An Ecological Approach to the Assessment and Promotion of Hearing Protection Behaviour in the Workplace

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Abstract

Background: Noise-induced hearing loss (NIHL) is a common debilitating occupational health problem in New Zealand and globally. In addition to the economic burden arising from compensation and rehabilitation for NIHL, quality of life is diminished. Unfortunately, interventions to prevent NIHL have not produced lasting favourable outcomes. The focus of NIHL prevention has mostly been on individuals at the personal level, which neglects environmental influences. The aim of this research was to understand the personal and environmental factors influencing hearing protection behaviour in workers and to develop an intervention to promote this. The theoretical framework for this study was the Ecological Model for Health Promotion; a planning model that helps identify and target behavioural influences across multiple levels of the social environment. **Methods:** Semi-structured interviews (Phase 1), cross-sectional survey (Phase 2), and the development and pilot of an intervention (Phase 3) comprised the three phases of this research. The interview phase identified barriers and supports to hearing protection. A short questionnaire was developed based on themes from the interviews and was administered to a large group to allow internal reliability and sub-structure to be investigated. The intervention phase was guided by the Ecological Model and behaviour change theories. **Findings:** Phases 1 and 2 of the research identified themes and factors that influence hearing protection behaviour. These findings suggested that supports and barriers to hearing protection behaviour are formed by intrapersonal, interpersonal, and organisational level influences as per the Ecological Model. The hearing protection assessment questionnaire was a reliable and valid tool to identify influences of hearing protection behaviour across different levels. Key supports and barriers to hearing protection behaviour were targeted in the development of an intervention programme. The intervention successfully elicited improvements in personal and environmental influences and promoted hearing conservation. **Conclusion:** The research demonstrated the utility of the ecological model in developing effective interventions aimed at preventing NIHL. This thesis provides insight into multi-level influences for hearing protection behaviour and targeting them to promote hearing health in workplaces.

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Glossary of Acronyms and Abbreviations

Abbreviations	Definition
NIHL	Noise induced hearing loss
Hz	Hertz
μPa	Micropascals
dB	Decibels
SPL	Sound pressure level
Pa	Pressure
L_{eq}	Equivalent continuous noise level
Na^{+}	Sodium ion
K^{+}	Potassium ion
IHCs	Inner hair cells
OHCs	Outer hair cells
TTS	Temporary threshold shift
PTS	Permanent threshold shift
WHO	World Health Organisation
ONIHL	Occupational noise induced hearing loss
ACC	Accident Compensation Corporation
OSHA	Occupational Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
ISO	International Standards Organisation
HPDs	Hearing protection devices
NRR	Noise reduction rating
HCPs	Hearing conservation programmes
HBM	Health Belief Model
TRA	Theory of Reasoned Action
TTM	Transtheoretical Model
HPM	Health Promotion Model
EPPM	Extended Parallel Process Model
SCT	Social Cognitive Theory

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Nature of contribution by PhD candidate	contributed to the data collection phase of the study, helped guide the analysis of the study data, prepared the first draft of the paper, and was involved in the review process of the draft manuscript
Extent of contribution by PhD candidate (%)	67%

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Name	Nature of Contribution
David Welch	contributed to the design and supervised the implementation and analysis of the study, interpretation of findings, and critically revising the draft manuscript for important intellectual content.
Shanthi Ameratunga	contributed to the design, supervision & interpretation of the study findings, and critically revising the draft manuscript for important intellectual content
Peter Thorne	contributed to the design, supervison & interpretation of the study findings, and critically revising the draft manuscript for important intellectual content

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The undersigned hereby certify that:

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- in cases where the PhD candidate was the lead author of the work that the candidate wrote the text.

