Résumé

L'efficacité comparée des interventions assistées par ordinateur personnalisées et ciblées dans la promotion de l'utilisation d'un dispositif de protection de l'ouïe

Madeleine J. Kerr, Kay Savik, Karen A. Monsen et Sally L. Lusk

L'objectif de cette étude était d'évaluer l'efficacité de deux interventions assistées par ordinateur et de messages incitatifs sur l'utilisation, par les travailleurs de la construction, d'une protection de l'ouïe. Des travailleurs de la construction (n = 343) désignés au hasard ont reçu un enseignement personnalisé (à partir de caractéristiques individuelles) ou ciblée (à partir de caractéristiques communes), avec ou sans messages incitatifs, dans le cadre d'un modèle expérimental prétest post-test comportant quatre groupes. L'appariement des messages effectué après les interventions visait à comparer la valeur de l'approche personnalisée et de l'approche ciblée. Une année après les interventions, l'utilisation d'une protection de l'ouïe chez les participants est passée de 42 à 50 % des fois où ils étaient exposés au bruit. Les différences entre les groupes n'étaient pas significatives. Cette importante amélioration dans l'utilisation d'une protection auditive démontre que les interventions peuvent avoir un impact sur la prévention de la perte d'audition due au bruit. Étant donné que les groupes ayant fait l'objet d'une intervention ciblée ou personnalisée ne présentaient pas de différences notables dans l'utilisation de la protection de l'ouïe, et que les interventions ciblées sont moins coûteuses à mettre au point, ces dernières sont plus avantageuses.

Mots clés : intervention assistée par ordinateur, perte d'audition due au bruit

Effectiveness of Computer-Based Tailoring Versus Targeting to Promote Use of Hearing Protection

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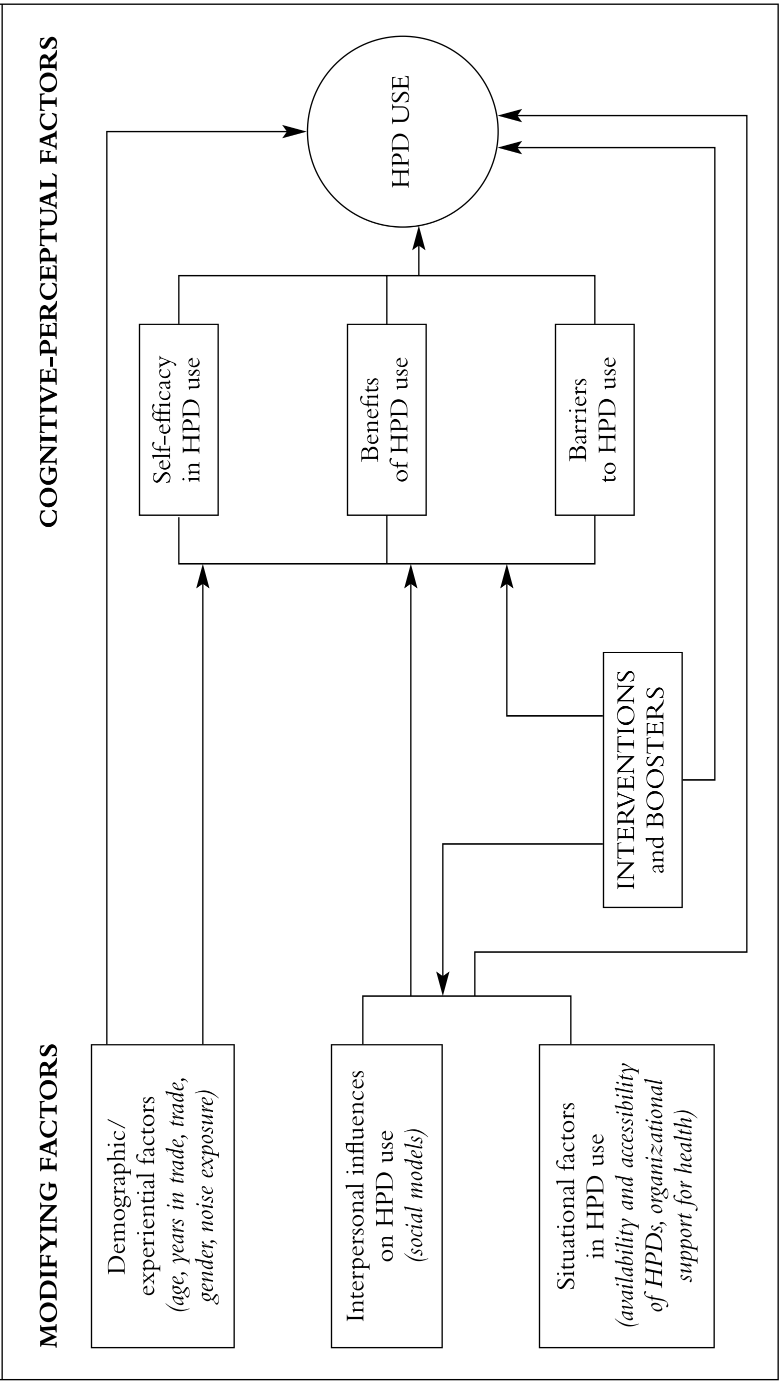
The purpose of this study was to evaluate the effectiveness of 2 computer-based interventions and booster messages on construction workers' use of hearing protection. Construction workers (n = 343) were randomly assigned to receive tailored (addressing individual characteristics) or targeted (addressing shared characteristics) education, with or without booster messages, in an experimental 4-group pretest–post-test design. Post hoc message matching compared the value of tailored and targeted approaches. Participants improved use of hearing protection from 42% to 50% of the time they were exposed to noise 1 year post-intervention. Differences between intervention groups were not significant. The significant improvement in use of hearing protection demonstrates that interventions can have an impact on preventing noise-induced hearing loss. Since targeted and tailored intervention groups did not significantly differ in use of hearing protection, and since targeted interventions are less costly to develop, targeted interventions offer greater value.

