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Hearing loss in veterans and the need for hearing loss prevention programs

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Abstract
Currently, there are more than 445,000 veterans receiving compensation for hearing loss associated with military service, and 395,000 receiving compensation for service-related tinnitus. In addition to compensation payments, service-related hearing disorders cost the US Department of Veterans Affairs in terms of provision of hearing aids, hearing aid-related services, and clinical services at its 220 facilities nationwide. It is imperative that hearing conservation among military personnel and veterans be addressed. In this paper, we describe the rationale for and the development of a multimedia Hearing Loss Prevention Program aimed at preventing the progression of hearing loss among veterans associated with social, recreational, and nonmilitary occupational noise exposure. The program was developed based on the principles outlined in the Health Belief Model of Rosenstock (1966) and the Health Promotion Model of Pender et al. (2002).

Keywords: veterans, hearing loss prevention, health promotion, multimedia program

Introduction
The issue of noise exposure in the military was of such considerable concern to Congress that in 2002 it directed the Veterans Administration to contract with the Institute of Medicine National Academies to conduct a review of noise exposure in the military using data from World War II to the present. The report examined the extent to which hearing loss could be expected among members of the armed forces, it assessed sources of hazardous noise during military service, and attempted to estimate the levels of noise exposure causing hearing loss. Further, the time course of hearing loss following noise exposure was examined, as were risk factors associated with noise damage and the compliance of the military services to hearing conservation programs (HCPs). The report confirmed the concerns of Congress in concluding that exposure to hazardous noise in the military is considerable and problematic.[1] The military is aware of the problem and is thus addressing it through HCPs and new hearing protection technology. A lesser-addressed subject is the impact of noise exposure during military service on the hearing of veterans in civilian life and ways to prevent further damage from noise. In this paper, we describe a new multimedia hearing loss prevention program that aims to educate veterans about hearing, hearing loss, and the dangers of exposure to noise, with a view to changing their attitudes and behaviors toward use of hearing protection.
Noise Exposure During Military Service

Noise exposure in the military is associated with combat and with work in industrial-types of environments such as shipbuilding yards and aircraft maintenance. Noise levels during combat are especially hazardous and difficult to control because the sources are not always predictable, and because personnel have concerns that hearing protection devices (HPDs) will jeopardize their safety by distorting localization cues and by attenuating important cues from other sources. Military noise sources and their levels have been compiled and published by the Army hearing program[5] and by Berger, Neitzel, and Kladden.[6] A few examples are listed here: in the cockpit of Chinook and Black Hawk helicopters the sound levels reach 102.5 and 106 dB, respectively. Fighter jet launch noise levels from an aircraft carrier reach 152 dB(A). Noise levels inside an Abrams tank and in armored personnel carriers average to 114 dB(A) when traveling at 30 mph and 117 dB(A) at 40 mph. Machine guns and pistols have peak noise levels greater than 150 dB(C).

All branches of the military have HCPs that have existed since 1948 when the Air Force first issued its hearing conservation guidelines. In 1955, the Navy/Marine Corps developed its first HCP, and in 1956 the army did likewise.[1] Since then, these programs have been improved and better monitored. Department of Defense (DoD) programs are required to meet or exceed Occupational Safety and Health Administration (OSHA) 1983 standards for hearing conservation,[7] except military personnel and unique military equipments, systems, and operations.[8] To this end, the services use a more stringent exchange rate than the 5 dB specified by OSHA;[7] the Navy uses a 4 dB exchange rate, while the Army and Air Force use a 3 dB exchange rate. The exchange rate is the relationship between sound level and dose, for example, for every 5 dB increase in sound intensity, the duration of safe exposure time is halved.[9]