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Chapter 1. Introduction

> *Health at work and healthy work environments are among the most valuable assets of individuals, communities, and countries. Occupational health is an important strategy not only to ensure the health of workers, but also to contribute positively to productivity, quality of products, work motivation, job satisfaction and thereby to the overall quality of life of individuals and society.*
>
> *Occupational health problems are not only problems of individual workers' health, but they are also problems relating to the healthiness and safety of work and the work environment, the organization of work and the management philosophy of the enterprise and workplace.*
>
> Excerpts from the Global Strategy on Occupational Health for All: The Way to Health at Work. Recommendation of the Second Meeting of the WHO Collaborating Centres in Occupational Health. 11-14 October 1994. Beijing, China.

Occupational noise contributes to between 7% and 21% (averaging 16%) of adult hearing loss around the world (Nelson, Nelson, Concha-Barrientos, & Fingerhut, 2005). In New Zealand, it is estimated that noise induced hearing loss (NIHL) contributes to between 17-25% of the overall burden of hearing loss (Thorne, Coad, Reddy, & Welch, 2013). In addition to the huge economic burden associated with NIHL, the quality of life for affected individuals is diminished (Sliwinska-Kowalska & Davis, 2012). Although there are regulations and legislation to protect workers from excessive noise exposure, NIHL prevention efforts have largely been ineffective (Verbeek, Kateman, Morata, Dreschler, & Mischke, 2012). There has been over-reliance on individual level approaches, such as use of hearing protection devices (HPDs), to prevent NIHL (Roelofs, Barbeau, Ellenbecker, & Moure-Eraso, 2003). Ecological models that use more than one behaviour change theory targeting both individual and environmental influences are more effective in health promotion interventions (Angus et al., 2013). This thesis describes an ecological approach to understanding factors influencing hearing health promotion across different levels. The Ecological Model for Health Promotion was used as a framework to target areas for behaviour change in relation to hearing health behaviour and health promotion. This enabled the development of a training intervention aimed at promoting hearing health across different levels of individual and environmental influences in the workplace.

The research used mixed methods: in-depth semi-structured interviews (phase 1), a cross-sectional questionnaire-based survey (phase 2), and the development and pilot of intervention programme (phase 3). The interview phase was designed to identify key barriers and supports to hearing protection. This phase informed the development of a short barriers and supports questionnaire, which was used to assess the hearing protection behaviour through a survey of 555 workers. The intervention phase was developed following the survey and was guided by the ecological model and behaviour change theories. The workplace intervention was adapted from a successful American school-based training called the Dangerous Decibels programme (Griest, Folmer, & Martin, 2007; Martin, Sobel, Griest, Howarth, & Shi, 2006).

1.1. Outline of the thesis

Chapter 2 presents a narrative review of the literature related to NIHL, interventions promoting hearing health, and the conceptual framework. The information provided within the literature review was used to formulate the research design, study questions, and phases one (interview), two (questionnaire survey), and three (development and implementation of intervention). The chapters describing the different phases are reported in an academic format, each with its own, introduction, methods, results, and discussion. The research questions and details of the methodology are discussed in Chapter 3. The details of the interview phase are reported in Chapter 4, while the Questionnaire phase is discussed over Chapters 5 and 6. The development of the intervention is described in Chapter 7 and its implementation outlined in Chapter 8. In Chapter 9, the thesis concludes with a discussion of the major findings, implications related to the prevention of NIHL, and recommendations for future directions.

1.2. Significance of the study

As discussed earlier, NIHL is a big problem globally and in New Zealand. Research is important in this area to build on the knowledge base and create a culture of hearing promotion. This study will add to the literature in discussing an ecological approach to hearing health promotion. Such information will be beneficial in the formulation of more effective ways of preventing NIHL and promoting worker health.

Chapter 1 has laid the foundation for this thesis as it provides a background to the problem, briefly described the methods and conceptual framework, and justified the need for high quality research related to the prevention of NIHL. The next chapter will now discuss literature relevant to NIHL prevention and hearing health promotion.

Chapter 2. Literature Review

The aim of this chapter is to provide an overview of literature related to noise-induced hearing loss (NIHL), health-promoting interventions, and the conceptual framework that forms the basis of this thesis. The literature review is divided into sections describing the background to the science of sounds and hearing, NIHL, and the utility of the ecological model and behaviour change theories.