Keywords: Computer-assisted instruction, randomized controlled trial, noise-induced hearing loss, ear protective devices

Worldwide, the prevention of occupational hearing loss is a priority for research, policy, and practice (Smith, 1998). Occupational health nurses and public health nurses are ideally positioned to address hearing loss prevention along with other health issues across worker populations. Construction workers are a population of concern because they are underserved by existing programs for hearing loss prevention (Suter, 2002). Knowledge is needed about the components of an effective hearing loss prevention program in order to inform policy and guide occupational health and safety practices. A recent Cochrane review of interventions to promote the use of hearing protection determined that there were only a few good-quality studies in this area and more randomized controlled trials are needed (El Dib, Verbeek, Atallah, Andriolo, & Soares, 2006).

We evaluated the effectiveness of a theory-based intervention designed by integrating concepts from the Predictors of Use of Hearing

Figure 1 ***Predictors of HPD Use***



Protection Model (PUHPM; Figure 1) into a computer-based educational program to promote the use of hearing protection devices (HPDs).

Background

Noise-induced hearing loss (NIHL) has been a known occupational risk for construction workers since the 1960s (Suter, 2002). Although the incidence and prevalence of NIHL are not known in Canada or the United States, isolated studies using audiometric tests have found that up to 74% of construction workers experience hearing loss (Hessel, 2000; Ringen, Seegal, & Englund, 1995; Schneider, Johanning, Belard, & Engholm, 1995; Sweeney et al., 2000). Regional estimates of the costs of NIHL in human suffering and financial resources can be found in hearing disability claims data. Provincial workers' compensation boards across Canada identify occupational hearing loss as a compensable condition (Canadian Hearing Society [CHS], 2003). For example, noise is the greatest cause of permanent disability cases settled by the Workers' Safety and Insurance Board in Ontario, with average payments as high as $15,000 annually over a claimant's lifetime (CHS; World Health Organization [WHO], 1997). In the past decade, studies have described widespread hazardous noise exposure among construction workers in Canada (Legris & Poulin, 1998; Sinclair & Haflidson, 1995; Thompson, 1997) and the United States (Kerr, Brosseau, & Johnson, 2002; Neitzel, Seixas, Camp, & Yost, 1999). Judicious use of hearing protection is an important component of a comprehensive hearing loss prevention program for construction workers (Suter).

