technology, an individually tailored, interactive, multimedia program delivered by computer. In addition, with recognition of the scarcity of data on the prevalence of NIHL, this study determined the extent of hearing loss in OEs.

SPECIFIC AIMS

Four aims were addressed in this study.

1) Design and test the effectiveness of an innovative intervention developed for OEs to increase their use of HPDs;
2) Determine the prevalence of hearing loss in OEs;
3) Demonstrate the feasibility of providing computer-based SAAT and hearing protection interventions at a construction worker training center;
4) Test and refine the Predictors of Use of Hearing Protection Model (PUHPM), a causal model designed to explain use of HPDs by OEs.

In addition, four hypotheses were also tested:

a) The tailored intervention will be more effective than a non-tailored control intervention in increasing OEs' use of HPDs from pretest to posttest;
b) At least 40% of OEs will show high-frequency (4 and 6 kHz) hearing loss;
c) At least 90% of OEs will be positive about receiving a computer-based SAAT and hearing protection interventions at a training center;
d) The Predictors of Use of Hearing Protection Model (PUHPM) will fit well and account for at least 30% of the variance in use of HPDs at pretest and posttest.

CONCEPTUAL FRAMEWORK

Intervention effectiveness research should be theory-driven, and therefore the theory underlying the intervention should be tested. The theory identifies predictors of health behavior and guides the analysis of their impacts on outcome behaviors (Sidani, & Braden, 1998). This study used the PUHPM shown in Figure 1 as the conceptual framework to identify the predictors of workers' use of HPDs and to guide the tailored intervention.

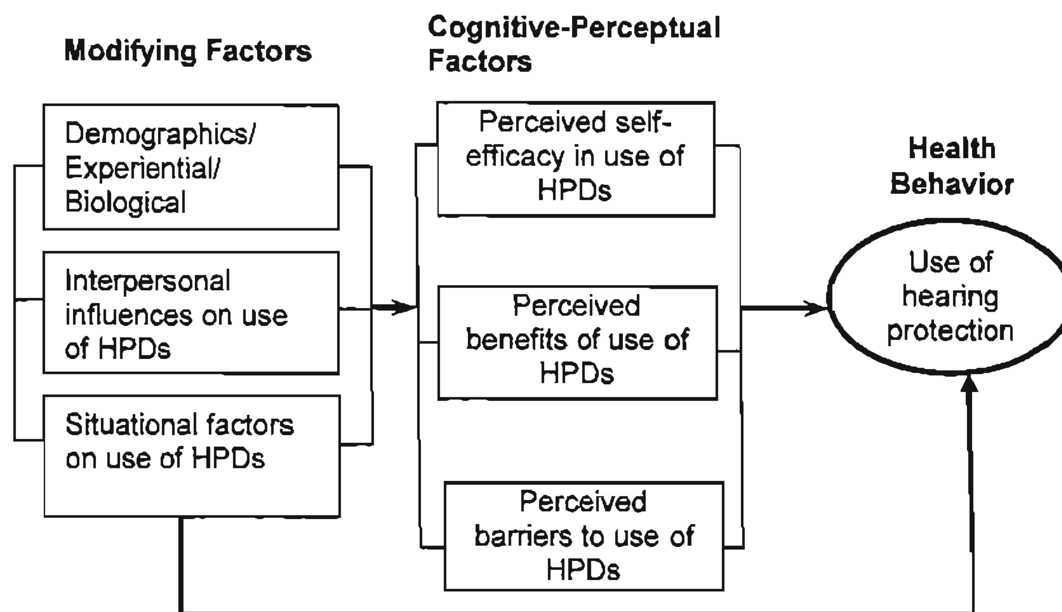

Figure 1. Predictors of Use of Hearing Protection Model (PUHPM)

The PUHPM was derived from the Health Promotion Model (Pender, 1987) and Social Cognitive Theory (Bandura, 1986). The PUHPM 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 PUHPM has been tested and demonstrated utility as a causal model for predicting hearing protection behaviors in different worker populations (Hong, Lusk, & Ronis, 2005; Kerr et al., 2002; Lusk, Ronis, et al., 2003; Ronis, Hong, & Lusk, in press).

MEASURES

Study participants completed questionnaires about use of hearing protection, demographics, and the factors from the PUHPM. Content of the survey was based on prior research that determined the predictors of hearing protection use among factory and construction workers (Hong et al., in press; Lusk, Hong, et al., 1999; Lusk, Ronis, et al., 2003).

The scales in the questionnaire had demonstrated good reliability in previous studies (Hong, et al, 2005; Ronis, et al,, in press, Lusk, Hong, et al., 1999). Reliability coefficients for all scales in this study are reported in Hong, Ronis, Lusk and Kee (in press) (see Appendix B).

To select content for the intervention, based on the items in the questionnaire, this study applied the same three criteria as in previous studies (Lusk, Kerr, et al., 1999; Lusk, Ronis, et al., 2003). The criteria include: (a) those items that correlated with use (.20 or higher); (b) those items with room for improvement in scores (that is, not already at ceiling) and; (c) those items potentially amenable to change (Lusk, Kerr, et al., 1999). Items that best met the inclusion criteria provided the majority of the bases for the computer-based survey and tailored intervention. A brief description of measures is provided below.

MODIFYING FACTORS

Demographic/Experiential/Biological Factors. Demographic data were collected using single-item measures for age, education, years in construction, gender, ethnic/racial background, hours of noise exposure. Perceived hearing ability was measured by a question about how workers perceive their hearing ability. Actual hearing ability was measured by SAAT.

Interpersonal Influences on Use of Hearing Protection was measured using two scales (social models, interpersonal support). *Social Models* were measured through questions about how much workers believed others (co-workers, supervisors) with whom they spent the most time actually used HPDs. *Interpersonal Support* was measured by questions about how much others (co-workers, supervisor, and family) encourage workers to use HPDs.

Situational Factors Affecting Use of Hearing Protection were measured using two scales (Availability of HPDs, Worksite climate). *Availability of HPDs* was measured by asking questions such as, "Your employers provide ear plugs or muffs." "You are satisfied with the supply of ear plugs or muffs at your job site." *Worksite climate* was measured by a 6-item Climate Influence (employers, supervisors and union) Scale, which was modeled on the Worksite Health Climate Scale (Ribisl & Reischl, 1993). Examples of climate scale items are "Your employers are generally concerned about your health and well-being," and "Your employers are committed to improving employee health."

COGNITIVE-PERCEPTUAL FACTORS

Perceived Self-efficacy in Use of Hearing Protection measured workers' confidence in their ability to use HPDs correctly. An example of an item from this scale is, "I am sure I can use my hearing protection so it works effectively".

Perceived Benefits of Use of Hearing Protection measured workers' beliefs regarding the positive results of using HPDs. A sample item for this scale is "Wearing hearing protection protects me against hearing loss from noise exposure".

Perceived Barriers to Use of Hearing Protection measured workers' perceptions of inconvenience, discomfort, difficulty of engaging in using HPDs. An example of an item in this scale is "Hearing protection keeps me from hearing what I want to hear". All cognitive-perceptual factors were measured on a 6-point Likert scale (1=strongly disagree, 6=strongly agree).

METHODS

STUDY DESIGN & PROCEDURE

To achieve the aims of the study, the study was conducted in three phases: (I) pre-study development of intervention, (II) intervention study, and (III) post-study evaluation of intervention.

1) Pre-study development of intervention: Two focus groups with twelve OEs in each group were completed. Findings of focus groups were presented in Hong, Lusk, Raymond, and

Decker (2002) (see Appendix A). Results of focus group discussions were used by the project staff and consultants to develop the scripts, storyboard, and video segments for the tailored intervention. Development of a combined SAAT and individualized hearing protection training program with multimedia technology and participants' feedback data are presented in Hong and Csaszar (2005) (see Appendix C).

2) Intervention Study: The effectiveness of the intervention was tested using an experimental pretest-posttest control group design (Campbell & Stanley, 1968), randomly assigning subjects to the experimental and control groups. Details of interventions, procedures, and characteristics of participants is described in Hong, et al (in press) (see Appendix B).

3) Post-study evaluation: Feedback questionnaires completed by the participants who completed intervention program and two post-intervention focus group discussions were completed. Findings of participants' satisfaction level and feedback are reported in Hong and Csaszar (2005) (see Appendix C).

STUDY SITE AND PARTICIPANTS

The study was conducted at the Local 324 Training Center of the International Union of Operating Engineers in Howell, Michigan. The study was conducted from December to Early April when workers came to the training for a three-year apprentice certification course or the 8-hour Hazardous Material (HAZMAT) refresher course.

The study participants are construction workers who operate heavy equipment such as bulldozers, graders, backhoes, asphalt road rollers, asphalt spreaders, and wheel loaders; the noise level for most of this heavy equipment is above 85 dBA.

A total of 612 operating engineers were recruited to the study in Year 1-pretest. About 66% (403/612) of them returned and participated in Year 2-posttest. Comparison between participants who did (n=403) and did not (n=209) return to complete posttest showed no significant differences in their demographic characteristics or type of intervention they received in Year 1. Overall attrition rate was 34%, lower than the estimated 40%. A total of 403 workers who completed pretest, intervention, and posttest were included in the analysis to examine the efficacy of the intervention in changing workers' hearing protection behaviors. They were predominantly middle aged (mean age= 43 years) male (91%) and white (91%). The majority (94%) of them had at least a high school education. They reported high noise exposures (7 hrs/day) and their use of HPDs was low (50% of the time needed).

RESULTS

Results are organized by specific aims. Portions of this write-up are abstracted from our own publications attached in Appendices. Publications related to each of the specific aims are listed at the end of report. Copies of all the publications are attached in Appendices.

Aim 1. Design and test the effectiveness of an innovative intervention for operating engineers to increase their use of HPDs

Hypotheses: Two hypotheses were considered to test both short- and long-term effects of interventions. 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.

1) Short-term intervention effect

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. For both Year 1 and Year 2, participants were randomly assigned to two interventions. Two-sided paired t tests were performed to determine the significance of changes in intention of HPD use in the future from before the intervention to right after the intervention for both Year 1 and Year 2. Results 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.

A repeated measures Analysis of Variance (ANOVA) examining changes in intention of HPD use in the future from before to right after the interventions by the two types of interventions was conducted. The test of time (before the intervention and right after the intervention) by the intervention type interaction in repeated measures ANOVA was significant for both Year 1 ($F[1, 382]=16.374$, $p=.001$) and Year 2 ($F[1, 387]=12.430$, $p=.001$), indicating significant differences in the amount of change between the two intervention groups. Changes in the tailored groups were significantly greater than in the control group for both years. The changes in intention of use in Year 1 for the tailored and control groups were 8% and 2%, respectively. In Year 2, the same trend (greater increase in intended use in tailored vs. control group) was shown (6% vs. 2%).

2) Long-term intervention effect

To determine the long-term effect of the interventions, the second outcome variable (mean use of HPDs) was examined approximately one year after the intervention. For testing the intervention effect within each intervention group, paired t-tests (two-sided) for pretest to posttest changes in mean use of HPDs were performed. Changes in mean use of HPDs between pretest and posttest for the tailored and control groups were 7% (from 50% to 57%) and 6% (from 50% to 56%), respectively. Findings from paired t-tests (two-sided) showed changes from pretest to posttest 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 pretest to posttest differed by the type of intervention. The result indicated no significant difference in the amount of change in mean use of HPDs between the two intervention groups.

While both interventions tested in this study significantly increased HPD use one year following the intervention, the second hypothesis was not supported by the data as the effects of the tailored and the control interventions did not show significantly different effects on the behavior of using HPDs one year post-intervention. Workers who received the tailored intervention increased their use of HPDs slightly more, but not significantly more than workers in the control group (7% vs. 6%).

This insignificant difference between the two intervention groups may be viewed as somewhat disappointing. Since both groups received a hearing screening test and an interpretation of the results, a new experience for most subjects, it was likely responsible for the increased use by the control group. 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 and a mailed one-page booster. The one-year interval between the intervention and the posttest measure might have contributed to dissipation of the effect of intervention. One year is very long time for workers to maintain their increased intention of use. Clearly further research is needed to determine how to maximize the effects of individually tailored interventions in workers.

Although the tailored intervention significantly increased workers' use of HPDs from 50% to 57% (actual change of 7% representing 14% improvement over the baseline), the change accomplished in this study was small progress toward the desired level of 100% use of HPDs to prevent NIHL. However, considering the difficulties in changing human behaviors, the fact remains that a one-shot intervention for less than 45 minutes (including survey and AT delivered a year earlier, plus a 50% chance of being sent a booster message) had a significant effect on increasing workers' use of HPDs is remarkable.

Publication related to Specific Aim 1:

Hong, O., Ronis, D. L., Lusk, S. L, & Kee, K. S. (in press). Efficacy of a computer-based hearing test and tailored intervention to prevent hearing loss. International Journal of Behavioral Medicine. (Appendix B) (

Aim 2. Determine prevalence of hearing loss in operating engineers

Over 60% of study participants showed hearing loss in the noise-sensitive higher frequencies of 4 and 6kHz. The rate of hearing loss was particularly higher among workers who reported longer years of working in the construction industry. A vast majority of participants who had worked in construction for a longer period (over 20 years) showed hearing loss at noise sensitive frequencies (4kHz & 6kHz): 75% of workers with 20-29 years; 89% of workers with 30-39 years; and 100% of workers with over 40 years in construction. Workers showed significantly poorer hearing in the left ear. The differences in the mean hearing levels between the two ears are clearly greater in higher frequencies (3-8kHz), most notably at 3, 4, and 6kHz, than in lower frequencies (0.5-2kHz). Thirty-eight percent reported ringing/buzzing in the ear and 62% indicated having problems in understanding what people say when in loud noise.

The average reported use of HPDs was 50% of the time they were required to be used. This rate is far less than the 100% use needed to prevent NIHL, demonstrating the need for further behavior change. The study further investigated if workers' use of HPDs has an effect on their hearing loss at noise-sensitive higher frequencies (4 & 6kHz). Bivariate correlation of HPD use with mean hearing levels at frequencies of 4 and 6kHz showed significant inverse association ($r = -.13$, $p < .001$). Workers who used HPDs more frequently had significantly better hearing than those who did less frequently.

Publication related to Specific Aim 2:

Hong, O. (2005). Hearing loss among operating engineers in American construction industry. International Archives of Occupational an Environmental Health, 78(7), 565-574. (Appendix C).

Aim 3. Demonstrate the feasibility of providing computer-based self-administered audiometric test (SAAT) and hearing protection interventions at a construction worker training center

Using multimedia technology, this study developed and tested a computer-based SAAT and a tailored intervention at a worker union training center. Detailed descriptions of development of the multimedia computer-based program and decision algorithm for tailoring is provided in Hong and Csaszar' paper published in the *International Journal of Audiology* (see Appendix D).

Feasibility was assessed by both quantitative and qualitative feedback from the participants through a survey and focus group, and clearly demonstrated that this computer-based program was well received by operating engineers, many of whom never used or did not use a computer regularly. Over 96% of the participants indicated they liked receiving an AT by the computer; the SAAT worked smoothly; and the computer-based training was well organized, effective and held their interests. Almost all (more than 99%) said they would recommend this program to other workers.