One issue examined in the Institute of Medicine of the National Academies Report of 2006 was the adequacy of military HCPs, with a view to ‘identifying when hearing conservation measures were adequate to protect the hearing of service members’. They examined the extent to which the services aim to control the noise environment, the availability, use and effectiveness of hearing protection, audiometric monitoring of personnel, and evaluation of program effectiveness. It was found that the Navy effectively used noise control to reduce noise levels on submarines by up to 30 dB, but that no other branches of service have been as successful in managing noise levels, in part, because noise control is not an option for all environments. In terms of hearing protection, the Institute of Medicine of the National Academies report discusses the fact that hearing protection could come in the form of limiting time of exposure to hazardous noise, or in the form of hearing protection devices (HPDs). Unfortunately, in a combat zone, the former is not possible to enforce; therefore, the military is reliant on use of HPDs. Such devices are available to all personnel. Today’s technology permits up to 50 dB of attenuation when ear plugs are worn in combination with ear muffs, and sometimes even more at frequencies above 2 kHz.[10] This level of attenuation provides adequate protection for almost all environments, a major exception being the flight deck of an aircraft carrier, which, “is perhaps the single most noise-hazardous work environment in the Department of the Navy. Dozens of personnel work in close proximity to multiple aircraft generating 140 dB(A) or more of recurring noise during workdays that may exceed 14 hours”. [11]

As mentioned above, a major barrier to the use of hearing protectors during combat is the concern that hearing protection will attenuate or distort sound cues critical to survival. This, at least in part, most likely explains why studies have found that between 30 and 50% of troops do not optimally use the protection they are provided with.[11-14] As published by National Institute for Occupational Safety and Health (NIOSH), the noise reduction rating of HPDs as a function of minutes not worn dramatically decreases the protection they provide. For instance, not wearing an HPD with an effective NRR of 30 for just 30 minutes will reduce its effectiveness by 17 dB.[14] Similarly, poorly fitted HPDs also result in decreases in attenuation.[15] The Institute of Medicine of the National Academies Report[1] found that audiometric monitoring in the military is difficult to assess. They found annual audiograms available for only about half of the service members in HCPs during the period 1988–2003. The committee encountered similarly scattered data when assessing the approaches taken within the military to evaluate its own HCPs. A variety of approaches have been taken, and a database has been developed, known as the Defense Occupational and Environmental Health Readiness System - Hearing Conservation (DOEHRS-HC) database. The committee felt that at this time the DOERS-HC has as yet unrealized potential to improve evaluation of hearing conservation programs. Combining data from all aspects of the military HCPs, the committee concluded that “hearing conservation programs in the military are currently not adequate to protect the hearing of military service members, and have not been adequate for the period since World War II. This has important human health, personnel readiness and financial implications.” They emphasize that, although the programs are strong, additional staff, training, and noise controls are needed.

The result of noise exposure is cochlear damage. Although on leaving the military it may not manifest itself as permanently elevated thresholds, there is some evidence that ears with past noise exposure, and thus likely cochlear damage, show greater effects of auditory aging.[16,17] Therefore, protecting individuals, such as veterans, with known past noise exposure from further noise, is critical.
Noise Exposure in Civilian Life

In addition to obvious sources of occupational noise exposure such as in the construction, logging, mining, and farming industries, there are other occupations not always considered to be a risk for noise-induced hearing loss (NIHL). For example, police car sirens measure 97 dB(A) inside the vehicle, jazz band concerts and rehearsals average 98 dB(A), and night club disc-jockeys are exposed to average levels of 103 dB(A).[6] The annual cost of disability payments for the estimated 30 million workers who were exposed to hazardous noise was estimated to be USD 242.4 million in 2001.[18]

A number of different standards have been suggested to address noise in the workplace in US, such as those by the OSHA, the Mine and Safety Health Administration (MSHA), the Federal Railroad Administration (FRA), and the DoD. The standard that is most often cited is that developed by OSHA in 1983, for workplace noise monitoring, audiometric testing, provision of hearing protection, training, and recording.[3] However, there are many other common sources of noise to which people are exposed for long periods of time that are not covered under these regulations, and which often exceed safe levels, such as sporting events, entertainment venues, sport vehicles, and even public transport. More specifically, the equivalent sound level experienced over a period of time Leq from a recorder placed on the right shoulder of a spectator at a hockey game found levels of 99.5 dB(A) for the 3.5-hour duration of the game, and of 96.9 dB(A) for game 6 of the US World Series in 1987.[19] Similarly, the average sound level at rock and pop concerts has been shown to be about 95 dB(A), with a range of 73–109.4 dB(A),[20] while personal listening devices can reach outputs of 91–121 dB(A) at maximum settings.[21] Classical musicians are also often exposed to sound levels greater than 85 dB(A) for long periods of time, resulting in a high prevalence of tinnitus and temporary threshold shifts.[22] Noise levels under motorcycle helmets have been measured on the open road at 78–90 dB(A) when traveling at 30 mph, to 114–116 dB(A) when traveling at 120 mph,[23,24] depending upon the specific motorcycle and helmet used. A recent survey of noise levels on the New York city transit system revealed maximum levels of 106, 112, and 89 dB(A) on subway platforms, inside subway cars, and at bus stops, respectively.[25] Children’s toys are also sources of noise. Toy mobile phones have been shown to reach levels of 122 dB(A) at the ear, toy guns reach 150–160 dB(C), and squeaky infant toys and toy vehicles have been measured as producing sounds of 78–108 dB(A) measured at a distance of 10 cm from the user.[26]