The section on the background to sound and hearing briefly describes the science of sound and provides an overview of the anatomy and physiology of the ear and impairment of the human hearing system.

The section on NIHL provides the history of occupational noise exposures, epidemiology of NIHL and standards and legislation developed to prevent NIHL. Furthermore, other strategies to prevent NIHL are discussed.

The final section of the chapter introduces the ecological model as the framework for this thesis. Different behaviour change theories and effective ways to deliver health promotion interventions aimed at preventing NIHL are also discussed.

2.1. A background to the science of sound and the human hearing system

2.1.1 **What is sound?**

Sound is energy that is transmitted through air or other media such as water or solids in a series of waves consisting of compressions and rarefactions (Hamill & Price, 2007). The rate of vibration determines the frequency of the sound, which is measured in hertz (Hz) and the magnitude of the movements produced are measured as the amplitude or the intensity of the sound (Pickles, 2012). Sounds detectable by humans range from very soft sounds of approximately 20 micropascals (µPa) to very loud sounds of approximately 20,000,000 µPa (Hamill & Price, 2007). A logarithmic scale called a decibel (dB) scale describes sound pressure level (SPL) by comparing the actual sound with reference to the average minimum audible pressure (Table 2.1), where for every doubling of the sound pressure there is a 3 dB increase in intensity (Aw, Gardiner, & Harrington, 2007).

Table 2.1 Typical noise levels described in decibels corresponding to sound pressure levels

	Pressure (Pa)	Decibel (dB)
Lowest sound than can be heard (threshold of hearing)	0. 00002	0
Quiet office	0. 002	40
Ringing alarm clock at 1 m	0. 2	80
Ship's engine room	20	120
Turbojet engine at 25 m	200	140

(Aw et al., 2007, p. 159)

In order to approximate the response of the ear, a weighting may be applied using a filter that responds to different frequencies as the ear does. The A weighting is commonly used for continuous noise, and sound measurements are expressed on a dB(A) scale (Aw et al., 2007). The human ear is more sensitive to certain frequencies than others and it is often useful to measure sound according to these weightings.

2.1.2 **Auditory anatomy and physiology of the ear**

The external ear

The external ear (Figure 2.1), which consists of the visible cartilaginous part of the ear (pinna) and external auditory canal (ear canal), collects sound waves. In addition to funnelling sound waves into the ear, the external ear helps in the amplification and localisation of sound and protects the middle ear. The external auditory canal leads to and guides sounds to the tympanic membrane (eardrum) (Yost, 2007). The innermost part of the ear canal is a circular canal in the skull (temporal) bone, and the outermost part is cartilage (Hamill & Price, 2007).

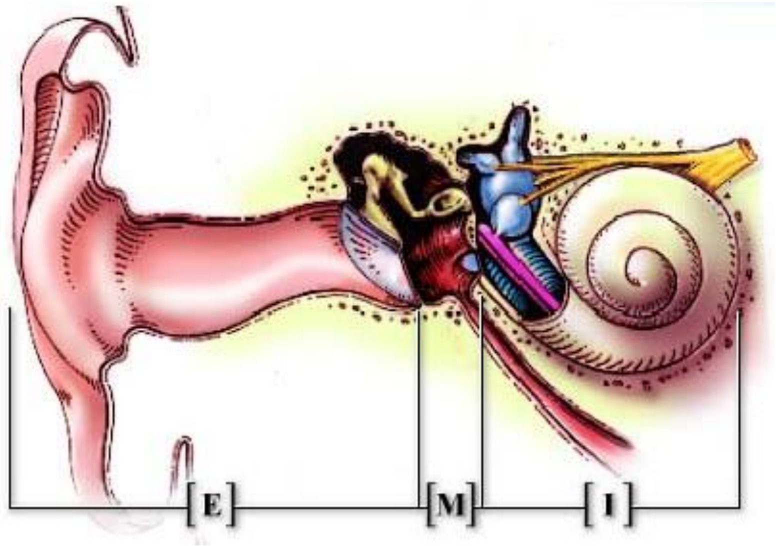

Figure 2.1 Illustration of the human ear showing the external (E), middle (M), and inner (I) ear regions

Image adapted from "Journey into the World of Hearing" www.cochlea.eu by R. Pujol et al., NeurOreille, Montpellier. Reprinted with permission.