Participants' favorable feedback strongly supported the continued utilization of this approach for designing and developing health screening and intervention to promote healthy behaviors. Although participants showed high satisfaction, they suggested several points to improve the program. Specific suggestions include: adding more statistics on NIHL, testimonials from workers with hearing loss or their family members, more frequent boosters, and information on noise levels of common equipment or tools used on and off jobs.

This study is one of the first of its kind to incorporate multimedia computer technology with SAAT and a tailored intervention. This innovative multimedia format will serve as a prototype for development, implementation, and testing of health screening and education in the future.

Publication related to Specific Aim 3:

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

Aim 4. Test and refine the PUHPM, a causal model designed to explain use of HPDs by operating engineers. (Publication: A manuscript is in preparation).

Structural equation modeling was performed using AMOS 5.0 (Arbuckle, 2003) to test and refine the PUHPM. The structure of the model includes direct paths from all factors to use, but particularly emphasizes the direct paths from the cognitive-perceptual factors (self-efficacy, benefits, and barriers). Our structural equation model took advantage of the two-wave structure of the parent study by including all PUHPM model predictors in Time 1 along with these three cognitive-perceptual factors at the posttest to predict use of HPD at the posttest. The statistically significant paths from the model are shown in Figure 2.

Fit of the model and prediction of use were very good. Though the χ^2 could reject the model as an exact fit to the data $\chi^2(31)=57.31$, $p=.003$, the measures of approximate fit were good: Normed Fit Index=.97, Tucker-Lewis Index=.92, and Comparative Fit Index=.99 (each indicating that the model explained over 90% of the covariance among factors). Finally the Root Mean Square Error of Approximation (RMSEA) at .046 indicated that the fit was close. The model explained 58% of the variance in Time 2 mean use.

Though the path from self-efficacy was not significant, the paths from benefits and barriers were significant, with standardized coefficients of .19 and -.20. These were the two strongest paths to Time 2 use other than the path from Time 1 use, which indicated stability of the behavior over time. Because the Time 1 versions of these variables were controlled, this indicated that these variables predicted changes in use over time. Other significant paths to Time 2 use came from exposure to noise, perceived hearing health, future intended use, and Time 1 benefits. Three non-significant paths to use were somewhat surprising – the path from self-efficacy mentioned above, the path from social influences, and the path from the intervention. These variables require more careful study. However, the model did very well, in terms of fit, identifying the most important variables, and in explaining variance in use of HPDs.

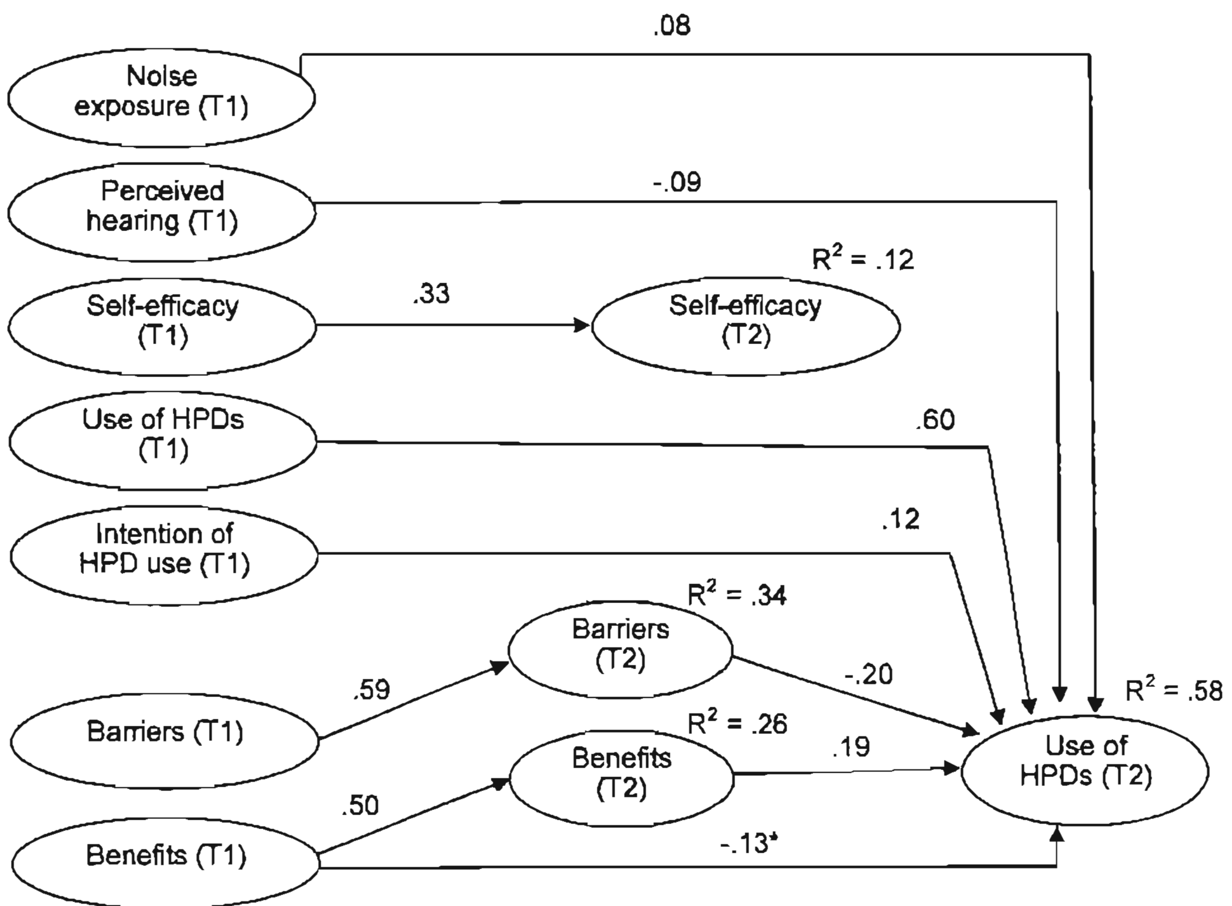

Figure 2. Significant paths from predictors to use of HPDs in Time 2.

CONCLUSIONS

This study revealed a high prevalence of hearing loss and low use of HPDs in OEs. More comprehensive hearing conservation programs, including periodic audiometric testing and hearing protection training should be in place for this highly vulnerable construction worker group.

This study successfully utilized multimedia computer technology to deliver a SAAT and a tailored intervention and demonstrated that a computer-based program is a promising modality for training in the worker population. This innovative multimedia format will serve as a prototype for development, implementation, and testing of health screening and education in the future

The study examined the efficacy of a computer-based SAAT and tailored hearing protection intervention and found significant short-term effects of the tailored intervention. The study also identified several limitations that might have contributed to the limited long-term effectiveness of the interventions. Further research is necessary to develop and evaluate an effective intervention to achieve and sustain significant behavioral change over prolonged periods of time to prevent NIHL in worker populations.

Workers suggested expanding the content of the intervention by adding more statistics on NIHL, testimonials from workers with hearing loss or their family members, more frequent booster interventions, and information on noise levels of common equipment or tools used on and off jobs. These should be incorporated into the future studies.

This work is an important contribution in the occupational health services by addressing a significant occupational health problem as well as advancing science related to delivery and vehicles for health screening and health education to change workers' health behaviors, thus improving their health and safety. This study demonstrated a successful collaboration between a trade union and a research university in developing and implementing regular audiometric tests and hearing protection training. It is hoped this work will serve as a prototype for effective collaboration among researchers, labor unions, contractors, and workers to promote workers' health and safety.

PUBLICATIONS

Published Proceedings

Hong, O., Ronis, D. L., & Roll, J. (2004). Interactive multimedia technology in prevention of hearing loss: workers satisfaction level and training effect. International Journal of Behavioral Medicine, Vo1 11, Supplement, 271.

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Articles in Peer-Reviewed Journal (The copies are attached).

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APPENDICES

Appendix A	Hong, O., Lusk, S. L., Raymond, D. M., & Decker, J. (2002). Voices from construction workers: Finding of focus group regarding use of hearing protection. Proceedings of 12th Annual Construction Safety and Health Conference: Power through partnerships, pp. 155-159.
Appendix B	Hong, O., Ronis, D. L., Lusk, S. L, & Kee, K. S. (in press). Efficacy of a computer-based hearing test and tailored intervention to prevent hearing loss. International Journal of Behavioral Medicine.
Appendix C	Hong, O. (2005). Hearing loss among operating engineers in American construction industry. International Archives of Occupational and Environmental Health, 78(7), 565-574.
Appendix D	Hong, O. & Csaszar, P. (2005). Audiometric testing and hearing protection training through multimedia technology. International Journal of Audiology, 44(9), 522-530

Appendix A

Hong, O., Lusk, S. L., Raymond, D. M., & Decker, J. (2002). *Voices from construction workers: Finding of focus group regarding use of hearing protection*. Proceedings of 12th Annual Construction Safety and Health Conference: Power through partnerships 155-159.

12th Annual Construction Safety & Health Conference
Power Through Partnerships

Material for the Conference Proceeding

Title of paper:
Voices from Construction Workers: Findings of Focus Group Regarding Use of Hearing Protection

Session Date: 05/21/2002
Session Time: 2:00-4:30

Presenters:
Oi Saeng Hong, PhD
Sally Lusk, PhD
Delbert Raymond, MSN
Jamie Decker, BSN

University of Michigan
School of Nursing

Voices from Construction Workers: Findings of Focus Group
Regarding Use of Hearing Protection

Background

Noise is one of the most important occupational health hazards in the construction industry because of heavy machinery and equipment, noise-producing tools, and transport vehicles (Legris, & Poulin, 1998). As a group, construction workers have the highest rates of work-related injury and illness in the U.S. (U.S. Bureau of the Census, 1995). Among these injuries, noise-induced hearing loss (NIHL) is the most common occupational hazard by construction workers (The Center to Protect Workers Rights, 1998).

While it is preferable to reduce hazardous noise exposure through engineering controls, it is often impractical, costly, or scientifically impossible to eliminate all harmful noise. Because this condition can be prevented by consistent use of hearing protection devices (HPDs) (Sataloff & Sataloff, 1993), protective action by individual workers is necessary.

However, workers do not consistently wear HPDs. Studies with groups of construction workers found that the use of HPDs ranged from 18% to 62% of the time they were supposed to use them (Lusk, Hong, Ronis et al., 1999). In particular, for operating engineers (OEs) who operate heavy equipment, a major source of noise in construction sites, the use of HPDs ranged from 49% to 62% of the time they were in high noise. This rate is far less than the 100% use needed to prevent NIHL (Dear, 1998). In addition, OEs reported greater noise exposure and more hearing loss than workers in other trades such as carpenters and plumber/pipefitters.

In recently completed research funded by NIOSH, researchers tested the effectiveness of a group intervention with construction workers. This classroom-format intervention significantly increased use of HPDs in certain trades but it did not result in significantly increased use of HPDs by OEs (Lusk et al., 1999). Based on these characteristics of OEs, such as exposure to loud and constant machine-generated noise, inadequate use of HPDs, high rate of perceived noise exposure and hearing loss, and a serious lack of information on prevalence of NIHL coupled with a non-significant effect of a class-format group intervention, OEs are targeted for this study.

Method

Focus group interviews were used to obtain qualitative data OEs' perceptions and opinions on the problem of NIHL, such as perceived risks, barriers to use, hearing protection strategy, and motivating factors, which contribute to their use of HPDs.

Twenty-four subjects for two focus groups were recruited from OEs coming to the Operating Engineers Local 324 Training Center for their skill-upgrading course, located in Howell, Michigan.

Findings

A) Benefits: Why do construction workers wear HPD's?

1. They know that the protection can prevent hearing loss.
2. Some workers work in higher noise jobs than others and need to use the protection more.
3. Their company or manager requires them to use it.
4. It can reduce stress on the job.
5. It shuts out the noises that workers do not want to hear.
6. It can shut out the sound of their boss.

B) Barriers: Why do construction workers NOT wear HPD's?

1. The protection is too bulky and uncomfortable to wear (specifically the earmuffs).
2. Hearing protection interfered with job performance; they cannot hear sounds that they need to hear like a coworker's voice or warning signals or sounds of the machines they worked on.
3. When working on jobs with a lot of dirt, the hearing protection can get dirty and workers do not want to stick them back in their ear.
4. The hearing protection is not available to the workers.
5. Sometimes workers go in and out of loud areas and do not want to keep putting the protection in.
6. Hearing protection was uncomfortable to wear or even caused them physical pain.
7. Sometimes workers just leave them hanging around their neck and forget about them.

C) Suggestions for better hearing protection training programs

1. Almost all of the workers strongly suggested that a hearing test should be added to the hearing protection training. The workers pointed to the fact that many workers either deny that they can loose hearing or don't know that their hearing is being affected by the working environment that they are in. A hearing test could help the workers see how much they have lost and can be a motivating factor for wearing the hearing protection.

2. Most of the workers also had a problem with the hearing protection blocking out wanted sound. In some instances this was discussed

as dangerous to the worker's health. Worker wanted to know more about hearing protection devices that could discriminate between beneficial sound (coworkers and warning sounds) and harmful sound (the loud noises of the machines).

3. Workers agreed that more could be done by the companies they worked for to get workers to wear the protection and to make more protection available to them.

4. Wearing the protection needs to be emphasized more by either making it mandatory or just taking extra measures to reinforce the behavior (incentives or putting up warnings about noise, etc.). By doing these things, the workers feel that a better working environment can be created, and that workers can feel safe about the quality of their hearing for years to come.

Then What?

Identified barriers to and benefits of HPD use and workers' suggestions for effective hearing protection training were used to develop content of the computerized tailored intervention and hearing test for OEs. Currently this multimedia interactive, self-screening hearing test and hearing protection training is being implemented at the OE Local 324 Training Center.

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Appendix B

Hong, O., Ronis, D. L., Lusk, S. L, & Kee, K. S. (in press). Efficacy of a computer-based hearing test and tailored intervention to prevent hearing loss. *International Journal of Behavioral Medicine*, in press

Date: Wed, 2 Nov 2005 21:22:46 -0500 (EST)
From: Oisaeng Hong <oshong@umich.edu>
To: Ulf Lundberg <ul@psychology.su.se>
Cc: cmr@psychmax.psychology.su.se
Subject: Re: Manuscript 47-05: Revised version

Dear Professor Lundberg,

My coauthors and I are excited to hear about your acceptance of the above paper for publication in IJBM.

Yes, we'll revise it once more based on the suggestions indicated below.
Look forward to further instructions from Dr. Christin Mellner.

OiSaeng Hong.

On Tue, 1 Nov 2005, Ulf Lundberg wrote:

> Dear Dr. Hong,
>
> I am pleased to inform you that your manuscript #47-05 (Hong et al.),
> entitled "Efficacy of a Computer-based Hearing Test and Tailored Hearing
> Protection Intervention", which was submitted to the International Journal
> of Behavioral Medicine (IJBM), has now been accepted for publication with
> some minor revision. One of the reviewers has the following suggestions in
> order to further improve your paper:

Note: Accepted for publication in Journal of International Behavioral medicine on 11/1/05

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

OiSaeng Hong, PhD, RN, Assistant Professor

University of Michigan, School of Nursing

David L. Ronis, PhD, MA, Associate Research Scientist

University of Michigan, School of Nursing &

U.S. Department of Veterans Affairs

Sally L. Lusk, PhD, RN, FAAN, Professor Emerita

& Gwang-Soog Kee, MA, Research Associate

University of Michigan, School of Nursing

Ann Arbor, MI

U.S.A.