The general population is often uninformed about the damage recreational noise can do to the auditory system, as evidenced by a number of studies. For instance, a 17-item questionnaire that assessed knowledge, habits, attitudes and perception of NIHL, and use of hearing protection, completed by two-hundred adults revealed that 17% of respondents thought hearing loss caused by noise can be cured by medication, 10% thought it could be cured by bed rest, and 4.5% by a doctor. Only 42% of respondents answered “yes” to the statement “Listening to my favorite music at very loud levels is potentially harmful to my hearing”, while about 34% of respondents said they would not know where to purchase HPDs from.[27] There are similar reports showing that adolescents and teenagers are usually uninformed about the potential damage noise can do to the auditory system.[28,29]

It seems that even when individuals are aware that noise can damage hearing, few choose to use protective devices. For instance, a study of mill workers reported that even though 93% of the workers knew about the hazards of noise on hearing and knew of protection methods, only 27% possessed hearing protectors, and of these, only 28% wore them all the time.[29] In another study it was found that 72% of young adults said they never wore hearing protection when exposed to loud sounds, even though 85% were aware that noise can damage hearing.[27] Likewise, of 204 rock-concert goers who completed a survey prior to entering a concert venue, 48.5% said they preferred to stand/sit in the loudest areas of the venue and 80% said they never wore hearing protection at concerts, even though more than 70% thought it was somewhat likely or very likely that the level of the music at concerts would damage their hearing.[31] Similarly, only 14% of the individuals who completed an online survey on the use of hearing protection at music venues reported wearing hearing protection routinely, and only 20% reported an intention to use protection in the future. However, when informed that there was the potential for permanent hearing loss, the number intending to use hearing protection increased to 66%.[29] These studies demonstrate the necessity of educating the public, in particular younger generations, which includes young veterans, about the hazards of exposure to loud noise.

Impacts of Hearing Impairment

Hearing loss impairs communication, and it is consequently associated with functional disability leading to depression, social isolation, anxiety, paranoia, and poor self-esteem.[32-35] Even marginal hearing loss negatively affects a person’s sense of independence and well being.[36] Hearing loss affects both partners in intimate relationships by causing feelings of frustration, anger, and antagonism between partners,[37,38] reduces interpersonal communication,[39] and results in poor social and psychological well being on the part of the unimpaired partner.[40] In the workplace, hearing-impaired individuals report feelings of panic, embarrassment and incompetence,[41] and fear for their future employability.[42] Untreated hearing impairment has been associated with a decline in cognitive function,[43] health-related quality of life, and functional capacity to conduct tasks of everyday living.[44] Thus, there is a very real need to educate the public about the reality of NIHL and its psychological and social implications.
Hearing Conservation Programs