The middle ear

The middle ear forms the second stage of sound conduction and consists of the tympanic membrane and ossicles. The inside of the tympanic membrane is attached to the first of three middle ear bones: the malleus, incus and stapes, which are collectively referred to as the ossicular chain (Hamill & Price, 2007). The malleus and the incus are joined firmly to allow the bones to rotate together and transfer energy to the stapes when the malleus is pushed by the tympanic membrane. The footplate of the stapes is embedded in the oval window in the wall of the cochlea (Pickles, 2012). Vibration passes along the ossicular chain to the oval window, and then into the fluids of the inner ear. The contraction of the middle ear muscles (tensor tympani and stapedius muscle) reduces the transmission of sounds to the inner ear (Geisler, 1998). The Eustachian tube is the source of air for the middle ear and also provides an outlet for mucus or other material that may collect in the middle ear (Hamill & Price, 2007).

The inner ear and its mechanical response

The inner ear is located within the skull's temporal bone and comprises of two sensory systems: the cochlea (organs of hearing), and the vestibular system (organs that sense position and motion of the head) (Hamill & Price, 2007).

The cochlea

The cochlea is embedded deep in the temporal bone and contains a coiled basilar membrane that is divided into three parts (scalae) filled with fluids (Geisler, 1998). The middle part (scala media) is separated from the upper part (scala vestibuli) by the Reissner's membrane, and the lower part (scala tympani) by the basilar membrane. The scala vestibuli and scala tympani (outer scalae) contain a fluid called perilymph, while the scala media (inner scalae), which does not communicate with the outer scalae, contains a fluid called endolymph. The perilymph is rich in sodium ions (Na^+) while the endolymph has high potassium ion (K^+) concentration. When the vibrations of the stapes are transmitted through the oval window, which opens onto the scala vestibuli, fluid in the cochlea is displaced to a second window (round window) which is between the scala tympani and the middle ear. The vibration causes a wave of displacements along the basilar membrane and attached structures causing the stimulation of sensory hair cells (Pickles, 2012). The basilar membrane is a composite acellular plate containing a thin sheet of fibres oriented in radial directions. It is narrower at the base (closest to the oval window) than at the apex (top of the cochlea) and this longitudinal difference accounts for variation in the resonant frequencies at the base and apex of the cochlea (Geisler, 1998).

The organ of Corti, which contains the hair cells, rests on the basilar membrane. The hair cells, of which there are about 15,000 in each human ear, consist of one row of (about 3,500) inner hair cells (IHCs) and between three and five rows of (about 12,000) outer hair cells (OHCs). The upper surface of the hair cell has sensory projections called stereocilia on their apical surface (Geisler, 1998). The longest stereocilia of the OHCs are embedded on the under-surface of the tectorial membrane and the stereocilia of the IHCs fit loosely into a raised groove (Hensen's stripe) on the under-surface of the tectorial membrane. When the basilar membrane moves, the relative movement of the tectorial membrane and the organ of Corti cause the stereocilia to bend at their base (Pickles, 2012).

The IHCs have stereocilia in nearly straight rows while the OHCs' stereocilia rows form a W-shaped pattern. Stereocilia are connected by side links and tip links that attach the shorter stereocilia to the taller stereocilium next to each one (Pickles, 2012). When the hair bundle is moved by sound, the relative movement of the rows of stereocilia causes the tip links to control the openings of micro channels inside the stereocilia, which permit the transfer of calcium ions into the body of the hair cell. This activates a chemical change (depolarisation) in the hair cell, which triggers the release of neurotransmitters at the base of the cell. These signals are subsequently interpreted by the brain as sound (Hamill & Price, 2007). The term *mechanical-to-neural transduction* describes this change from mechanical energy of sound vibration into neural information in the inner ear (Yost, 2007).