Running Head: Efficacy of hearing protection intervention

All communication and reprint request to:

OiSaeng Hong, PhD, RN
Director of Occupational Health Nursing Program
School of Nursing, University of Michigan
400 N. Ingalls, Room 3182
Ann Arbor, Michigan 48109-0482
U. S. A.
Phone: 734-763-3450
Fax: 734-647-0351
E-mail oshong@umich.edu

Abstract

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 worker's 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 one year after the intervention, both tailored and control groups showed significant increase in their reported use (7% vs. 6%) from pre-intervention to post-intervention 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 changing workers' hearing protection behavior is difficult.

Keywords: Tailored intervention, Computer-based, Hearing protection, Construction worker

Introduction

Occupational noise-induced hearing loss (NIHL) is hearing loss that develops slowly over several years as a result of exposure to loud noise (American College of Occupational and Environmental Medicine [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 to eliminate all harmful noise. Because NIHL can be prevented by consistent use of hearing protection devices (HPDs) with proper fit (National Institute for Occupational Safety and Health [NIOSH], 1996; Sataloff & Sataloff, 1993), protective action by workers is necessary. In a study of airport workers exposed to high noise (≥85dBA 8 hour 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 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 work force, 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, et, al., 1998; Lusk, Hong, Ronis, Eakin, Kerr, & Early, 1999). According to 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 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, Tessaro, DeVellis, Benedict, Kelsey, Belton, & Sanhueza, 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 non-tailored 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, et al., 2005; Kerr et al., 2002; Ronis, Hong, & Lusk, in press). 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, years worked in construction 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, et al., 1999; Ronis, et al., in press). A detailed description of questionnaire items has been reported in 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., in press). Reliability coefficients for all scales, with the number of items, range of scales (e.g., 1-6), for the current sample are presented in Table 1.

METHODS

Study Design

To test the effectiveness of the intervention, this study used an experimental pre-test-post-test 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: 1) *intention of HPD use in the future*; and 2) *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

twelve months and the most recent) and measured at pre-intervention and at 12-month post-intervention. 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 correlation ($r=.89$, $p<.01$) between workers' self-report 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 U. S. Approximately 900-1000 Operating Engineers from the entire state coming to the Training Center for the 8-hour Hazardous Material (HAZMAT) refresher course, were invited to participate in the study. An estimated 70 trainees attending a three-year apprenticeship program were also included in the study. Because the same individuals attended 8-hour HAZMAT refresher annually to meet federal requirement, post-intervention evaluation was obtained with the same subjects one year later during the HAZMAT course. Trainees in the apprenticeship program could also participate in the post-intervention assessment because they returned a year later for the initial HAZMAT courses.

Interventions

Tailored Intervention

The content of tailored intervention was developed based upon 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 ea plugs 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 <u>strongly disagree</u> or <u>moderately disagree</u> 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 seconds 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 Occupational Safety and Health Administration 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, Ronis, et al., 2003).

Data collection Procedure

All trainees in 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 every day 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 minutes and 33 minutes in the booths, respectively. Both groups spent the same amount of time for the introduction (6 minutes), hearing test (6 minutes) and the survey (9 minutes). Length of the training for the tailored and control groups were 22 minutes and 12 minutes, 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) mailed to their homes in early May (one to four months following the original intervention) 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 one 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 post-intervention 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 post-intervention. 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 post-intervention 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, pre-intervention 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 pre-intervention and the post-intervention survey were included in the analysis. A summary of the demographic characteristics of the participants at pre-intervention in Year 1 is presented in Table 3. Participants were predominantly middle-aged (mean age= 43years) male (91%) and white (91%). The majority (94%) of them had at least a high school education. They reported high noise exposures (7 hrs/day) and their use of HPDs was low (50% of the time needed). Over 70% of the participants showed hearing loss in at the 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 pre-intervention 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 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 vs. 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 one year after the intervention. Change in reported *mean use of HPDs* between pre-intervention and post-intervention 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 pre-intervention and post-intervention 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 changes from pre-intervention to post-intervention 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 pre-intervention to post-intervention differed by the type of intervention. The test of the intervention type by time (pre-intervention and post-intervention) 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 relationship 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 pre-intervention intention of use (.87, p=<.001) were significant factors to increase Year 1 post-intervention intention of use, which subsequently affected HPD use (.53, p=<.001) in Year 2.

Discussion

Two hypotheses were tested in this study: 1) immediately after the intervention, the tailored intervention group would report a higher intention of HPD use in the future than the control group; and 2) one 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 subject could obtain personalized feedback following the training session from the staff present, just by asking questions.

While both interventions significantly increased HPD use one 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 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, Ronis, 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. Since at pre-intervention 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 less than 45 minutes, 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 one-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 an hour) once a year. Ideally, short ongoing motivational messages should be provided to

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Table 1. PUHPM components and scales (N=403)

Model components	Instrument	# of items[a]	Range	Mean	Alpha
<u>Modifying Factors</u>					
Demographic/ Experiential/ Biologic Factors	Age	1	20-67	43	n/a
	Gender (91% male)	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 to 95	38	n/a
Interpersonal Influences	Soc. Mods + Int. Support	5[b]	1 to 3	2	n/a[c]
Situational factors	Availability of HPDs	3	1 to 6	4	.71
	Worksite Climate	6	1 to 6	4	.86
<u>Cognitive-Perceptual Factors</u>					
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
<u>Dependent Variable</u>					
Health-related behavior	Intention of HPD use	1[d]	0-100%	71	n/a
	Use of HPDs	2[d]	0-100%	50	.95

[a] All items, except where noted, use a 6-point Likert response scale.
[b] Items measured with 3-point scale (1=never, 2=sometimes, 3=often).
[c] Formative scale
[d] Measured by percentage (0-100%) of the time.

Table 2. Study design

		TIME 1 Jan-Apr, 2002			TIME 2 Jan-Apr, 2003		
R	Experimental Group	O	Xt	M_I	O	X*	M_I
R	Control Group	O	Xc	M_I	O	X*	M_I

R = Random assignment
Xt = Tailored intervention   Xc = Control intervention
O = Hearing test + Data collection via computerized survey
M_I = Measure of intention immediately after intervention
* 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.

Table 3. Characteristics of study participants (N=403)

	Total (N=403)	Tailored (n=221)	Control (n=182)	
Variable	*Mean (SD)*[a]	*Mean (SD)*	*Mean (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
Pre-training use of HPDs(%)[b]	50 (34)	50 (34)	50(34	F(1, 401)=.01, p=.93
Pre-training intention of use (%)[b]	71(26)	71 (28)	72 (25)	F(1, 401)=.25, p=.62
Variable	*Frequency (%)*	*Frequency (%)*	*Frequency (%)*	*Chi-square p- value*
Gender (Male)	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)[c]	269 (71)	141 (68)	128 (76)	Chi^2 (1)=2.88, p=.09

[a] Standard Deviation, [b] Measured as percentage of time (0-100%)

[c] 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)

	Intervention Group	Before training Mean (SD)	Right after training Mean (SD)	Mean Change (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	Degree of freedom	F statistic	P-value
Year 1	Time [a]	1, 382	56.06	.001
	Training type [b]	1, 382	.12	.730
	Time x 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 x Training type	1, 387	12.43	.001

[a] Pre-intervention and post-intervention

[b] Tailored and control interventions

Figure 1. Predictors of Use of Hearing Protection Model

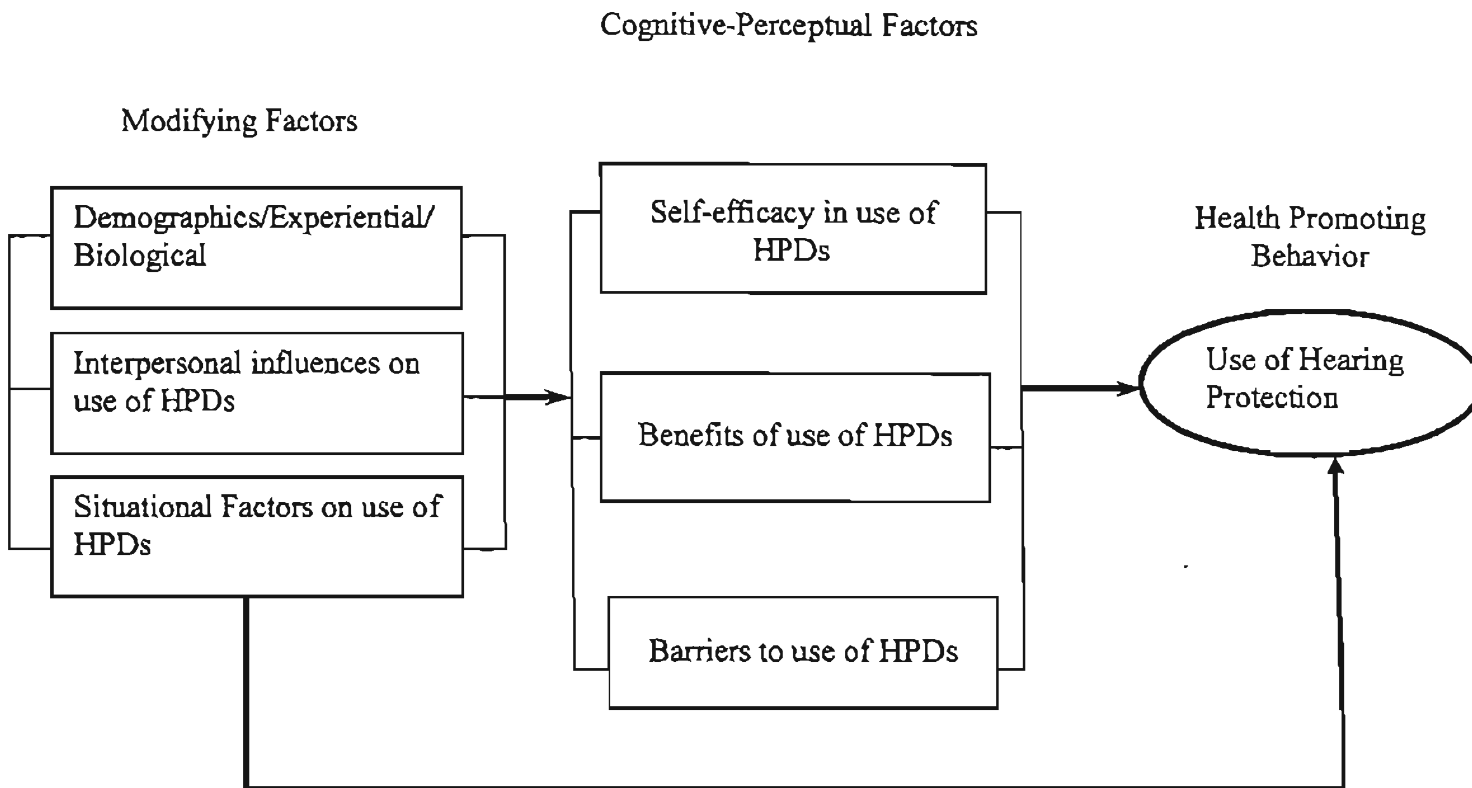
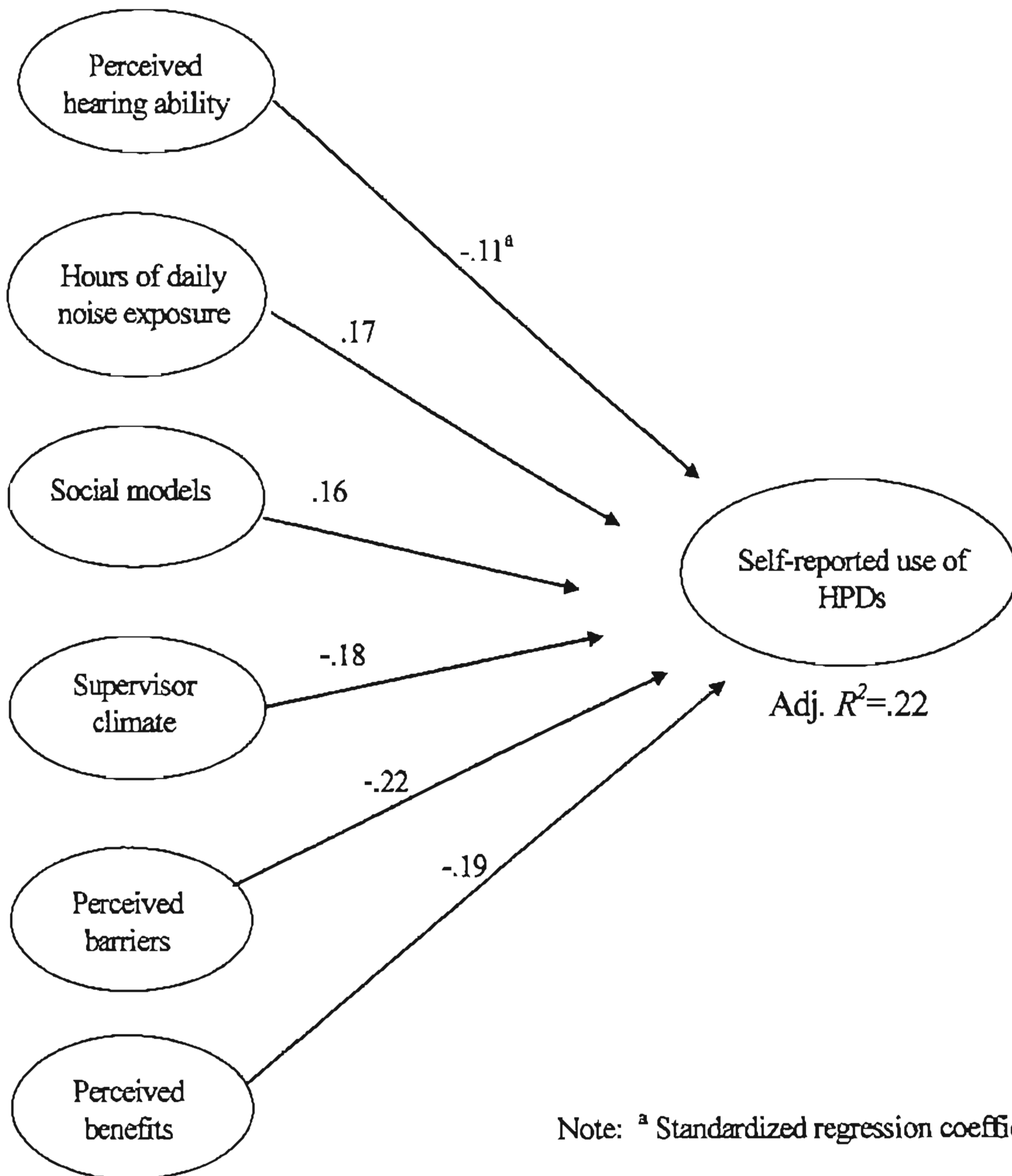


Figure 2. Significant Predictors of Hearing Protection



Note: [a] Standardized regression coefficients

Figure 3. Sequence of Computer-based Self-administered Hearing Tests and Interventions