As noted above, OSHA, MSHA, FRA, and DoD have had regulations for hearing conservation in the workplace for over ten years. They provide standards for workplace noise monitoring, audiometric testing, provision of hearing protection, training, and recording. Yet, adherence to these standards is poor. For example, in a workplace assessment of ten foundries in the state of Washington, noise levels were measured over seven-hour periods, and management and employees were interviewed about noise monitoring, the availability and use of HPDs and informational materials, training on HCPs, and audiometry practices. Noise levels were found to routinely exceed 85 dB(A) and often were in the 90–95 dB(A) range. None of the ten companies evaluated had made any effort to decrease noise levels, nor were there plans to do so in the future. Management had not issued copies of OSHA regulations for hearing conservation, nor had any of the individuals interviewed ever read them. Further, although HPDs were available to workers, little training on use and fitting was provided. Three companies did not provide annual training or audiometric testing, and training at the other seven companies was limited to the presentation of an interactive video in English only. Moreover, those employees who showed a significant threshold shift at annual examinations were never informed of it. Equally disturbing findings were reported from a Michigan state surveillance program for occupational NIHL in which 1378 individuals with NIHL were interviewed about the hearing conservation practices at their workplaces. If an interview revealed no baseline training or audiometric testing, and training at the other seven companies was limited to the presentation of an interactive video in English only. Moreover, those employees who showed a significant threshold shift at annual examinations were never informed of it. Equally disturbing findings were reported from a Michigan state surveillance program for occupational NIHL in which 1378 individuals with NIHL were interviewed about the hearing conservation practices at their workplaces. If an interview revealed no baseline training or audiometric testing, and training at the other seven companies was limited to the presentation of an interactive video in English only. Moreover, those employees who showed a significant threshold shift at annual examinations were never informed of it.[45] Equally disturbing findings were reported from a Michigan state surveillance program for occupational NIHL in which 1378 individuals with NIHL were interviewed about the hearing conservation practices at their workplaces. If an interview revealed no baseline training or audiometric testing, and training at the other seven companies was limited to the presentation of an interactive video in English only. Moreover, those employees who showed a significant threshold shift at annual examinations were never informed of it.

Outside the workplace, HCPs are even more lacking, as evidenced by a review of HCPs in schools which found that despite recommendations from experts over many years,[47-49] “basic hearing conservation information that could prevent countless cases of NIHL remains absent from most school curricula.” The authors report that although twenty nine organizations produce and disseminate hearing conservation curricula and materials targeted at school-aged children, few schools use such resources at all.

Effectiveness of hearing conservation programs

Studies examining the effectiveness of HCPs are limited, but tend to show positive findings such as increased knowledge about hearing health, and increased current and intended use of HPDs.[51-53] More specifically, employees who participated in HCPs at five fabrication plants showed less deterioration in hearing thresholds after five years than did a control group not exposed to occupational noise.[53] Similarly, regular use of HPDs increased from 20 to 85% among a group of firefighters who were provided with an educational program about NIHL,[51] and intended use of HPDs was almost twice as great for agriculture students who participated in a HCP than among a control group that did not (81% vs 43%).[52]

Theoretical basis of preventive health behaviors

In 1966, Rosenstock published the Health Belief Model (HBM) that was developed in order to explain individual differences in uptake of health services by the public.[54] The model was initially based on four constructs:

- Perceived susceptibility: the feeling of being vulnerable to a condition and the extent to which the individual believes he/she is at risk of acquiring the condition.
- Perceived severity: the belief in the seriousness of the consequences incurred if affected by the condition both medically (death, disability, pain) and socially (effects on family life, personal relations, etc).
- Perceived benefits: the belief that intervention will result in positive benefits.
- Perceived barriers: the barriers an individual believes he/she needs to overcome in order to effectively conduct some form of intervention. This includes costs, negative side effects, social stigma, time needed, etc.

Two additional constructs were added later:

- Perceived efficacy: the belief in the extent to which the intervention will be effective at treating/preventing the condition.
- Cue to action: a cue that prompts an individual to take action. This could be internal such as symptoms of a health problem or external such as media communications, interpersonal communications, or information from healthcare providers.

Data show that, to varying degrees, these constructs are effective at predicting health-related behaviors, such as prenatal care visits,[55] breast cancer self-examination,[56] continued enrollment in diabetes-related pharmaceutical services,[57] and Hepatitis B vaccination.[58]

The HBM was adapted by Pender and colleagues[59] to explain why individuals engage in preventive health behaviors, such as participation in a HCP or use of HPDs. These authors added to the model a number of factors thought to modify the impact of the HBM construct and named their version the Health Promotion Model (HPM). Additions include demographic characteristics, biologic characteristics, interpersonal influences, situational factors, and behavioral factors. Lusk and colleagues conducted a number of studies examining the HPM in relation to use of hearing protection in occupational settings. The model has been shown to be effective for predicting use of hearing protection among factory workers,[60] construction workers,[61] and farm workers.[62]

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(NCRAR) has developed a program based upon theoretical principles laid out in the HBM and the HPM that aims to educate individuals about hearing loss and noise damage, with the goal of changing knowledge, attitudes, and intended behaviors toward use of hearing protection in occupational and recreational settings.