Consistent use of HPDs prevents NIHL (Savell & Toothman, 1987), an irreversible impairment with significant monetary and personal costs. In Canada, "not all provinces have regulations for noise exposure and hearing conservation" and some regulations are very similar to those in the United States (WHO, 1997). British Columbia revised its regulations in 1996 to require use of HPDs at an 85-decibel exposure limit (WHO). In the United States, the Occupational Safety and Health Administration mandates use of HPDs at noise levels above 90 decibels for an 8-hour daily exposure in the construction industry (US Department of Labor, Occupational Safety and Health Administration, 2005). Use of HPDs is not widespread, however, according to a review and analysis of construction noise by Suter (2002). Similarly, Lusk, Kerr, and Kauffman (1998) found that 24% of construction workers never used HPDs and only 5.3% always used them when exposed to loud noise. Worker motivation and education in HPD use are an essential part of hearing loss prevention programs (National Institute for Occupational Safety and Health, 1996). Research into the effectiveness of educational interventions is needed to guide programs for the prevention of NIHL in the population of construction workers.

An exemplar of a successful comprehensive hearing loss prevention program for construction workers is that of the Workers' Compensation Board of British Columbia, proposed by Suter (2002) as a model for the United States in part because of its high percentage of HPD use. The program includes annual audiometric testing, training, and counselling of construction workers. Ten years of data reveal improvement in the hearing of construction workers exposed to noise to a level comparable to that of non-exposed workers (Suter). Research to discover the mechanism of this exemplary program's effect on HPD use would further the adaptation and replication of effective hearing loss prevention programs in the construction industry.

Research Employing the PUHPM

A research team of occupational health nurses led by Lusk and colleagues derived the PUHPM from Pender's (1987) Health Promotion Model (HPM) by empirically testing the HPM with factory workers (Lusk, Ronis, Kerr, & Atwood, 1994), construction workers (Lusk, Ronis, & Hogan, 1997), and Mexican-American garment workers (Kerr, Lusk, & Ronis, 2002). The HPM demonstrated utility as an explanatory model, accounting for up to half of the variance in use of hearing protection. Furthermore, exploratory forms of the HPM explained more variance. The exploratory versions allowed direct paths from all factors to the behaviour, consistent with the revised HPM (Pender, 1996; Pender, Murdaugh, & Parsons, 2002). These empirical tests of the HPM in original and exploratory forms provided the rationale for deriving the PUHPM.

As shown in Figure 1, the PUHPM includes the intervention, three types of modifying factors, three types of cognitive-perceptual factors, and the dependent variable, use of hearing protection. In the PUHPM, all factors have a direct effect on HPD use and, additionally, the modifying factors have an indirect effect on this behaviour, exerting their influence through the cognitive-perceptual factors. Interventions and informational boosters are expected to affect selected modifying factors and cognitive-perceptual factors as well as the behaviour itself.

Modifying factors. Demographic and experiential factors such as age and noise exposure at work are background factors in the model. Interpersonal influences are the social norms or expectations of significant others, social role models for HPD use, and interpersonal support for the behaviour. Situational factors include the availability of HPDs and organizational support for employee health.

Cognitive-perceptual factors. Self-efficacy is confidence in one's ability to use HPDs. Benefits refers to the expected positive effects of HPD use and barriers are the potential negative aspects of this behaviour. This model depicts the factors that are believed to influence the use of hearing protection and that provide the basis for the content and process of interventions.

Lusk and colleagues designed an intervention package for construction workers based on predictors of HPD use from a test of the PUHPM (Lusk, Hong, et al., 1999). HPD use increased from a baseline of 44% to only 52% of the time the workers were exposed to loud noise, leaving much room for improvement in achieving the goal of 100% use. The researchers recommended that future studies examine tailoring to the interests or beliefs of the individual as the next step in the development of successful theory-based interventions.

Tailored and Targeted Health Communication

Tailored and targeted interventions have been shown to be more effective than generic interventions; however, improving on generic interventions through tailoring or targeting requires assessment of population subgroups, with more extensive assessment of individuals needed for the more intensive tailored approach (Ryan, Skinner, Farrell, & Champion, 2001). Kreuter, Lukwago, Bucholtz, Clark, and Sanders-Thompson (2003) define tailoring as "any combination of information or change strategies intended to reach one specific person, based on characteristics that are unique to that person, related to the outcome of interest, and have been derived from an individual assessment" (p. 137). They define targeting as "the use of a single intervention approach for a defined population subgroup that takes into account characteristics shared by the subgroup's members" (p. 136). Revere and Dunbar (2001) reviewed 37 randomized controlled trials of computer-based tailored and targeted interventions. Of the 14 targeted intervention studies, 13 (92.9%) showed positive results. Of the 23 tailored intervention studies, 21 (91.3%) showed positive results. Ryan et al. examined the relationships between targeted and tailored interventions in a simulation study related to mammography behaviours. They quantified the similarity of an individually tailored intervention to a hypothetical group targeted intervention, and found that about 60% of the population received content in the tailored interventions that was considered a good match with that of the targeted intervention; however, 80% of tailored interventions differed in some way from message combinations developed for all other participants. Ryan et al. recommend further study to differentiate behavioural outcomes of well-targeted interventions and tailored interventions.