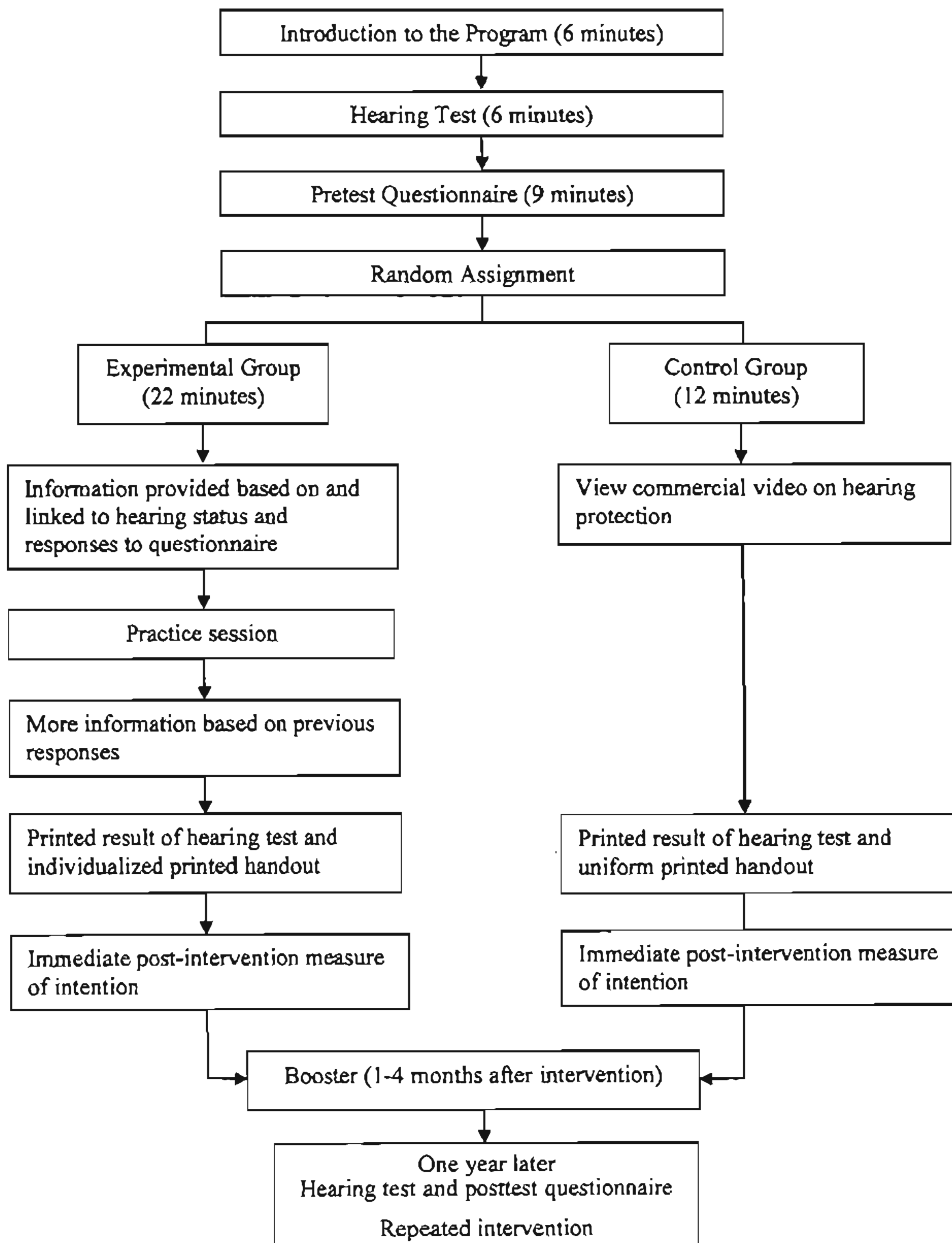
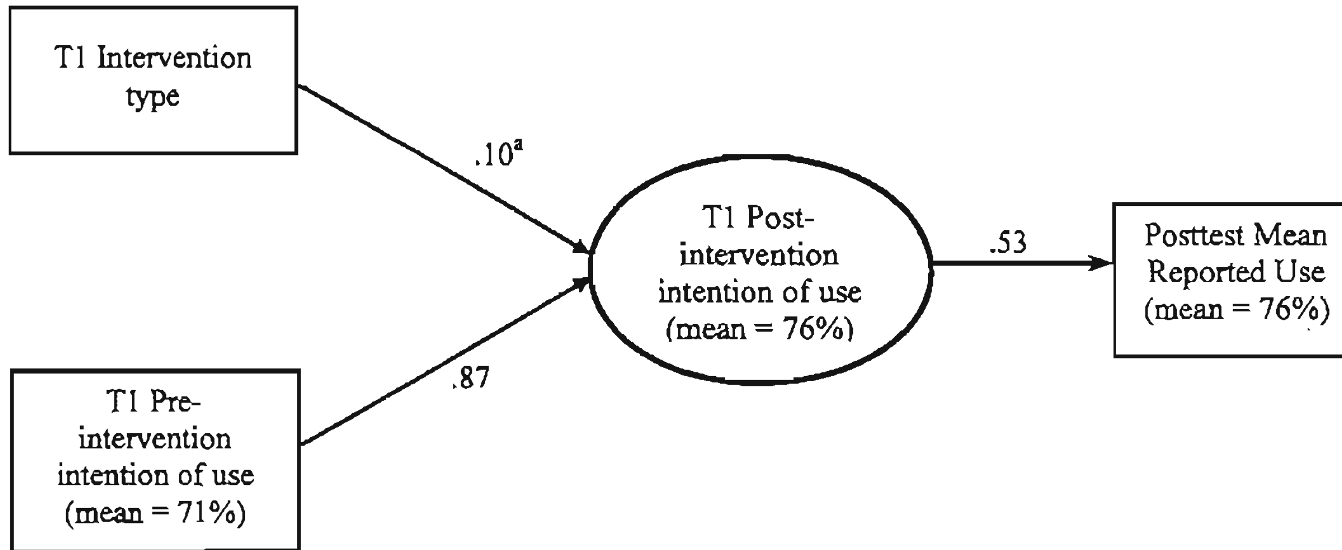


Figure 4. Path Model for Intervention Effect on Posttest Mean Reported Use through Changes in Intention



Note: [a] Path coefficients

Appendix C

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ORIGINAL ARTICLE

OiSaeng Hong

Hearing loss among operating engineers in American construction industry

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Abstract *Objective*: Occupational noise exposure and noise-induced hearing loss (NIHL) among construction workers has long been recognized as a problem in the United States, yet little is known about the prevalence of NIHL among American construction workers. The purpose of this study was to determine the prevalence and characteristics of hearing loss among operating engineers (OEs) who operate heavy construction machinery. *Method*: As a part of hearing protection intervention, an audiometric test was conducted for both ears at frequencies 0.5 through 8 kHz in the soundproof booth. Prior to the audiometric test, a paper-pencil pre-hearing test questionnaire was administered and an otoscopic examination was completed. Prevalence of hearing loss was determined based on hearing threshold levels (HTLs) in the worst ear with a low fence of 25 dB. *Result*: A total of 623 workers were included in the analysis and they were predominantly middle-aged Caucasian males (mean age = 43 years, Caucasian = 90%, male = 92%). Over 60% of OEs showed hearing loss in the noise-sensitive higher frequencies of 4 and 6 kHz. The rate of hearing loss was particularly higher among workers who reported longer years of working in the construction industry. Workers showed significantly poorer hearing in the left ear, and a typical characteristic of NIHL, a V-notch at 4 or 6 kHz, was not shown in this population. Thirty-eight percent reported ringing/buzzing in the ear and 62% indicated having problems in understanding what people say in loud noise. Average reported use of hearing protection devices (HPDs) was 48% of the time they were required to be used. Significant inverse relationship was found between higher frequency (4–6 kHz) hearing loss and use of HPDs ($r = -0.134$, $p < 0.001$). Workers using HPDs more had significantly better hearing than those who did not. *Conclusion*: The study demonstrated a significant NIHL problem and low use of HPDs in OEs. An effective hearing conservation program, including a periodic audiometric testing and hearing protection intervention, for this study population should be in place.

Keywords Noise · Hearing loss · Construction workers · Hearing protection · Prevalence

O. Hong
Health Promotion & Risk Reduction Program,
School of Nursing, University of Michigan, 400 N. Ingalls,
Room 3182, Ann Arbor, MI 48109-0482, USA
E-mail: oshong@umich.edu
Tel.: +1-734-763-3450
Fax: +1-734-647-0351

Introduction

Noise-induced hearing loss (NIHL) is a major occupational health hazard and is the second most reported occupational disease and injury in the USA (National Institute for Occupational Safety and Health [NIOSH] 1996a). It is an irreversible sensorineural hearing impairment caused by prolonged exposure to noise. NIHL causes communication interference that can substantially affect social integration, self-image, and the quality of life (National Institutes of Health [NIH] 1990). NIHL ranks among the most significant occupational health problems in many countries (Chen and Tsai 2003; Hessel 2000; Hong et al. 1998a; Kahan and Ross 1994; McBride et al. 2003; NIOSH 1996a). More than 30 million (one out of ten) American workers are exposed to loud noise that could result in hearing loss (NIOSH 1996a).

NIHL is one of most prevalent occupational health problems among construction workers. In particular, operating engineers (OEs) who operate heavy construction equipment are more exposed to hazardous noise than workers in other construction trade. Despite the risks of high noise exposure (Legris and Poulin 1998) and high degree of perceived hearing loss reported by OEs (Lusk et al. 1999), there are no published data on prevalence of NIHL in OEs in the USA. The purpose of this paper is to present the prevalence and characteristics of NIHL in OEs.

Background

Noise exposure in construction workers

Noise is one of the most important occupational health hazards in the construction industry because of heavy machinery and equipment, transport vehicles, and noise-producing tools operating at 90 130 dBA (Legris and Poulin 1998; McClymount and Simpson 1989). An estimated 6–7.6 million (US Bureau of Census 1992; US Department of Labor 1993) American workers are employed in the construction industry. More than half a million American construction workers are exposed to potentially hazardous levels of noise (Hattis 1998; Suter 2002). As a group, construction workers have the highest rates of work-related injury and illness in the USA (US Bureau of the Census 1995). Among these injuries, NIHL is the most common occupational hazard faced by these workers (The Center to Protect Workers Rights 1998).

Construction workers are constantly exposed to variable amounts of noise from their own equipment and activities, as well as noise from the tools and activities of others working around them (Franks 1990; Hager 1998). Individual construction worker's noise exposure level depends on how much noise the equipment he/she operates is making, how close the worker is to the equipment, and how long he/she is exposed (Legris and Poulin 1998; Schneider and Susie 1993). Several studies have identified common noise sources and documented exposure levels on construction sites (Anon 1984; Hattis 1998; Kerr et al. 2002; Legris and Poulin 1998; McClymount and Simpson 1989; Schneider and Susie 1993; Sinclair and Haflidson 1995; Utley and Miller 1985). Sound level measurements of construction equipment and activities conducted by McClymount and Simpson (1989) revealed a wide range of noise levels, from 85 dBA of a hand saw to 122 dBA of hammers striking a nail head on a stud.

The Center to Protect Workers Rights reported some typical exposure levels associated with construction equipment as measured on a new construction site over a 15-month time period (Schneider and Susie 1993). According to this report, high noise exposure was common to all trades throughout the construction site. In general, the noise levels bordered on or exceeded the OSHA permissible exposure level of 90 dBA of an 8-h time-weighted average (TWA), such as pneumatic chipping hammer (103–113d BA), jack hammer (102–111 dBA), stud welder (101 dBA), concrete joint cutter (99–102 dBA), bulldozer (93–96 dBA), and earth tamper (90–96 dBA). Individual pieces of equipment varied considerably in sound levels by distance or function. For example, a Grade-all (an earth-moving truck) produced 94 dBA at a distance of 10 ft and 82 dBA at 75 ft; a crane produced 75–80 dB when idling and 90–96 dB while operating (Schneider and Susie 1993).

More recent data reported by Legris and Poulin (1998) particularly demonstrate that the target population for this study, OEs, is exposed to harmful noise. According to their report, all heavy equipment operators except backhoe operators are exposed to an average of over 85 dBA TWA during their shift. Bulldozer operators are exposed to 96–99 dBA (Legris and Poulin 1998). Vibrating road roller operators and wheel roaders are exposed to 97 and 94 dBA, respectively. Asphalt road roller and asphalt spreader operators are exposed to 95 and 91 dBA, respectively. Grader operators are exposed to 89 dBA. Operations on loose ground consisting of soil sand generated 88 dBA and crushed rock 90 dBA. Workers who operate backhoes and power shovels are exposed to 84 and 88 dBA, respectively. Although both have cabs that protect the workers from noise, on sunny days the large windows make the cab very hot unless it is air-conditioned. The operators are likely to open the cab door to expel hot air, thereby reducing the sound-proofing. Although each worker generally has a favorite type of machine to operate, OEs tend to be masters of a variety of equipment. Workers who operate multiple pieces of equipment on a given shift are exposed to noise levels of 95 dBA or greater. Others also measured noise levels for heavy equipment operators and reported 88–93 dBA for crane operators (Kerr et al. 2002) and 105 dBA for bulldozer operators (Sinclair and Haflidson 1995).

Using a different approach to measure noise exposure, Lusk et al. (1999) asked construction workers (n = 837) about their perception of exposure to high noise, defined as a noise level causing them to shout to be heard by a co-worker three feet or less away from them. The majority of workers (plumber/pipefitters, 70%; carpenters, 78%; OEs, 85%; and national plumber/pipefitter trainers, 69%) reported that they were exposed to high noise on their recent job sites. Both noise monitoring data on the various types of noise exposures encountered in construction and the self-reported worker's perception on noise exposure demonstrate that construction workers, particularly OEs, are working in the presence of hazardous noise. Hence, for the purpose of saving time and costs, the present study did not repeat noise measurement for construction equipment and construction sites. Instead, this study focused on determining prevalence and characteristics of hearing loss among OEs who work in the presence of hazardous noise.

Prevalence of NIHL in construction work

Most construction workers lose some or a significantly large amount of their hearing after years at the trade (Schneider et al. 1995). A 1975 study of hearing in sheet metal workers in the USA revealed a high prevalence of hearing loss among workers ages 40 and older (Kenney and Ayer 1975). Based on their hearing loss index (25 dB of average loss in both ears at 1, 2, and 3 kHz), 75% of

workers in their 40s and 100% between the ages of 50 and 60 years had hearing loss. Using audiometric data from both the Health Examination Survey (1960–1962) and the National Health and Nutrition Examination Survey (1971–1975), Norman and Smith (1998) reported that construction trade workers uniformly exhibited the greatest risk of NIHL across all audiometric measures, with manufacturing and mining workers experiencing the next highest risk. Blue-collar construction workers were more than three times as likely to suffer hearing loss as white-collar workers in certain industries outside of construction. While many health professionals in the construction industry suspect there is a high degree of hearing loss among OEs, currently there are no published reports as to the extent of hearing loss in this population. This serious lack of information provided an indication of the need for this study with the purpose of determining the prevalence and nature of hearing loss in OEs.