The National Center for Rehabilitative Auditory Research Hearing Loss Prevention Program

The NCRAR HLPP will be available in two forms, one that specifically targets active duty military personnel, and one that targets veterans and other older individuals that is in part completed. Veterans may not be aware of hearing conservation and do not necessarily realize the impact that recreational and leisure noise can have upon hearing ability, tinnitus, and the resultant quality of life. In particular, we want to inform veterans and active duty military personnel of the cumulative nature of noise damage. The HLPP is a multimedia, computer-based, self-administered program that provides education and the opportunity for users to screen their own hearing ability. The program was developed based on the following specifications:

- The educational section of the program can be viewed within 20 minutes, making it practical for use in, for example, a hospital waiting area.
- The program is modular in design so that users can select components in which they are specifically interested. According to learning theory, this should result in optimal outcome because adults tend to learn best when information is practical and relates meaningfully to their lives.[63]
- The program is self-administered (i.e., users do not require instruction in its use).
- The program is low maintenance and does not require upkeep from healthcare professionals.
- The presentation volume level is adjustable to accommodate hearing impaired individuals, since approximately 31% of individuals over age 65 are hearing impaired, with the percentage rising to between 40 and 50% of individuals over age 75.[64] The program automatically reverts back to a calibrated level for the hearing screening module.
- The visual components of the program are clearly visible in accordance with published guidelines[65] because more than 26 million people over age 40 are affected with some type of visual disorder and more than four million individuals in the US aged 55 or older are currently experiencing severe vision loss.[66] The guidelines include use of large san serif font, light text on a dark background, and large spaces between lines of text.
- The reading level of the program is between Grades 5 and 8 in order that the program be comprehensible to most of the adult population. More specifically, approximately 44% of people in the US over age 65 years have read up to grade 5 or below, while another 30% have read approximately between grades 5 and 8.[67] Throughout the HLPP, written content is supplemented with verbal commentary. Although the two are highly correlated, verbal comprehension level is generally higher than reading level, especially in adults who have had little literacy education.[68]

The program consists of an eye-catching, looping video designed to draw users’ attention; on-screen instructions to ensure that headphones are placed on the correct ears, and that the volume is at a comfortable listening level; six educational modules; and a hearing screening module. The program has been developed to permit easy addition of future modules. Touch screen technology is used throughout the program. Module 1 is a video called “How to Protect your Hearing” which gives an overview of hearing protection and is intended to cover basic information, so that if an individual stops using the program after this first module, he or she has at least heard key educational messages. Module 2 is called “Which Protection is right for you?” and consists of interactive computer screens and two short videos. The interactive screens provide information about different types of hearing protectors with examples of what each type is most suited for. The videos teach the user how to insert/fit the protectors. Module 3, “When to Protect your Hearing?” is a video that teaches the user about typical sound levels in the environment. Module 4, named “How Loud is too Loud?” is an interactive module in which the user selects specific listening situations, is shown their typical sound levels, safe exposure times, and the appropriate type of hearing protection to use when one is exposed to those sounds. Module 5 is a video titled “Why Protect your Hearing?” which addresses some of the negative impacts of hearing loss on quality of life and interpersonal interactions. Module 6 is a multifaceted module known as “What Happens when you Hear?” that provides information about the anatomy and physiology of a healthy, and noise-damaged, auditory system via animated clips developed by American Speech Language and Hearing Association.[69] An interactive section of Module 6 provides an introduction to the physics of sound and includes a glossary of terms used throughout the program. Finally, in Module 7 users can screen their hearing for high frequency pure tone perception. The program administrator can select the frequencies to be screened, the testing step-size, and the testing algorithm. In table 1, we list each construct of the HBM, the way in which that construct could be associated with hearing and hearing protection, and the module in our program that addresses that construct.