The auditory nerve

There are about 30,000 fibres in each human ear and only about 5-10% of the them are connected to the outer hair cells, with the majority connected to the IHCs (Pickles, 2012). The nerve fibres connect the hair cells of the cochlea with the cochlea nucleus. Information about each sound is conveyed to the central nervous system by thousands of parallel nerve fibres (Geisler, 1998).

2.1.3 **Impairment of the auditory system**

Conductive hearing loss

Conductive hearing loss describes the situation where something impedes the conduction of sound through the outer and middle ear: for example, obstruction of the auditory canal by earwax or rupturing of the eardrum (Suter, 2002). In addition, damage to the ossicles and impairment of the differential transfer of pressure to the oval and round windows causing reduction in energy transfer to the cochlea leads to conductive hearing loss (Pickles, 2012). A common condition among young children is *otitis media*, which is caused by an infection or accumulation of mucus in the middle ear causing hearing loss (Yost, 2007). Another condition responsible for conductive hearing loss during early or middle adulthood is otosclerosis, which results from the progressive immobilisation of the stapes due to the invasion of the bone of the inner ear into the stapes footplate at the oval window (Geisler, 1998). Conductive hearing loss usually results in greater hearing loss for low frequencies. A person with a conductive loss with preserved high frequency hearing may be able to hear “sh”, “s”, and “t”, but will have difficulty hearing low frequency sounds such as “m” and the vowel sounds (Hamill & Price, 2007). Treatment by antibiotics, the use of hearing aids and surgery can compensate for conductive hearing loss (Pickles, 2012).

Sensorineural hearing loss

Impairment to the auditory nerve, or more commonly to the hair cells in the cochlea results in sensorineural hearing loss. Ototoxic drugs, ageing, infections, genetic disposition, and acoustic trauma can cause sensorineural hearing loss.

Ototoxicity

Ototoxicity is the ability of drugs or chemicals such as aminoglycoside, antibiotics, anticancer drugs, salicylates, quinines, and erythromycins to cause damage to the inner ear affecting hearing and or balance (Rybak, 2008). These ototoxic drugs are harmful to the cochlea and the hair cells and in some cases the use of such drugs leads to the sensation of tinnitus or "ringing" in the ear (Yost, 2007). In addition, industrial solvents such as those used in the production of paints, which can be absorbed directly by the skin, have been found to affect the hearing and vestibular systems (Sulkowski et al., 2002).

Disease and injury of the inner ear

Infections of the inner ear commonly result from initial middle-ear infections (acute *otitis media*), but congenitally acquired illness such as meningitis may also harm the inner ear. Diffusion of toxins from the middle ear to the inner ear causes labyrinthitis (acute inner ear infection) which has a high association with hearing loss. Head trauma resulting from motor vehicle accidents, falls, acts of violence, industrial and recreational accidents also causes injury to the inner-ear's mechanisms leading to sensorineural hearing loss (Waldman & Brewer, 2007). In addition, the growth of tumours on the auditory nerve is a condition that affects the transmission of neural information that leads to abnormalities in hearing function (Yost, 2007).

Tinnitus

Tinnitus is the experience of phantom sounds or "ringing in the ears" in the absence of acoustic stimulation. While the root causes of tinnitus may be unclear, damage to the ear is often responsible for its onset (Geisler, 1998). Tinnitus is thought to be caused in the auditory cortex when the cells that would normally receive input from the ear no longer do so due to damage. The cortical cells are believed to adapt pathologically to the absence of input and thereby create the phantom response (Sataloff, 2006b). Any disorder of the outer, middle, inner ear or the auditory nerve caused by either ageing, hearing loss or noise exposure may cause tinnitus (Andersson, Eriksson, Lundh, & Lyttkens, 2000). In addition, the administration of large doses of aspirin, which is known to reduce cochlear sensitivity, can also result in temporary tinnitus in humans (Pickles, 2012).