More comprehensive studies on NIHL in construction workers have been undertaken in other countries such as Germany (Arndt et al. 1996), Sweden (Schneider et al. 1995), and Canada (Roberts 1985, 1989). All these studies found a significantly high rate of NIHL among construction workers. A German study of older construction workers reported a prevalence ratio of hearing loss of 1.5 (95% confidence level = 1.29–1.82) for construction workers compared to white-collar workers (Arndt et al. 1996). A Swedish study with over 100,000 construction workers reported that 50% of sheet metal workers ages 35–39 years and 90% of workers ages 55–59 years had hearing loss exceeding 30 dB at 4 kHz in the left ear (Schneider et al. 1995). A Canadian study of 5,000 construction workers by the Workers' Compensation Board in British Columbia showed that 49% had NIHL (Roberts 1985). Another Canadian study of construction workers in 1989 who received audiometric tests ($n = 32{,}800$) revealed 50% of these workers had significant hearing loss, with 22% classified as severe to profound (Roberts 1989). Based on this review, this study conservatively hypothesized that at least 40% of OEs would show hearing loss at higher frequencies of 4 and 6 kHz.

Method

Study site and participants

The present study was conducted at the Training Center for the Local 324 of the International Union of OEs in a Midwestern state in the USA. The representatives of the Training Center were very interested in cooperating with the research team to conduct the study because: (1) they were well aware of the fact that OEs were exposed to numerous sources of noise in the construction sites in addition to the noise generated by the equipment they operated; and (2) annual audiometric test and training on use of HPDs were not legally required for construction workers and, thus, the majority of OEs had not been given these essential services for preventing NIHL.

Study participants were OEs in a Midwestern state, who were coming to the Training Center of the International Union of OEs for a 3-year apprentice certification course or the 8-h Hazardous Material (HAZMAT) refresher course. OEs operate heavy equipment such as bulldozers, graders, backhoes, asphalt road rollers, asphalt spreaders, and wheel loaders. The noise level for most of this heavy equipment is above 85 dBA. All OEs who came to the Training Center were invited to participate in the study and participation was voluntary.

Data collection procedure

Data were collected using a paper-pencil pre-hearing test questionnaire and an audiological assessment, including otoscopic examination and self-administered audiometric screening testing (SAAST), from January 2002 to April 2003. Prior to the audiometric test, an otoscopic examination of the aural and ear drum was performed by trained registered nurses to determine the presence of visible abnormalities, such perforated ear drums, signs or symptoms of ear disease, and excessive ear wax in the ear canals, which may affect the audiometric test or indicate the need for medical attention. Computer-based SAAST was part of a multi-media interactive hearing protection intervention implemented to prevent NIHL among OEs.

The SAAST was conducted for both ears at frequencies 0.5, 1, 2, 3, 4, 6, and 8 kHz, using a microprocessor pure-tone audiometer. The audiometer was calibrated according to the American National Standards Institute (ANSI) S3.6-1969 standard (ANSI 1969). The SAAST was conducted in the double-walled audiometric booth that conformed to the ANSI criteria for ambient noise in audiometric rooms (ANSI 1977).

A hearing threshold level (HTL) was defined as the lowest single intensity that the participant detected at least 50% of the time, with a minimum of three trials. HTLs were recorded in 5-dB increments. HTLs were obtained between 0 and 95 dB and a HTL of 95 dB was recorded if the participant did not respond to the limits of the test protocol. To minimize contamination of hearing loss by temporary threshold shift, workers were instructed to have a period of at least 14 quiet hours without noise exposure or to wear the HPDs at least on the day of the audiometric test.

Data analysis

For estimates of the prevalence of hearing loss, the following were applied. First, prevalence of hearing loss was estimated without any age adjustment to measure the real hearing status of construction workers, as rec-

Table 1 Demographic characteristics of study participants ($N=623$)

Variable	Mean (SD)
Age (years)	42.96 (9.98)
Years in construction	18.14 (10.93)
Hours of noise exposure/day	6.54 (3.21)
Use of HPDs (% of the time)	48.27 (32.02)
Variable	**Frequency (%)**
Education level (High school or above)	581 (93.4)
Ethnicity	
Caucasian/White	556 (89.8)
African American/Black	32 (5.2)
Native American/American Indian	13 (2.1)
Others	11 (1.9)
Gender (male)	566 (91.6)
Recreational hunting (yes)	399 (63.8)
Perception of hearing	
Excellent	28 (4.5)
Very good	110 (17.8)
Good	266 (43.0)
Fair	164 (26.5)
Poor	51 (8.2)
Problem understanding what people say (yes)	384 (62.3)
Ringing and buzzing in ears (yes)	224 (37.8)
Types of equipment used	
Loader	436 (70.0)
Backhoe	402 (64.5)
Bulldozer	396 (63.7)
Excavator	369 (59.2)
Forklift	322 (51.8)
Roller	278 (44.6)
End dump	265 (42.5)
Bobcat	257 (41.3)
Crane	206 (33.1)
Tractor	203 (32.6)
Scraper	190 (30.5)
Boom truck	166 (26.6)

ommended by the NIOSH Criteria Document (NIOSH 1996b). Second, HTL of 25 dB was used as the low fence. Third, HTL measurements in the worst ear were used to measure the true extent of hearing loss if there is unequal hearing loss in the two ears. Fourth, rate of asymmetric hearing loss was calculated using the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS)'s definition. According to the AAO-HNS (1997), asymmetric hearing loss is defined as HTL difference of greater than 15 dB at 0.5, 1, or 2 kHz or 30 dB at 3, 4, or 6 kHz between two ears. Fifth, prevalence of hearing loss was determined at each of the test frequencies (0.5–8 kHz) and pure-tone threshold average (PTA) at 0.5, 1, 2, and 3 kHz (PTA[0.5, 1, 2, and 3]) and 4 and 6 kHz (PTA[4, 6]). The prevalence of hearing loss at PTA(0.5, 1, 2, and 3) was determined using the American Academy of Otolaryngology (AAO)-79 Method, the most popular method for calculating material impairment of hearing to assess the risk of NIHL (AAO, 1979). The study was interested in prevalence of hearing loss at PTA(0.5, 1, 2, and 3) because understanding speech is the most critical function of human hearing. The study was particularly interested in workers' hearing status at PTA(4, 6) because NIHL affects these higher frequencies earlier and more severely than the lower frequencies.

Lastly, the extent of hearing loss was then assessed using the grading system proposed by the World Health Organization (WHO, 1986): less than 25 dB (normal), 25–40 dB (slight), 41–60 dB (moderate), 61–80 dB (severe), and above 80 dB (extreme).

Results

Characteristics of the participants

A total of 772 workers completed SAAST, but 149 who reported noise exposure within 14 h before the hearing test were excluded from the analysis. Although we invited all OEs registered for HAZMAT training, participation was voluntary and about 5% of them did not participate in the study. It would be important to compare basic demographics between participants and nonparticipants to see any significant differences but it was not feasible because the registration list for HAZMAT training did not include individual OEs' demographic information other than their names and union identification numbers.

Demographic characteristics and selected variables of the study participants are summarized in Table 1. The participants were predominantly middle-aged (mean = 43years), and had worked in construction for an extended period of time (mean = 18.1 years, standard deviation = 10.9). The study also asked workers about how many hours they were exposed to high noise, defined as a noise level causing them to shout to be heard by a co-worker three feet or less away from them. Workers reported a mean noise exposure of about 7 h per day on their jobsite. Although they should use HPDs all the time when in high noise, they reported using HPDs less than 50% of the time that was required. Participants were at least high school educated (93%), Caucasian (90%), and male (92%). The majority of them (64%) reported hunting as a recreational activity.

More than 65% of participants perceived their hearing was good. Regarding hearing-related symptoms, about 38% indicated they had ringing or buzzing in their ears, and over 60% reported a problem understanding what people say in noisy environments. As shown in Table 1, workers operated a variety of heavy equipment. Common types of construction equipment OEs operated included loader (70.0%), backhoe (64.5%), bulldozer (63.7%), excavator (59.2%), and forklift (51.8%). A majority of the participants (77%) reported that they operated more than two types of equipment.

Table 2 Mean, standard deviation (SD) of HTLs, and prevalence of hearing loss at all test frequencies ($N = 623$)

HTLs (dB)		Test frequency (Hz)						
		500	1000	2000	3000	4000	6000	8000
Mean (SD)	Left ear	11.29 (8.46)	12.02 (9.58)	12.56 (14.91)	23.69 (20.72)	29.84 (22.35)	30.00 (21.46)	29.97 (23.55)
	Right ear	10.98 (7.89)	12.67 (8.74)	11.41 (13.17)	20.66 (19.32)	26.76 (21.40)	26.81 (20.13)	28.20 (21.80)
Mean difference between two ears		0.33^{NS}	-0.66^{*}	1.09^{*}	3.05^{**}	3.26^{**}	3.13^{**}	1.81^{*}
Mean (SD)	Worst ear	13.12 (9.09)	14.50 (10.09)	15.07 (15.74)	27.04 (20.99)	33.80 (22.55)	34.11 (21.23)	34.94 (23.31)
Frequency (%) of hearing loss[a]		54 (8.7)	80 (12.8)	121 (19.4)	289 (46.4)	369 (59.2)	387 (62.1)	386 (62.0)

Note: NS non-significant; $^{*}p < 0.05$, $^{**}p < 0.001$.
[a] Hearing loss was calculated based on HTLs in the worst ear between left and right ears.

Approximately 60% of workers indicated that they operated several (> 5) different machines.

Prevalence of hearing loss

Hearing loss at single frequencies

The means and standard deviations of HTLs for both ears and the worst ear at all test frequencies are presented in Table 2, along with mean difference between the left and right ears. There was a statistically significant difference in the mean HTLs between the left and the right ears at all test frequencies but 0.5 kHz. The left ear showed significantly poorer hearing at frequencies of 2–8 kHz and had slightly better hearing at 1 kHz than the right ear ($p < 0.05$). As shown in Table 2, the differences of the mean HTLs between the two ears are clearly bigger in higher frequencies (3–8 kHz), most notably at 3, 4, and 6 kHz, than in lower frequencies (0.5–2 kHz). Mean differences between the left and the right ears for frequencies lower than 2 kHz were smaller than 1.1 dB and up to about 3.3 dB, the largest HTLs differences at 4 kHz. In both ears, 6 kHz had the greatest mean HTL, compared with the other tested frequencies. However, differences among mean HTLs at 4, 6, and 8 kHz are negligibly small. Based on the AAO-HNS (1997) definition of asymmetric hearing, the study found that about 19% of the workers (113/623) had asymmetric hearing.

Mean HTLs for both ears were within the range of normal hearing for test frequencies of 0.5–3 kHz, whereas average HTLs at higher frequencies of 4–8 kHz were between 27 and 30 dB. For the worst ear, mean HTLs at higher frequencies (above 3 kHz) showed above 25 dB.

Prevalence of hearing loss at single frequencies estimated based on the HTLs at the worst ear is also presented in Table 2. Prevalence of hearing loss dramatically increases at the higher frequencies (from

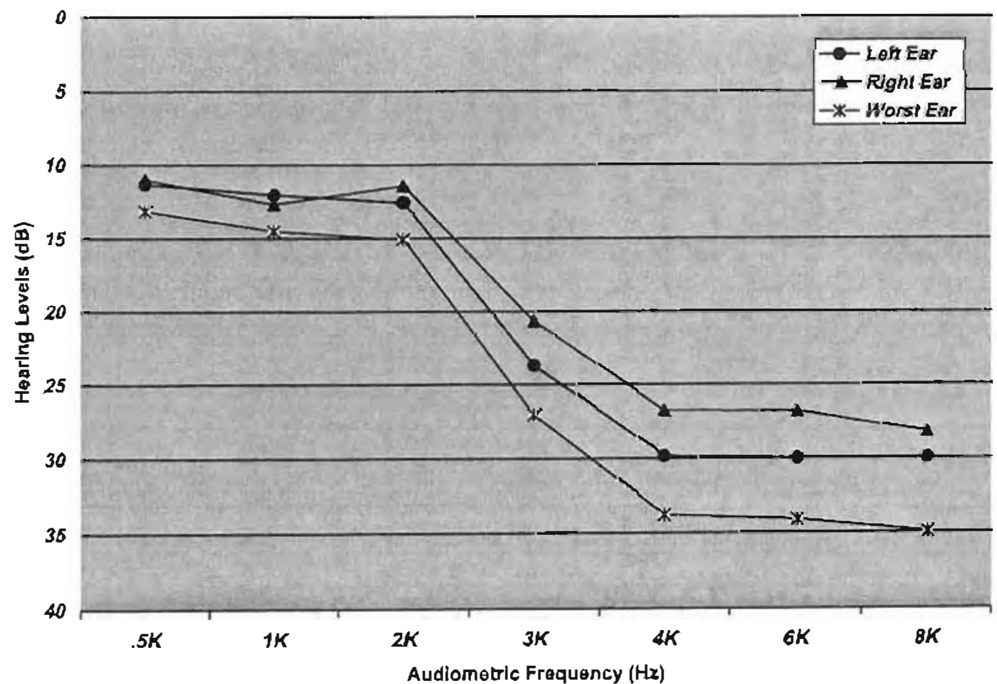

Fig. 1 Mean and standard deviation (*SD*) of HTLs at all test frequencies ($n = 623$)

Table 3 Distribution of hearing loss at PTA(0.5, 1, 2, and 3) and PTA(4, 6)

Extent of hearing loss	PTA(0.5, 1, 2, and 3)		PTA(4, 6)	
	n	%	*n*	%
Normal (<25 dB)	481	79.5	244	39.2
Mild (25–40 dB)	95	15.7	129	20.7
Moderate(41–60 dB)	22	3.6	134	21.5
Severe (61–80 dB)	7	1.2	80	12.8
Extreme (>80 dB)	–	–	16	2.6

3 kHz). As presented in Table 2, more than 45% of OEs showed hearing loss at 3 kHz. A vast majority (60% and above) of them showed hearing loss at 4–8 kHz.

Mean HTLs for the both ears and the worst ear are also depicted in Fig. 1. As seen in Fig. 1, mean HTLs steadily increase as frequency increases in both ears and the worst ear, dramatically increased at 3 kHz and flattened at 4, 6, and 8 kHz. The mean HTLs in the higher frequency range from 4 to 8 kHz increased up to 27–35 dB.

Hearing loss at PTA(0.5, 1, 2, and 3) and PTA(4, 6)

The means of HTLs at PTA(0.5, 1, 2, and 3) and PTA(4, 6) were 17.4 dB and 33.9 dB, respectively. As expected, a greater prevalence of hearing loss was shown at PTA(4, 6), most noise sensitive frequencies, than PTA(0.5, 1, 2, and 3). About 60% (359/623) of the workers had abnormal hearing at the PTA(4, 6) whereas 38.5% (233/623) workers showed hearing loss at PTA(0.5, 1, 2, and 3).