The purpose of this project was to (1) develop, using PUHPM, tailored and targeted interventions to increase HPD use among construction workers; (2) evaluate these by contrasting the effectiveness of tailored and targeted interventions; (3) assess the effect of a booster intervention; and (4) test the utility of PUHPM as a model for changing behaviour with regard to HPD use. We hypothesized that the tailored intervention plus booster would be the most effective intervention.

Methods

Design and Sample

Ethics approval for the study was obtained from the University of Minnesota Institutional Review Board: Human Subjects Committee. The four-group pretest–post-test experimental design contrasted the effect of a tailored with that of a targeted intervention on construction workers' HPD use and, additionally, tested the effect of a subsequent informational booster on workers' HPD use (Campbell & Stanley, 1963). Individuals were randomly assigned to one of four groups: tailored intervention, tailored intervention plus booster, targeted intervention, and targeted intervention plus booster. We faced a series of decisions in operationalizing the control group design. According to Barkauskas, Lusk, and Eakin (2005), in designing comparison interventions, researchers must consider "the conceptual framework, content and dynamics of the experimental intervention." Because construction workers are underserved by standard hearing loss prevention programs, we considered the no-intervention control group ethically unacceptable. A usual-treatment model was not feasible because at our sites education in hearing protection was variable, was of minimal quality, and differed too greatly from the computer-delivered intervention to be an adequate comparison (Barkauskas et al.). We turned next to a devised control model by designing a comparison intervention that applied the same conceptual framework to the content and differed only in the dynamics of applying the concepts using targeting instead of tailoring. In this way, the comparison intervention represented a strong approach in the field and provided a rigorous evaluation of tailoring. Participants who were randomized to the booster condition received a booster consistent with the tailored or targeted intervention they received.

Construction workers were recruited through the health and safety educational programs of one municipal employer and two large union apprenticeship programs in metropolitan areas of the American Midwest. The organizations were willing to offer their workers an innovative educational program. Workers who declined to participate in the research received the targeted educational program with no data collected. An initial pre-intervention sample of 723 construction workers included apprentice carpenters (*n* = 399), municipal construction labourers (*n* = 175), and apprentice roofers (*n* = 149). A final sample of 343 construction workers completed the post-intervention session approximately 1 year later.

Instruments to Measure the Model

The electronic survey was integrated into the computer-based educational program following an electronic informed-consent process. Questions to measure components of the PUHPM (Figure 1) were developed in prior research to determine the predictors of HPD use among factory and construction workers (Lusk et al., 1994; Lusk, Kerr, Ronis, & Eakin, 1999). Most concepts were measured on three-item scales and had Likert-style response formats (1 = strongly disagree; 6 = strongly agree). In this study, reliability using Cronbach's alpha ranged from .54 to .88. Reliability for most scales was above the .70 generally considered acceptable (Nunnally & Bernstein, 1994): benefits minus barriers, .81; social models, .85; availability and acceptability, .89; organizational support, .82. The self-efficacy scale had an alpha of .69. The dependent variable use of hearing protection was measured by workers' self-report of the percentage of time (0%–100%) they used hearing protection when exposed to loud noise in their most recent job, the job before that, and in the preceding 12 months. A scale combining the three variables was created, with a resulting alpha of .90.

Intervention

The computer-delivered educational interventions were theory-based using concepts from the PUHPM. For example, health messages were designed to increase perceptions of self-efficacy and benefits of using HPDs while decreasing perceptions of barriers to HPD use. The interventions included the Occupational Safety and Health Administration content requirements for factory worker education: use of HPDs, effects of noise on hearing, and meaning of audiometric testing. Each worker began by answering questions about current HPD use, predictors of use from the PUHPM, and perceptions of noise exposure and hearing ability.