Computer-based interventions aimed at modifying health-related behaviors have been found to be effective at changing the beliefs, attitudes, and behaviors of individuals in terms of cigarette smoking cessation,[70][71] breast cancer screening,[72] dietary fat reduction,[73] and hearing conservation.[60][74] Regarding hearing conservation, individuals at the University of Michigan developed a multimedia hearing conservation program that aims to increase use of hearing protection among factory workers and others who encounter high levels
of noise in their occupational setting. Their studies have shown the program to be effective at increasing use of HPDs among construction workers and factory workers and of changing attitudes toward hearing protection among a group of operating engineers. It is thus expected that the NCRAR program will be equally effective for changing the attitudes, intentions, and behaviors of veterans.

The next phase of development for the HLPP will be an evaluation of the program’s effectiveness. Initially, the system will be placed in the waiting area of a busy VA hospital, but ultimately it could be located anywhere targeted individuals might have the time available to participate. A small portable kiosk will house the computer and monitor. This kiosk will be sound-attenuating in order to provide privacy and a quiet environment needed for the hearing screening module. A formative evaluation will be conducted first with the intent of improving the product and ensuring that the goals of the program are being met. This evaluation will involve observation of user behavior while completing the program, informal testing of users to determine whether the program is effectively meeting its objective, and one-on-one interviewing to answer questions such as: What message did the program give? Was each module easily understood? Were any sections of the program confusing? Which sections did users find interesting? Which sections did they find boring? Did users find the program informative? Did they encounter difficulties navigating the program? What improvements and additional content areas would users like to see? Was the program of an appropriate length? Once formative evaluation is complete, a summative evaluation will occur in the form of a structured study. This study will assess whether the program changes users’ knowledge and attitudes about hearing loss and hearing protection, intended behaviors regarding use of hearing protection and avoidance of noise, and actual behaviors regarding use of hearing protection and avoidance of noise.

Summary

Noise exposure during military service is a major problem that has resulted in considerable financial and clinical burden for the Veterans Administration. Development of a HCP specifically targeting the veteran population should be a valuable tool for educating veterans about the hazards of noise and for changing their intended and actual behaviors toward use of HPDs during civilian life.

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Table 1: Adaptation of Health Belief Model constructs in the hearing loss prevention program

<table>
<thead>
<tr>
<th>Concept</th>
<th>Participation in a HLPP behaviors</th>
<th>How HLPP addresses it?</th>
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<tbody>
<tr>
<td>Perceived susceptibility</td>
<td>Belief that exposure to noise will damage hearing</td>
<td>Module 3: When to Protect your Hearing?</td>
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<td></td>
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<td>Module 4: How Loud is too Loud?</td>
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<td></td>
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<td>Module 6: What Happens When you Hear?</td>
</tr>
<tr>
<td>Perceived severity</td>
<td>Belief that hearing impairment has negative consequences functionally,</td>
<td>Module 5: Why Protect your Hearing?</td>
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<tr>
<td></td>
<td>socially, and/or psychologically</td>
<td>This module describes the ways in which hearing loss affects many aspects of quality of life</td>
</tr>
<tr>
<td>Perceived benefits</td>
<td>Belief that preventing hearing loss will benefit the individual at some</td>
<td>Module 3: When to Protect your Hearing</td>
</tr>
<tr>
<td></td>
<td>level, whether functionally, socially, and/or psychologically</td>
<td>Module 5: Why Protect your Hearing?</td>
</tr>
<tr>
<td>Perceived barriers</td>
<td>Belief that hearing protection is expensive, difficult to use,</td>
<td>Module 2: Which Protection is right for you?</td>
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<td>uncomfortable, ineffective, and/or has some other negative attributes</td>
<td>Module 4: How Loud is Too Loud?</td>
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<tr>
<td>Self-efficacy</td>
<td>The individual’s belief that he/she can effectively use hearing</td>
<td>Through out the program the same three simple solutions for preventing noise damage are specified: “Turn it down”, “Move away”, “Wear hearing protection”</td>
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<td>protection and/or has the capacity to change his/her sound environment/listening habits</td>
<td>These modules describe different types of hearing protectors, and how and when to use them</td>
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<tr>
<td>Cues to action</td>
<td>Awareness of hearing difficulties/tinnitus, health-related campaigns</td>
<td>Module 7: Test your Hearing</td>
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<tr>
<td></td>
<td>addressing hearing protection, input from family or friends</td>
<td>It is hoped that the hearing screening findings will provided an added cue to action if hearing loss is already present</td>
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