Distribution of extent of hearing loss at two indicators is presented in Table 3. As expected, severity of hearing loss increased at PTA(4, 6). About 37% showed moderate hearing loss (HTL > 40 dB) at PTA(4, 6), which was significantly higher than that at lower frequency hearing loss at PTA(0.5, 1, 2, and 3). The study also revealed that almost all OEs (99.6%) with lower frequency hearing loss at PTA(0.5, 1, 2, and 3) had higher frequency hearing loss at PTA(4, 6), whereas only

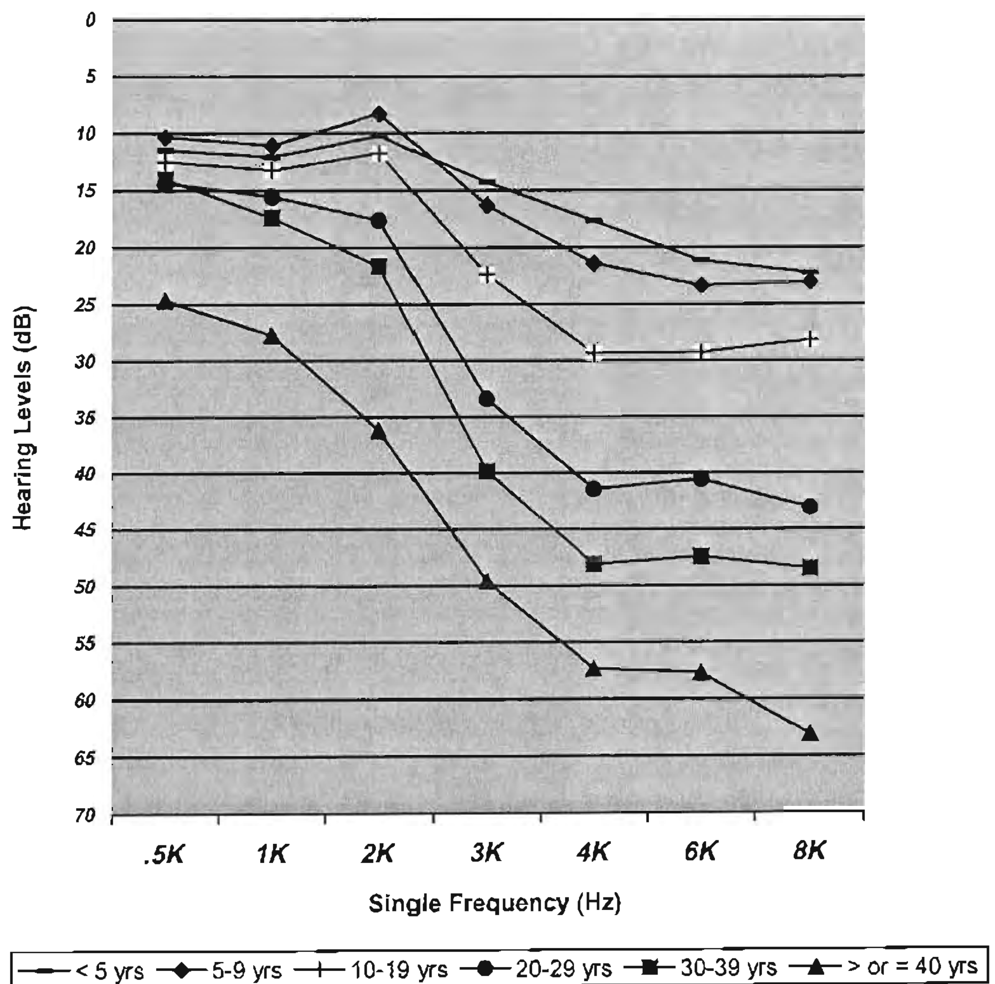

Fig. 2 Mean hearing levels at single frequency by years in construction (worst ear) (n = 623)

Table 4 Prevalence of hearing loss at PTA(0.5, 1, 2, and 3) and PTA(4, 6) by years in construction

Years in construction	Mean age (year)	Number of workers	Number of workers (%) with hearing loss at two indicators	
			PTA(0.5, 1, 2, and 3)	PTA(4, 6)
<5	34.51	92	7 (7.6)	28 (30.4)
5–9.9	34.31	61	6 (9.8)	16 (26.2)
10–19.9	39.03	169	21 (12.4)	86 (51.2)
20–29.9	46.29	140	38 (27.1)	105 (75.0)
30–39.9	53.85	116	43 (37.1)	103 (89.6)
≥40	60.80	13	6 (46.2)	13 (100.0)
Total	42.94	591	121 (20.5)	351 (59.6s)

34% of OEs with higher frequency hearing loss at PTA(4, 6) demonstrated hearing loss at PTA(0.5, 1, 2, and 3).

Hearing loss by working years in construction industry

In order to see the trends of hearing loss by years worked in construction, the HTLs at the single test frequency and three indicators were categorized into the following six construction year groups: less than 5 (n = 92), 5–9 (n = 61), 10–19 (n = 169), 20–29 (n = 140), 30–39 (n = 116), and 40 years and over (n = 13). The mean HTLs for these construction year groups are presented in Fig. 2. The breakdown by years worked in construction clearly demonstrates, as it may be expected, progressive hearing loss with years in construction.

As shown in Fig. 2, workers' hearing sensitivity begins to decline in the higher frequencies of 3–8k Hz even in the shorter construction year group (> 5 years). This decline continues as the construction year increases, as is demonstrated by higher HTLs among the workers with longer years in construction. A noise notch, a typical characteristic of NIHL, was not apparent for all construction year groupings. The pattern of hearing loss showed among workers who had worked in construction for longer than 20 years (mean age > 45 years) is very characteristic of sloping configuration from both noise and aging. The extent of hearing loss at two indicators is presented by years worked in construction in Table 4, along with mean ages of workers. The prevalence of hearing loss among workers with longer work history in construction industry is much higher than that in workers with shorter years in construction. As shown in Table 4, a vast majority of workers who had worked in construction for a longer period (over 20 years) showed hearing loss at noise sensitive frequencies (4–6 kHz): 75% of workers with 20–29 years; 89% of workers with 30–39 years; and 100% of workers with over 40 years in construction.

Use of HPDs and hearing loss

Use of HPDs was measured by two questions regarding the self-reported percentage of time (0–100%) HPDs were used at the most recent jobsite and in the past 12 months at work. Because of strong correlations between these measures ($r = 0.91, p < 0.01$), the averaged score of the two items was used to reflect workers' use of HPDs. On average, they used HPDs 48% of the time when they should have in high noise, which was far less than the 100% use needed to prevent NIHL (Dear 1998).

The study further investigated if workers' use of HPDs has an effect on their hearing loss at noise-sensitive higher frequencies (4–6 kHz). Bivariate correlation of HPD use with HTLs at PTA(4, 6) showed significant inverse association ($r = -0.134$, $p < 0.001$). Workers who used HPDs more frequently had significantly better hearing than those who did less frequently. The relationship between HPD use and hearing ability was further examined by comparing prevalence of hearing loss at PTA(4, 6) between the two (MORE, LESS) user groups. MORE user groups (n = 138) included workers who used HPDs almost all the time (≥80%) and LESS user groups (n = 450) were those who used HPDs less than 80% of the time they were required. Two users group did not show significant differences in their demographic characteristics such as age (42.2 vs 42.8 years) and years of working in construction (17.4 vs 18.1 years). Significant difference in prevalence of higher frequency hearing loss was identified between the MORE and LESS user groups ($p < 0.001$). Prevalence of hearing loss among the MORE user group was significantly lower than the LESS user group (47 vs 64%, $p < 0.01$).

Discussion

Findings of this study clearly demonstrated that OEs faced significant risk of hearing loss. The prevalence of hearing loss showed in OEs was far greater than anticipated. Based on the review of the earlier studies with construction workers, the present study conservatively hypothesized that about 40% of OEs would have hearing loss at higher frequencies (4 and 6 kHz). Surprisingly, the results of the present study uncovered that over 60% of OEs showed hearing loss at PTA(4, 6). It should be mentioned that actual prevalence could be slightly higher or lower than the reported 60% because the study did not have information on hearing status for

those who were invited but did not participate in the study. This may be a shortcoming of the study.

OEs, perhaps more than most other workers in construction trades, require long hours in close proximity to the noisy heavy equipment. Progressive damage to their hearing was noticed at higher frequencies above 3 kHz, and this risk for hearing loss was especially heightened among OEs with longer years of working in construction industry, presumably because longer years in construction means more years of noise exposure. Prevalence rates for both lower and higher frequencies accelerated as their tenure in construction increased. For example, compared to OEs with a short tenure in construction (< 5 years), OEs who worked in construction industry for over 40 years demonstrated strikingly higher prevalence of hearing loss for both lower (8 vs 46%) and for higher frequencies (30 vs 100%).

Assessing lower and higher frequencies separately takes into account the fact that NIHL preferentially affects the higher frequencies, with hearing loss beginning characteristically around 4 or 6 kHz before the deterioration of hearing loss at lower frequencies as the higher frequency loss progresses. This study confirmed the prevalence of hearing loss at 4 and 6 kHz, attributable to noise exposure, was far exceeded than hearing loss at lower frequencies critical to the ability to understand speech. These findings are consistent with earlier reports (Dobies 1995; Hong et al. 1998a; May 2000; NIH 1990; Orgler et al. 1987). The study also showed that almost all (99.6%) workers with hearing loss at PTA(0.5, 1, 2, and 3) showed hearing loss at PTA(4, 6) as well, whereas only 34% of workers with hearing loss at PTA(4, 6) had hearing loss at PTA(0.5, 1, 2, and 3). Therefore, hearing loss at the higher frequency may be used as an indication of susceptibility to effects of noise and the likelihood of progression of loss to lower frequencies.

A large proportion (62%) of OEs in this study reported difficulty in understanding people's conversation in noisy environment. Any level of NIHL may muffle high-frequency sounds such as whistles or buzzers and may result in difficulty discriminating speech consonant sounds such as those in the words fish and fist, particularly in noisy environments with background noise, many voices, or room reverberation (Smoorenburg 1992).

The left ear had acquired significantly more loss than the right ear in the study population, which corroborates previously reported study findings (Broste et al. 1989; Marvel et al. 1991; Pirila et al. 1992; Simpson et al. 1993). NIHL, for reasons that are still not yet clearly identified, usually become manifest first and rapid in the left ear (Gasaway 1994; Rudin et al. 1988; Touma 1992). Although no definitive causes were examined for poorer hearing in the left ear among the study participants, some plausible explanations were considered. First, poorer hearing in the left may reflect OEs' unique directional noise exposure from operating heavy construction equipment. Most OEs may look over their right shoulder when they operate heavy equipment, and thus their left ear was more exposed to the noise generated by the machine's engine. Also, some workers may have the window open during their work when they operated equipment with no air conditioning during summer season. This phenomenon was also reported by the study with farmers who presumably operate tractors (Broste et al. 1989; Marvel et al. 1991). Another possible explanation for the poorer hearing in the left ear is that a large proportion of OEs (64%) had shot firearms for hunting. Since most individuals are right-handed, the muzzle blast from a rifle or shotgun reaches the left ear at a higher level than the somewhat protected right ear. Using firearms, chain saws, and other portable power tools also tends to expose the left ear more directly to the source of noise (Marvel et al. 1991).

Occupational health professionals agree on the importance of workers' use of HPDs in preventing NIHL. The present study showed protective effect of using HPDs; workers who reported frequent use of HPDs had significantly better hearing. Although the study could not determine a definitive causal relationship between the use of HPDs and hearing loss because of its cross-section nature, this finding corroborates previous studies. For example, Savell and Toothman (1987) found no loss in hearing ability in 265 employees who consistently used HPDs, even though they worked in areas with high noise exposures (86–103 dBA). In the study with Korean airport workers exposed to high noise (≥85 dBA, 8-h TWA), Hong et al. (1998b) found that workers who used HPDs consistently had significantly less hearing loss than those who did not. A more recent study in Canada reported that construction workers who always wore HPDs showed better hearing, compared to those who did not (Hessel 2000).

This study is considered as one of the first ones assessed prevalence and characteristic pattern of NIHL and demonstrated a protective effect of HPD use on hearing among OEs in the USA, which are considered valuable information. However, the progression of this loss and its relationship with use of HPDs should be studied systematically using serial audiograms in a carefully designed longitudinal study.

NIHL has an insidious onset and may be well advanced by the time that it gives rise to appreciable disability. The first sign of NIHL is a V-shape dip or notch in the audiogram with the maximal HTL at 4 or 6 kHz. Interestingly, a V-shaped notch at 4 or 6 kHz, a typical audiometric characteristic of NIHL, was not present in this population. This is a common pattern of audiogram for workers who have been exposed to loud noise for many years without proper protection (Suter 2002). Lower frequencies (0.5–2 kHz) take longer to get affected by noise than the higher frequencies (3–6 kHz). Workers can barely notice early stages of NIHL because they do not notice any interference in their daily conversation. The noise notch flattens with increasing noise exposure, and may eventually become indistinguishable

from the changes of aging (presbycusis), where the hearing shows a gradual deterioration at the higher frequencies. Early detection of such loss through periodic audiometric tests may assist in prevention of further loss, and recognition of existing loss is important for educational and medicolegal purposes. The OSHA recognized that an annual audiometric test is essential for an effective hearing conservation program (USDL OSHA 1983). Unfortunately, an audiometric test, a key element of a hearing conservation program, was not being provided to the majority of construction workers in the USA. According to the 1997 Michigan annual report on NIHL, for example, less than 4% of newly-reported NIHL cases in construction workers had regular audiometric test performed at their jobs (Reilly et al. 1998).

NIHL is permanent and cannot be cured because hair cells, once damaged, do not regenerate. NIHL has resulted in significant monetary costs and human suffering. Loss of hearing negatively affects an individual's quality of life, social interaction, and personal safety in the workplace. Fortunately, it is one of the most preventable occupational health problems (NIH 1990; NIOSH 1988). Hence, more comprehensive hearing conservation program including a periodic audiometric testing and training on use of HPDs should be implemented in the construction industry. The OSHA rules (29 CFR 1910.95) in the USA require periodic noise exposure monitoring, engineering and administrative controls, personal hearing protection, annual audiometric test, and worker training. Currently, this requirement does not apply to construction workers. The construction industry has been covered by its own noise standard, 29 CFR 1926.52 (USDL OSHA 1971), which simply requires that all workers exposed to noise at or above an 8-h TWA of 90 dBA must be provided with protection against hazardous noise. It should be noted that all permissible noise exposure limits mentioned in this paper are only relevant to the USA. As different countries have their own national noise standards and recommendations, interpretation of reported findings should be done accordingly.

Hearing conservation programs in construction have been in place in other countries such as Sweden and Canada since 1969 and mid-80s, respectively (Schneider et al. 1995). The evaluation results of Swedish program for each decade demonstrated that the prevalence of hearing loss had declined across age groups (Schneider et al. 1995). Ideally, replacing and modifying construction equipment to decrease noise level should be the priority. But it is reasonable to recognize that eliminating the source of noise by replacing old machines with new quiet ones is costly and not always possible. Furthermore, the nature of the construction work such that the workers are exposed to noise generated by their own tools or equipment as well as other noise generally prevalent in the constructions sites makes it difficult to control noise exposure.

Considering that construction workers are constantly changing the workplace, having several employers at multiple jobsites and prevalently self-employed, it might not be practical for contractors to provide regular audiometric test for workers who may only work for them a few days or a few weeks. An innovative approach with cooperation among contractors, trade unions, and government bodies is necessary to provide construction workers with annual audiometric test and hearing protection training. This study demonstrated a successful collaboration between OE trade union and a research university in implementing self-administered audiometric screening as a part of hearing protection intervention. It is hoped this work will serve as a prototype for effective collaboration among researchers, labor unions, contractors, and workers to promote workers' health and safety.