The single-session educational interventions comprised an 8-minute introduction including a consent section, a 15-minute survey, and a 40- to 50-minute educational program. The survey and educational program were in an interactive multimedia game-type format presented with an espionage storyline in which participants were engaged in the mission of foiling a noise villain by using their HPDs. The targeted version gave a standard, generic message incorporating these concepts, whereas the tailored intervention individualized the health messages based on worker responses to questions assessing the components of the model. Six months after the computer-delivered educational session, participants randomized to the booster condition received a mailing at the home address they provided. The mailing included an informational handout and a plastic pouch with five different pairs of earplugs. The colourful informational handout reflected either the tailored or targeted messages the participant received during the computer-delivered education session. The booster handout also reminded the participants of the session by reinforcing the "espionage game" theme and replicating the appearance of the session handout.

Statistical Analysis

Descriptive statistics are presented as percentages, means and standard deviations, or medians and ranges. A summary measure of HPD use was computed from the mean of three measures: percentage use in the current job, in the previous job, and over the preceding year. Comparison of the three trade groups or those who did and did not complete the study was done using a chi-square test of association for categorical data and ANOVA or *t* test for interval data. If assumptions of parametric tests were not met, groups were compared using Kruskal-Wallis ANOVA or Mann-Whitney *U* test. The distribution of the summary measure of HPD use was skewed. However, the post-measure of HPD use adjusted for the baseline measure was not markedly non-normal. Therefore, comparisons between HPD use at baseline and follow-up data used a Wilcoxon Matched-Pairs Signed-Rank test and comparisons of HPD use between tailoring groups and booster groups used a Mann-Whitney *U* test. Comparisons between the four groups created by the possible combination of tailoring and booster used a Kruskall-Wallis ANOVA.

The multivariable model assessing which variables in the theoretical model explained a significant amount of the variance in follow-up HPD use was constructed using stepwise regression. Baseline use of HPDs was included as a covariate. Bivariate associations between independent variables and post-HPD use were assessed using Spearman's correlations or ANCOVA (with baseline HPD use as a covariate), depending on the level of measurement of the independent variable. Variables associated with post-HPD use at a $p < .1$ level were considered candidates for multivariable analysis. Appropriate regression diagnostics gave no indication that any assumptions of multiple regression analysis were violated. Final results were considered significant at $p < .05$.

Post hoc Analysis of Tailored Versus Targeted Content

Ryan et al. (2001) describe an innovative method for examining differences between tailored and targeted intervention content through the use of match scores, which they piloted using hypothetical targeted data. The present study employed the match-scores method with actual tailored versus targeted message data. Two content experts independently compared messages, at each of 11 tailoring points, to the corresponding targeted message and rated their judgements of similarity using a match score of 0 (poor fit), 0.5 (close fit), or 1 (nearly exact fit). The content experts compared their match-score ratings and reached consensus through discussion. Using these ratings, match-score sums were then computed for each participant in the tailoring group (n = 163) to estimate the fit of their individually tailored message combination with the targeted message combination.

Results

Description of Sample

As shown in Table 1, the percentages of men and women differed significantly among trade groups, with labourers representing the most women (19%). The trades differed significantly in education level, with labourers having the lowest percentage of high-school graduates (78%). Age and tenure in the trade differed significantly among the trades: labourers were the oldest (42 years) and had the most longevity (14 years). The trades reported similar exposures to noise but differed significantly in variables representing HPD use, hearing-test history, and reported hearing-test results. Of the three trades, labourers reported the highest median pre-intervention HPD use, percentage of recent hearing testing, and percentage with fair or poor hearing ability (34%).

Retention rates from baseline to post-test were 77% for labourers, 42% for carpenters, and 31% for roofers; therefore follow-up data were available for less than half of participants (n = 343/723). Baseline and follow-up participants were similar with respect to noise exposure, education, and ethnicity, but those lost to follow-up were significantly more often men (94% vs. 90%), were younger (31 vs. 33 years), had fewer years in construction (4 vs. 5 years), and used HPDs less (20% vs. 50% in preceding 12 months). These differences can be accounted for by the higher attrition rates of the apprentices (roofers and carpenters) compared to the more stable group of labourer employees.