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Appendix D

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

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Original Article

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*OiSaeng Hong**
Peter Csaszar†

*School of Nursing, University of Michigan, Ann Arbor, MI, USA
†Electrical & Computer Engineering, Lawrence Technological University, Southfield, MI, USA

Audiometric testing and hearing protection training through multimedia technology

Pruebas audiométricas y entrenamiento para la protección de la audición por medio de tecnología multimedia

Key Words

Computer-based audiometric testing
Workers
Noise-induced hearing loss
Hearing protection

Abbreviations

ANSI: American National Standards Institute
CDC: Centers of Disease Control and Prevention
dB: Decibel
GED: General equivalency diploma
HAZMAT: Hazardous Material
HPDs: Hearing protective devices
LAN: Local area network
NIOSH: National Institute for Occupational Safety and Health
NIHL: Noise-induced hearing loss
OSHA: Occupational Safety and Health Administration
PUHPM: Predictors of Use of Hearing Protection Model
SAAT: Self-administered audiometric tests
TTS: Temporary threshold shift
USDL: United States Department of Labor

Abstract

The purpose of this paper is to present the development process of a computer-based audiometric testing and tailored intervention program, and assess its feasibility by obtaining users' feedback. The program was implemented for 397 operating engineers at their union training center, and its feasibility was evaluated by obtaining quantitative and qualitative feedback from the participants through a survey and focus group. Over 96% of the participants indicated they liked receiving a hearing test by computer; the computer-based test worked smoothly; and the computer-based training was well organized, effective and held their interests. Almost all (more than 99%) said they would recommend this program to other workers. This project is considered as one of the first ones incorporating multimedia computer technology with self-administered audiometric testing and tailored training. Participants' favorable feedback strongly supported the continued utilization of this approach for designing and developing health screening and intervention to promote healthy behaviors.

Sumario

El propósito de este trabajo es presentar el proceso de desarrollo de pruebas audiométricas computarizadas y un programa de intervención a la medida, además de evaluar su factibilidad por medio de la retroalimentación de los usuarios. El programa se implementó para 397 ingenieros operativos en su centro de entrenamiento sindical y su factibilidad fue evaluada obteniendo retroalimentaciones cuantitativas y cualitativas de los participantes por medio de un grupo específico y de un cuestionario. Más del 96% de los participantes indicaron que desearían realizar una prueba computarizada de audición: la prueba computarizada se desarrolló tranquilamente; el entrenamiento computarizado estuvo bien organizado, fue efectivo y atrajo su interés. Casi todos (más del 99%) dijeron que recomendarían el programa a otros trabajadores. Este proyecto se considera como uno de los primeros que incorpora la tecnología multimedia computarizada con pruebas audiométricas auto administradas y con entrenamiento a la medida. La favorable retroalimentación de los participantes apoya fuertemente la continua utilización de este sistema para diseñar y desarrollar programas de tamiz de salud y de intervención para promover conductas saludables.

Noise-induced hearing loss (NIHL) is a major occupational health hazard and is the second most reported occupational disease and injury (National Institute for Occupational Safety and Health [NIOSH], 1996a). Occupational hearing loss among construction workers has long been recognized as a problem (Atherley & Nobel, 1985). Most construction workers lose some or all of their hearing after years at the trade (Schneider et al, 1995). Since NIHL occurs gradually, an individual may not realize he or she is becoming hearing-impaired until a substantial amount of his or her hearing is lost. While it is preferable to reduce hazardous noise exposure through engineering controls, it is often impractical, costly, or impossible to eliminate all harmful noise. Since NIHL can be prevented by consistent use of hearing protective devices (HPDs) (Hong et al, 1998; Sataloff & Sataloff, 1993), protective action by the workers is a necessary aspect of any hearing loss prevention intervention. However, workers do not consistently wear HPDs. Studies with groups of construction workers found that the use of HPDs ranged from a low of 18% to a high of 62% of the time they were supposed to use them (Lusk et al, 1999), far less than the 100% use needed to prevent NIHL (Dear, 1998). Therefore, it is important to educate workers about the hazard of noise and protection of their hearing by using HPDs whenever they are exposed to loud noise.

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OiSaeng Hong, PhD, RN
School of Nursing, University of Michigan, 400 N. Ingalls, Room 3182, Ann Arbor, Michigan 48109-0482 USA.
E-mail oshong@umich.edu

Early detection of hearing loss is another crucial aspect of hearing conservation programs, and requires audiometric tests. Periodic audiometric tests make it possible to track and document hearing loss, hopefully preventing further development of NIHL (Welch & Roto, 1995). More importantly, regular audiometric tests not only monitor for hearing loss, they also provide the best opportunity to educate workers about NIHL and motivate them to change behaviors regarding hearing protection (Royster. 1985; Royster & Royster, 1991). 'Audiometric results provide the only concrete evidence to workers that their daily HPD use can affect hearing ability' (Royster, 1985). Thus, workers who view their audiograms and see demonstrable hearing loss are much more likely to be motivated to use HPDs and to use them properly (Schneider, 1995). Empirical studies have demonstrated that information about the status of workers' hearing ability as an immediate consequence of using or not using HPDs was an effective reinforcer to increase use of HPDs (Karmy & Martin, 1982; Zohar et al, 1980).

The Occupational Safety and Health Administration (OSHA) recognized that an annual audiometric test is essential for an effective hearing conservation program (United States Department of Labor [USDL]-OSHA, 1983). Unfortunately, an audiometric test, a key element of a hearing conservation program, is not provided to the majority of construction workers. According to the National Occupational Exposure Survey (NIOSH, 1988), fewer than 3% of general building contractors and 8% of heavy construction companies provide routine audiometric tests for their employees. The 1997 Michigan annual report on NIHL revealed that less than 4% of newly-reported NIHL cases in construction workers had regular audiometric tests performed at their jobs (Reilly et al, 1998).

Periodic audiometric tests for all construction workers, provided either by their unions, their employers, or by occupational safety and health agencies, should be instituted (Franks, 1990). However, due to construction work patterns, the constantly changing and temporary nature of the workplace, it might not be practical for contractors to provide annual audiometric tests for construction workers who may only work for them a few days or a few weeks. Worker unions can play an important role in educating their members about noise and hearing protection, providing no or low-cost audiometric tests through their health and welfare funds, and in working with contractors to develop and implement rational and effective hearing conservation programs (Schneider, 1995). Considering the significance of these two essential components of hearing conservation (use of HPDs and regular audiometric tests), this study developed and implemented computer-based audiometric tests and tailored intervention designed to provide construction workers with audiometric tests and promote their use of HPDs, ultimately, to prevent NIHL.

Integration of computers into the realm of health care has been ongoing since the inception of computers in our society. The benefits of computers for health education have been discussed in the literature (Balas et al, 1996; Krishna et al, 1997; Lewis, 1999). Along with new technology and advancements in computers, computer-based instruction has been able to effectively utilize multimedia by making programs more attractive to and interactive with the viewer. Some advantages to using multimedia are the interactivity of programs, adaptation to the user, and the assessment and documentation capabilities (Strecher et al, 1999).

Computer-tailored interventions are a relatively new health education approach. These interventions are characterized by customizing health information content, with the assistance of computers, to match the characteristics of each person (Bull et al, 1999; de Vries & Brug, 1999; Marcus et al, 1998). Greater accessibility of computer technology has facilitated addressing large segments of the population who can now receive health screening and sophisticated interventions that are not general but highly individualized. Computer technology can be potentially useful for tailoring specific aspects of a training aimed at behavioral change according to an individual's health status, perceptions, beliefs, and attitudes that are most in need of alteration (Rhodes et al, 1997). Such personalization addresses one of the major tenets associated with adult learners: adults tend to be pragmatic learners and relate best to issues that are meaningful in the context of their lives (Dirkx & Prenger, 1997).

In this study an interactive multimedia self-administered audiometric tests (SAAT) and training program delivered by computer was developed to prevent NIHL, which is a threat upwards of five million (NIOSH, 1998) to perhaps as many as 30 million workers in the United States (NIOSH, 1996a). The program provides hearing test and tailored intervention to address the most salient needs of workers relative to their hearing ability and hearing protection behaviors. The purpose of this paper is to present the development process of a multimedia computer technology for SAAT and tailored hearing protection intervention. The feasibility of this intervention strategy is assessed through feedback from the study participants.

Methods

Study site and target population

The study was conducted at a trade Union Training Center in a midwestern state in the United States of America. The target population was trainees and operating engineers from the entire state coming to the Training Center for a three-year apprentice certification course and the 8-hour Hazardous Material (HAZ-MAT) refresher course, respectively. Operating engineers operate heavy equipment such as bulldozers, graders, backhoes, asphalt road rollers, asphalt spreaders, and wheel loaders; the noise level for most of the aforementioned heavy equipment is ≥85 dBA. Trainees in the apprenticeship program also were included in the study because these trainees are young people just starting out in the field of construction work and this study was expected to offer an efficient way to learn skills and knowledge about how to protect their hearing from the beginning of their construction work career. Annual audiometric test and training on use of HPDs are not legally required for construction workers and, thus, the majority of operating engineers have not been given these essential services for preventing NIHL. Union leaders at the training center were very interested in cooperating with the study.

Development of multimedia computer-based program

A multimedia SAAT and tailored training program was developed through the five steps shown in Figure 1. A multidisciplinary team of scriptwriters, audio and video production specialists, graphic designers, computer programmers, audiolo-

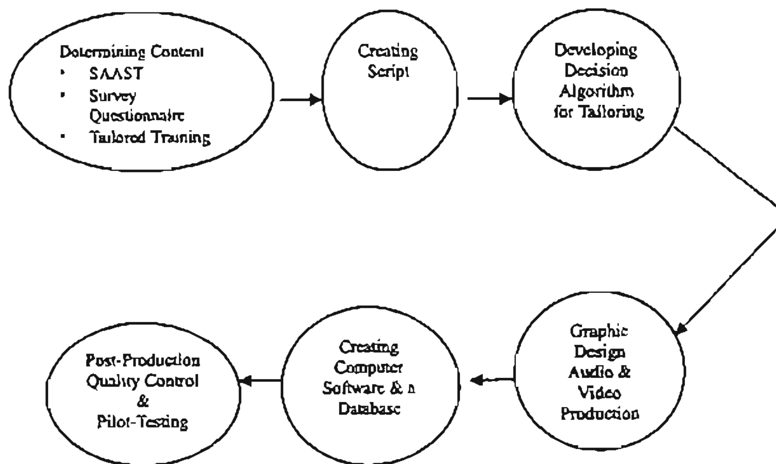

Figure 1. Steps of the development process.

gists, and researchers in the field of occupational hearing conservation had worked together in the development. Each step is described in detail in the following section.

Step 1: Determining the content of the program and writing scripts

The content of the program consisted of three major areas: SAAT, a survey, and tailored training. The content of the SAAT included the importance of audiometric test in hearing conservation, instructions for SAAT, explanation about audiogram and its interpretation, presenting the worker's own audiometric test result, and individualized feedback on his or her hearing status. Second content area was development of question items for a survey questionnaire to assess key characteristics of each person based on the Predictors of Use of Hearing Protection Model (PUHPM). The model includes three cognitive-perceptual factors (perceived benefits, barriers, self-efficacy) as predictors for use of HPDs, the dependent variable. Also included are three modifying factors. In the model, all three predictors have a direct effect on use of hearing protection, 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 workers' hearing protection behaviors (Hong et al, 2005; Ronis et al, 1999). The survey for this study included questions to measure all factors of the PUHPM. The survey was used as the theory-based decision-making algorithm about which answers to the questions in the assessment questionnaire should be linked to feedback messages.

Once the program content was determined, a script was developed to establish adherence to technical and instructional protocols. The script provided a screen-by-screen description of what study participants would see, hear, and do during the entire program from the introduction, through SAAT, the survey, and finally the actual intervention. Decision-making algorithms for the logic library of personalized feedback on SAAT results and tailored intervention and branching were included as important elements of the script. The script served as the blueprint for creating and assembling all parts of the computer-based SAAT, survey, and tailored training, and provided a guideline for all research team members including graphic designers, audio-video specialists and computer programmers.

The scripted content, in particular for SAAT and tailored training, was reviewed and validated by a research team as well as by two external consultants (experts in hearing conservation and audiology) to be sure it contained correct information. A sample program script (which included project information, scene number and label, computer graphics, on-screen text, navigation and interactivity, video clips, and audio narration) is shown in the appendix.

Step 2: Development of decision algorithm for tailoring

The study created a decision algorithm to provide the logic that matches a particular message to the individual's characteristics for the tailored training. Tailoring training algorithms were developed based on findings from previous studies (Hong et al, 2005; Lusk et al, 1999) and the first author's expertise and knowledge of NIHL and its prevention. This expertise was gained in over eighteen years of experience in this field. The tailoring algorithms for hearing protection training included workers' use of HPDs, hearing status, perceived benefits of and barriers to the use of HPDs, and self-efficacy. These factors were determined as significant predictors of hearing protection behavior through the previous research (Hong et al, 2005; Lusk et al, 1999).

The following rules were used in developing the decision algorithm for tailoring the individual's SAAT result: (1) Hearing loss was determined based on hearing thresholds at frequencies of 4 and 6 kHz because NIHL affects these two frequencies earlier and more severely than the lower frequencies. (2) Hearing thresholds above 25 dB without age adjustment were considered hearing loss to measure the real hearing status. (3) Hearing thresholds in the worst ear were used as a conservative measure of hearing loss when there was unequal hearing loss in the two ears. (4) The extent of hearing loss was assessed using the grading system proposed by the World Health Organization (1986): less than 25 dB (normal), 25–40 dB (slight), 41–60 (moderate), 61–80 dB (severe), and above 80 dB (extreme).

When the decision algorithm for tailoring was developed, the research team, as well as two external consultants with extensive experience in hearing conservation and audiology, evaluated the adequacy of the algorithm. An example of information tailored to take workers' hearing ability into account based on their SAAT results is as follows: If the SAAT results showed a worker's hearing was normal, the worker received the following content as part of the intervention, '*Congratulations! Your hearing test showed that your hearing is normal. That's great! Remember, this test is only a screening of your hearing, and cannot be used as a diagnosis. It's important to protect your hearing whenever you are exposed to loud noise.*' Providing meaningful feedback to the workers about their hearing test results is critical for educating and motivating the workers to protect their hearing (Royster, 1985). For most people, feedback about their own hearing is inherently interesting. Praise for good hearing will reinforce the worker's continued use of HPDs. Warnings for workers with hearing loss will help to motivate the worker to use HPDs before the loss accumulates to a significant amount (Royster, 1985; Royster & Royster, 1991).

Following is an example of information tailored to responses on a survey (perceived barrier) item such as '*Wearing ear plugs or muffs is unsafe because it blocks out danger signals and warning sounds*'. If a response to this statement was either 'strongly agree' or 'moderately agree', then the worker received the following information: '*Based on your answers earlier, you seem concerned about blocking out warning signals or not being able to hear what you want by wearing your ear plugs or muffs. Actually, ear plugs and muffs that fit properly let you hear what you want and need to hear because they reduce both the background noise and the warning sound equally.*'

STEP 3: GRAPHIC DESIGN, AUDIO AND VIDEO PRODUCTION

Once the script and tailored algorithm were completed, a graphic designer was responsible for the overall visual look of the entire program. This included the creation of content graphics, screen layouts, text design using proper font size, style and color, and animation sequences used in the actual program to provide the participants with a visual and interactive experience. Graphic arts consisted of original illustrations, live action videos, and photographs scanned or taken with a digital camera.

Audio and video production included the auditioning and selection of actors. To reduce production cost, this study used many of the audio and video clips developed for previous studies (Hong et al, 2005; Lusk et al, 1999). Recording narration segments and video shoots were done in a studio or on location. A multimedia technician digitized and edited all video and audio. Sound effects and music were added to the program after digitization.

STEP 4: CREATING COMPUTER SOFTWARE AND A DATABASE

Computer programmers provided information technology service. Using the script as a guide, software engineers developed a complex multimedia application by integrating text, graphics, visual effects, sound, and video elements with the appropriate authoring tools (Macromedia Authorware). This multimedia shell allows the worker to conduct the SAAT and take the survey. Based on SAAT results and responses to the survey, the multimedia shell makes it possible for the worker to receive tailored training with selection and retrieval of relevant content from the information library. In that information library each message was coded for how and when it was to be used. For SAAT, the software followed a testing protocol determined by the research team and launched hearing measurements on the microprocessor-controlled audiometer connected to the computer through parallel port. Upon completion, the device was queried for the results. SAAT results then served as one of the branching conditions for the script-based, subject-tailored section of the presentation.

Software engineers also programmed links from the SAAT and survey to the record in a Microsoft Access database for both tailored training and future data analysis. From this database, the tailored training was generated using the software's algorithms, in which specific logic statements were evaluated based on conditions capturing the participant's SAAT results and responses to predictor items in the questionnaire. Advanced computer technology can manage the enormous amount of information needed in this type of intervention. Software engineers coordinated the installation of the hardware and the data delivery systems, including configuring a local area network (LAN) for the implementation at the study site. They were also responsible for troubleshooting all hardware and software problems during the testing and during the actual implementation of the study.

STEP 5: POST-PRODUCTION QUALITY CONTROL AND PILOT-TESTING

The first version of the software underwent several rounds of alpha testing to assure quality control by eliminating all technical and logical glitches. Other research team members and a group of nursing students and faculty also tested the program and provided feedback on the content, techniques and logic of the program, editorial mistakes in grammar, spelling, spacing, or punctuation, and usability of the interface.

Reviews by volunteers other than research team members were particularly helpful, and provided us with fresh perspectives. Besides discovering technical and logical glitches, their evaluations about the effectiveness of instruction itself pointed out unclear content and confusing parts of the program. Based on the composite feedback, revisions were made and the software underwent another rigorous round of quality control. The program was also pilot-tested with 30 construction worker trainees at the union training center before the full-scale implementation of the program.

Program implementation

The fully developed program was implemented from January 2002 to April 2003 to operating engineers. The study had been reviewed and approved by the university Institutional Review Board-Health. The program was implemented in eight double-walled soundproof audiometric booths to ensure worker privacy as well as providing a quiet environment for conducting the SAAT. For the SAAT, pure-tone air conduction threshold measurements were administered using a microprocessor pure-tone audiometer. Through a pilot study with three volunteers, audiometric thresholds measured by SAAT using a microprocessor audiometer were compared thresholds obtained by conventional protocol and both results were consistent. The audiometer was calibrated according to the American National

Standards Institute (ANSI) S3.6-1996 standard (ANSI, 1996). The audiometric booths conformed to the ANSI 3.1-1999 for ambient noise in audiometric rooms (ANSI, 1999). For hearing threshold measurement, both ears were tested at frequencies 0.5 through 8.0 kHz, based on OSHA requirement and NIOSH recommendation. OSHA requires audiograms for each ear to include the frequencies 0.5, 1, 2, 3, 4, and 6 kHz, because these are the most important frequencies for understanding speech and for determining the cause of the hearing loss (USDL-OSHA, 1981). NIOSH recommends including 8 kHz (NIOSH, 1996b).

Prior to the SAAT, aural histories were taken and otoscopic examinations were conducted by trained nurses for all participants to determine the status of ear drums, presence of any signs/symptoms of ear disease or excess wax in the ear canals, which may affect the hearing test or indicate the need for medical attention. About fifteen individuals were excluded from the study because they had acute ear infection or excessive wax that was impossible to remove at the study site. Once the participants were placed in audiometric booths, the computer-based program (consisting of introduction to the program, SAAT, survey, and training) was initiated by the participants. At the beginning of the SAAT, along with the actor's demonstration on the computer screen, clear verbal instructions about how to place earphones and use response buttons were given by the computer. Ideally, earphones for audiometric tests should be properly placed by individuals trained in hearing conservation. However, it was not feasible to know the right moment for fitting earphones for individual participants without stopping the computerized program, because the SAAT was incorporated into the multimedia program and eight individuals were simultaneously going through the program at any given time slot.

Since the study was conducted in winter when workers attended the eight-hour Hazardous Material (HAZMAT) refresher course, the majority of the study participants were noise-free. Some trainees in the apprentice certification program were exposed to noise during their hands-on practice with equipment. The best time to perform audiometric tests is toward the end of work shift when any temporary threshold shift (TTS) can be identified. However, due to timing of implementation, this project might have inadvertently overlooked some important information for a proper hearing conservation for those workers with TTS. This may be a limitation of the study.

The union training center provided office space to install eight audiometric booths, a printer, and desks and chairs for otoscopic examinations and collecting hardcopy feedback questionnaires. Each audiometric booth was equipped with a computer, flat display monitor, keypad, microprocessor-based audiometer, earphones, and response button (hand-switch). Considering the fact that many construction workers did not use a computer in every day life, a keypad (like a telephone key pad), the simplest possible hardware for user interfacing, was used in this study. The keypad had numbers (0–9), a 'yes' button, and a 'no' button. Participants used these to answer multiple-choice questions and enter required data such as percentage of their HPD use, date of birth, and union identification numbers for tracking purpose.

All eight computers were connected to a local area network (LAN) at the study site in order to communicate with the networked central printer for producing handouts, and to upload data to the main computer for future data analysis. On average, participants spent a total of 37 minutes completing the SAAT (six minutes), the questionnaire survey (nine minutes), and the tailored training (22 minutes). Upon completion of the SAAT, the workers received training about how to interpret an audiogram, and their actual audiogram with an interpretation of the results on the screen and with narrated audio explanation. Participants also received individualized printed material on the pre-designed colorful handout. The handout included the participants' audiograms, information regarding their hearing status, feedback tailored to their hearing abilities based on their SAAT results, and the pertinent points covered in their personally tailored interventions.

Results

Characteristics of study participants

A total of 397 workers who completed the computer-based entire program and feedback questionnaire were included in the analysis of summative evaluation. Demographic characteristics of the participants are summarized in Table 1. Participants ranged in age from 20 to 68, with a mean age of 42 years. The majority of them were white (88%) and male (92%). More than 90% had completed at least a high school diploma or a General Equivalency Diploma (GED). Substantial numbers of workers (34%) never used the computer and only 25% reported that they used the computer often. On average, they had been working in the construction industry for eighteen years, and were exposed to loud noise for about seven hours per day. They reported less than

Table 1. Demographic characteristics of study participants (N = 397)

Variable	*Mean (SD)*
Age (Years)	42 (10)
Years in construction	18 (11)
Hours of noise exposure/day	7 (3)
Use of HPDs (% of the time)	50 (34)
Pre-training Intention to use HPDs in future (% of the time)	71 (26)
Variable	Frequency (%)
Educational level	
Less than High School	34 (9)
High School or above	361 (91)
Ethnicity	
Caucasian/White	350 (88)
African American/Black	18 (5)
Native American/American Indian	10 (3)
Others	15 (4)
Gender (Male)	365 (92)
Computer use	
Often	99 (25)
Sometimes	158 (41)
Never	133 (34)

50% actual use and 71% intention to use in the future. These are far lower than 100% use necessary to prevent hearing loss.

Participants' feedback

Since this is one of the first studies that have applied multimedia computer technology to a combined SAAT and hearing protection training for operating engineers, a goal of the study was to evaluate methods from the workers' perspectives. The study inquired as to whether or not workers accepted this new method, if they would use it in the future, and whether they would recommend this program to others. Hence, the study assessed participants' reactions to a computerized SAAT and tailored training program immediately after completing the SAAT and training. Participation in completing a written feedback questionnaire was voluntary. Participants' responses were measured using a six-point Likert scale ranging from 'strongly disagree' (1) to 'strongly agree' (6). Worker response and feedback regarding the computer-based SAAT and training has been very positive; the findings of the workers' satisfaction levels are summarized in Tables 2 and 3, respectively. In addition, a focus group discussion with ten study participants was conducted to obtain qualitative data regarding their experience with the combined SAAT and intervention program.

As mentioned before (see Table 1), a fairly large proportion of participants (37%) never used a computer, and only 22% reported using a computer often. Yet, as shown in Table 2, the majority of them (96%) liked undergoing audiometric testing via the computer, and more than 97% reported the computerized SAAT worked smoothly. Nearly all (99%) of the participants reported that they understood the instructions for the SAAT. More than 90% of the participants agreed that they understood the audiometric test results presented by the computer expert system.

Workers also showed a high level of satisfaction (see Table 3) with computer-based training. More than 95% of participants indicated that they liked receiving training in a computer format, and that the training program was effective. Over 92% of the workers reported that they learned a lot from the training program and that the training program would motivate them to use HPDs when in loud noise. A significant increase of participants' self-reported use of HPDs (from 50% before intervention to 76% of intended use immediately after completion of the training [$p < .001$, two-tailed]) validated workers' reports that they were motivated to use HPDs more when in high noise. The majority of the participants (96%) said the training program was well organized and held their interest. All participants said they would recommend this computer-based audiometric test and training program to other construction workers. Focus group results corroborated well with the findings summarized in Tables 2 and 3. The following statements are illustrative of the participants' favorable feelings: 'Best part of the whole program was having the hearing test results back immediately.' 'This combined hearing test and training program is very important because I believe a hearing test by itself may not motivate people to use HPDs'. 'I'd like to suggest to put the computers and booths in a trailer to bring it around the State for hearing test and training for fellow construction workers.' 'No problems interacting with the computer during this section'.

Table 2. Workers' satisfaction with computer-based SAAT (N = 397)

Feedback items	*Number (%) of workers who agreed to the statement*
I understood the instructions for the hearing test.	385 (99)
The computerized hearing test worked smoothly.	381 (97)
I liked getting the hearing test by computer.	368 (96)
I understood the results of my hearing test.	356 (93)
I would recommend the program to other construction workers.	379 (100)

Table 3. Participants' satisfaction with computer-based training program (N = 397)

Feedback items	*Number (%) of workers who agreed to the statement*
The people in the program were believable.	372 (99)
I liked getting the training by the computer.	364 (96)
Overall, this training program held my interest.	362 (96)
The training program was well organized.	355 (96)
The program caused me to think more about using hearing protection devices.	360 (96)
The program made sense.	354 (89)
The training program was effective for me.	364 (96)
I was motivated to use hearing protection.	357 (94)
I learned a lot from the training program.	354 (93)
The length of the training program was about right.	341 (90)

Conclusions

This study demonstrated that interactive multimedia computer technology was a feasible mode of delivery of both hearing screening test and health interventions in the workplace. Results from the analysis of workers' quantitative and qualitative feedback clearly indicated that this computer-based interactive multimedia SAAT and training was well received by this group of construction workers, many of whom did not use a computer regularly. Development of a multimedia health screening and tailored intervention is a complex process and requires careful planning, a variety of skilled professionals, tools, and equipment. Computer technologies allow sophisticated individualized messages for each participant and prevent lengthy and irrelevant information.

Computer-based instruction is not a new concept, but the integration of multimedia computer technology into the activ-

ities of health professionals has been slow (Leaffer & Gonda, 2000). This project is considered one of the first of its kind to incorporate multimedia computer technology with SAAT and tailored training. Participants' favorable feedback strongly supported the continued development of this approach.

This innovative multimedia format will serve as a prototype for development, implementation, and testing of health screening and education in the future. Distribution of a package including SAAT and the tailored intervention through CD-ROM is planned to aid in reducing a serious preventable impairment, NIHL. A demo program on CD has already been produced and distributed to interested parties. In addition, a collaborative research project is currently being developed between our research team and hearing scientists at the Oregon Science University and Veteran's Administration Hospital in Portland to implement this multimedia hearing protection intervention program with modification for veterans and newly discharged soldiers. The basic computer programming for both SAAT and tailored training and graphic arts and live-action video developed for this study will be used as a foundation and modified, as appropriate, in the proposed Oregon project. This will reduce a substantial amount of production cost for the Oregon project.

This type of computer-based health screening and intervention with data collection and management has several advantages including: a) efficient and consistent delivery of health messages to a large group; b) provision of training at the participant's convenience without a trainer's presence on-site; c) learner-controlled pace; d) consistent testing and record-keeping; e) a high level of interactivity and participants' active engagement; f) easy management of a large combination of health information messages with the capacity to update them regularly; g) portability of the program; and h) efficient electronic data collection and transmission through modem or LAN (Lee & Owens, 2000; Velicer et al, 1993).

There are several limitations in the development of a complex multimedia program: 1) requirement and availability of a skilled multidisciplinary design team; 2) high development costs; and 3) long design and production hours (Lee & Owens, 2000). Although a multimedia computer program of this type requires high upfront investment for initial production, greater cost effectiveness in the long run is one important advantage, because the program can be used by a large population sample for an unlimited time period. In general, this type of computerized health screening and training system with electronic data collection, in which data can be stored, retrieved and transferred to multiple sites holds great potential for quality assurance, research utilization, and multi-site projects to access large groups of diverse populations in a variety of setting such as primary care clinics, nursing homes, union training centers, factories, and schools. Thus, it is our hope that this project stimulates other health professionals to consider using this innovative approach for designing and developing health screening and intervention to promote healthy behaviors.

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Appendix A: An example of scripts

Characters: Alan, a white male worker, and Chris, an African-American female worker

Scene # *Time Code*	*Computer Graphics*	*Video*	*Audio*
1. (SV1)	a. Images moving across the screen in different directions. Dissolve in and dissolve out printed words (e.g. 'work,' 'play,' 'life') (Need four different images of construction work. Use TIP images of boat and lawn mower.)	a. Fade in still shots of factory footage, people at work, at play, various ages, genders, and ethnicities.	a. Chris: 'Your hearing is important to you. It affects how well you work ... and play ... even how well you deal with other people. How good – or bad – your hearing is affects everything in your life.'
	Upbeat background music with montage. Music cue fades out as Alan begins to speak in part b. Continue showing pictures of construction work, construction equipment, lawnmower, etc.	Voice over Chris and Alan.	Alan (new): 'Constant exposure to loud noise can be a threat to your hearing. But noise is a threat you can do something about. As construction workers, you know your work is noisy. You also know how important it is to be able to hear what's going on around you. Today, you'll learn how to protect your hearing and your health.'
	Fade out all b. Dissolve out montage. Dissolve in 'Welcome'. Half-screen video of both guides	b. Cut to mid-shot of both narrators.	b. Alan (new): 'Welcome to today's program. I'm Alan.' Chris: 'And I'm Chris. Whenever you work on a job site with loud noise, you need to protect your hearing. This year, you'll be part of an exciting, new type of training that will teach you about the hazards of noise and the right way to use hearing protection.'
	c. Continue to show 'Welcome'.	c. Fade out all.	c. Alan (new): 'This program is part of a project designed by nurse researchers at the University of Michigan.'