Intervention Effects

Overall, participants' HPD use rose significantly between time one and time two ($p < .001$, Wilcoxon Matched-pairs signed-rank test); the median reported use of HPDs was 42% at time one and 50% at time two. On average, tailored participants improved their HPD use by 8.3% (sd = 30.2), while targeted participants improved their use by 6.1%

Table 1 *Sample Demographics and Noise and Hearing Variables*

	Carpenters n = 161	Labourers n = 135	Roofers n = 47	p Value
Gender				
male	161 (100%)	109 (81%)	45 (96%)	< .001[a]
Education				
high school graduate	157 (98%)	105 (78%)	39 (87%)	.003[a]
Ethnicity				
White versus all others	139 (86%)	120 (89%)	38 (81%)	.38[a]
Asian	4 (2.5%)	2 (1.5%)	1 (2%)	
Black	9 (6%)	8 (6%)	2 (4%)	
Hispanic	7 (4%)	2 (1.5%)	3 (6%)	
American Indian	2 (1%)	3 (2%)	3 (6%)	
Age				
(mean, *SD*)	27.1(6.9)	42.4 (8.3)	30.6 (4.6)	< .001[b]
Years in trade				
(median, range)	2 (0–28)	14 (0–35)	4.5 (1–16)	< .001[c]
Exposed to noise (median, range) (1 = never; 5 = always)	3.0 (2–5)	3.0 (2–5)	3.0 (2–5)	.16[c]
HPD use (%) (median, range)				
Most recent job site	25 (0–100)	75 (0–100)	0 (0–100)	< .001[c]
Job site before that	30 (0–100)	50 (0–100)	0 (0–70)	< .001[c]
Past 12 months	33 (0–100)	75 (0–100)	0 (0–75)	< .001[c]
Last hearing test (%)				
< 2 years	16.3	1.5	8.7	
2–5 years	64.4	98.5	71.7	
> 5 years, never	19.4	0	19.6	< .001[a]
Reported hearing test results (%)				
Don't know	33.1	8.9	36.4	
Good	56.7	57.0	54.5	
Fair, poor	10.2	34.1	9.1	< .001[a]

Note: Percentages may not add up to 100% due to rounding.
[a] Chi-square test of association; [b] ANOVA; [c] Kruskal-Wallis ANOVA.

(*sd* =29.8) (p = .51, Mann-Whitney *U* test). Concurrent with the improved HPD use, four variables specified in the PUHPM showed significant improvement over baseline: benefits minus barriers, self-efficacy, social models of HPD use, and availability of HPDs ($p < .01$, Wilcoxon Matched-pairs signed-rank test).

There was no significant difference in the effects of booster and non-booster conditions (p = .24). Booster participants improved their HPD use by 9.5% (*sd* = 28.9) and non-booster participants improved their use by 5.6% (*sd* = 30.6). The tailored intervention plus booster, hypothesized to be the highest-intensity intervention, improved HPD use by 12.6% (*sd* =28.7, p = .13 vs. all others, Kruskal-Wallis ANOVA).

Testing of the Model

In preparation for multivariate analysis, a high correlation (*rho* = –.54) between scales was remedied by subtracting the mean barriers to use scale score from the mean benefits of use score, creating a single scale measuring perceived benefits minus barriers. Bivariate associations between independent variables and post-intervention HPD use are shown in Table 2. Several variables were eliminated from the model because of non-significant associations with p values > .10: noise annoyance, tailored versus targeted intervention, booster versus no booster, and gender. Post-intervention HPD use was regressed on the remaining nine independent variables. As shown in Table 3, 58% of the variance in post-intervention use of hearing protection was explained by three variables: baseline HPD use, social models of HPD use, and benefits minus barriers.

Post hoc Analysis of Tailored Versus Targeted Content

Match-score sums ranged from 2 to 9 out of a possible 11, with a mean of 5.5. For participants in the tailored group, a higher match score showed a positive correlation with a change in hearing protection use (r = .17, p = .03). This suggests that the researchers successfully created an effective targeted message intervention for construction workers.

Discussion

Occupational health nurses face considerable challenges in promoting the use of hearing protection among construction workers. Initial results confirmed low use of HPDs in these workers, emphasizing the need for interventions to promote use. The significant differences in reported hearing tests, hearing ability, and use of HPDs among the three trade groups included in this study suggest that construction workers cannot

Table 2 ***Bivariate Associations of Model Variables with Post-HPD Use***

	Correlations[a]			*p* Value
Age	.23			< .001
Years in trade	.27			< .001
Noise annoyance	.004			.94
Social models of HPD use	.60			< .001
Availability of HPD	.45			< .001
Organizational support	.24			< .001
Self-efficacy in HPD use	.14			.01
Benefits of/barriers to HPD use	.55			< .001
HPD use baseline	.64			< .001
		No	**Yes**	
Tailored intervention[b]		48.7 (2.0)	50.5 (2.1)	.54
Booster[b]		48.0 (1.9)	51.9 (2.3)	.19
Gender male[b]		45.3 (5.2)	49.9 (1.5)	.39
Trade[b]	**Carpenters**	**Labourers**	**Roofers**	
	48.0 (2.1)	56.6 (2.5)	34.6 (4.2)	< .001

[a] Spearman's correlations.
[b] ANCOVA, means (SE) post-HPD use adjusted for baseline HPD use reported.

Table 3 ***Post-intervention Regression Model***

Variable	β (se)	Standardized Beta	*p* Value
HPD use pre-intervention	.37 (.04)	.37	< .001
Social models of HPD use	11.9 (1.5)	.33	< .001
Benefits/barriers	5.6 (.85)	.27	< .001

Note: Statistics for the entire model: $f_{3,339} = 154.4$; $p < .001$; $R^2 = .58$.

be treated as one group and that researchers should consider the individual trades when designing and delivering interventions.

While overall use of HPDs increased to 50% at time two, it did not approach the 100% use necessary for workers exposed to high noise levels, which points to the difficulty in achieving behaviour change among this population necessary for prevention of NIHL. To ensure high ethical standards with respect to providing essential information to all participants in the targeted and tailored groups, the targeted intervention protocol was designed with the needs and attitudes of construction workers in mind, resulting in a theory-based, well-targeted intervention. This intervention was as effective as the tailored one. Hence, because tailored interventions are more time-consuming and expensive to develop, in this case targeted interventions would be the better value. Receipt of boosters did not result in significantly increased use, suggesting a need for further studies to identify effective combinations of interventions and boosters to increase use.

Multiple regression showed significant relationships of theoretically specified variables with post-intervention HPD use, demonstrating the utility of the PUHPM. The most important predictors from this model were comparable to those in previous research for three other groups of construction workers (Lusk et al., 1997) and for factory workers (Lusk et al., 1994), and the variance in HPD use accounted for by the model was similar. The PUHPM serves as a robust guide for designing interventions to promote use of hearing protection. Occupational health nurses, public health nurses, and other clinicians can apply these findings by focusing their interventions on the strongest determinants of change in hearing health behaviour identified in this study: social models of HPD use and perceived benefits of and barriers to HPD use. Findings from this test of the PUHPM can be used to plan revisions in the prototype computer-delivered educational program in order to maximize and simplify messages to target these important influences. Because social models of HPD use are interpersonal influences in the work environment, further development of the concept would inform the design of future interventions at the organization or system level to complement educational programs for workers.

This study examined tailored versus targeted messages post hoc and determined that the control intervention had been well targeted to address the overall responses of construction workers. We concur with the conclusion of Ryan et al. (2001) that "our challenge is to be able to develop parsimonious theoretical models outlining what is worth tailoring for what types of people and in what sociocultural contexts" (p. 556). Our results suggest that hearing protection research with construction workers should focus intervention tailoring on the key concepts of *social models* and *benefits versus barriers* with regard to the PUHPM. Tailored intervention testing will contribute to the development of a targeted message that can be translated for broad dissemination in the construction field.

Several limitations of this study must be acknowledged. First, although the design made use of random assignment to the four intervention groups, the sample itself was not randomly selected from the population of construction workers. Our convenience sample of workers from construction trade unions may not adequately represent non-union workers, a large segment of the labour force. Next, the low retention rates from baseline to post-test may have biased the results so that they do not represent those lost to follow-up, specifically younger workers with less experience and lower use of hearing protection. Finally, the three trades were combined in analyses even though several variables differed significantly across trade groups. We addressed this limitation by assessing these variables as possible confounders in the multivariate analysis.

In conclusion, further study is needed to determine the most effective combination of boosters and interventions and to contrast targeted and tailored interventions. However, based on the results of this study, when costs (in time and money) are considered, targeted interventions offer the better value. No workers should have to lose their hearing in order to earn a living. With the negative effect of hearing loss on quality of life, it is essential that effective interventions be provided to increase use of hearing protection. The interventions tested in this study were effective in increasing use of hearing protection, the first step in preventing noise-induced hearing loss.

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Authors' Note

This research was supported by funding from the National Institute for Occupational Safety and Health (NIOSH RO1CCR 513049), Madeleine Kerr, PI.

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