Noise-induced hearing loss

Hearing impairment caused by occupational and recreational sound exposure is known as noise-induced hearing loss (NIHL) (Meinke & Stephenson, 2007). The hair cells of the inner ear are central to the hearing process but are also vulnerable to overstimulation by high levels of noise. Loud noise damages the inner ear by structurally changing the stereocillia, supporting cells of the *organ of corti* and its nerve fibres. However, some of these changes are temporary, and normal auditory function returns (Yost, 2007). This happens in the mildest cases of acoustic trauma where morphological changes to the roots of the stereocilia can be reversed (Pickles, 2012). Such temporary damage along with reduced hearing due to physiological adaptation is referred to as temporary threshold shift (TTS). However, permanent threshold shift (PTS) is irreversible and caused by gradual damage to the cochlea or as a result of acoustic trauma caused by a single extremely loud sound such as a gunshot (Yost, 2007). PTS may occur on exposure to sounds between 70 and 140 dBA depending on intensity and duration (Clark, 2008).

Hair cell injury and loss is the most common reason for NIHL and OHCs are more prone to damage than IHCs (Duan et al., 2004; Harris, Hu, Hangauer, & Henderson, 2005). Excessive overstimulation of hair cells by intense sounds causes the hair cells to be fatigued and damaged. When the hair cells are constantly overworked for long periods, they are damaged causing permanent hearing loss (Pickles, 2012). In addition, high levels of noise can rupture the tympanic membrane causing middle ear damage (Yost, 2007).

However, laboratory experiments with mice and guinea pigs show that significant degeneration of the cochlea nerve occurs after noise exposure, even when there is no hair cell loss and even when thresholds have returned to normal (Kujawa & Liberman, 2009). This suggests that, at least in laboratory experiments, that reversibility of noise-induced threshold shifts may not mean complete recovery of cochlea structures as neuronal loss will affect hearing.

Individuals affected by NIHL may not notice their gradually worsening condition until a considerable decline in their hearing ability is experienced. NIHL is most extreme at 3, 4 , or

6 kHz frequencies identified on the audiogram as a "noise notch" and continued exposure to high noise levels will cause the notch to deepen and extend to other frequencies affecting speech intelligibility (Meinke & Stephenson, 2007). In general, the level of hearing loss, the rate at which it develops and frequencies which are affected are determined by the characteristics of noise exposure, especially the level and duration of noise (McBride & Williams, 2001).

2.1.4 **Non-auditory effects of noise**

In addition to causing hearing loss, there are non-auditory effects of noise such as annoyance, risk of cardiovascular diseases, sleep and cognitive performance in adults and children (Fritschi, Brown, Kim, Schwela, & Kephalopolos, 2011; Stansfeld & Matheson, 2003).

Annoyance

Exposure to environmental noise affects comfort and wellbeing (Lindvall & Radford, 1973). Noise annoyance is not only confined to noisy industries but is a global problem due to increased transportation, construction and infrastructure development noise near dwellings (Fritschi et al., 2011; Miedema, 2007). Noise annoyance is a "societal problem that is beyond the influence of most individuals" (Miedema, 2007, p. 42). With regards to occupational noise exposure, a number of studies report diminished job satisfaction, post-work irritability, anxiety, and depression attributed to the annoying aspects of noise on workers in noisy industries (McCullagh & Robertson, 2009; Melamed, Rabinowitz, & Green, 1994; Singh, Bhardwaj, & Deepak, 2010; Singh, Bhardwaj, Deepak, & Bedi, 2009; Tantranont et al., 2009). Consequently, the annoying aspects of noise on workers have a negative effect on performance and safety at work (Melamed, Fried, & Froom, 2004; Melamed, Luz, & Green, 1992; A. Smith, 1990).

Sleep disturbance

There is evidence that noise causes sleep disturbances and has an impact on behaviour and well-being when awake (Basner, 2008; Griefahn, Brode, Marks, & Basner, 2008; Halonen et al., 2012). Daytime sleepiness because of sleep deprivation can cause cognitive problems, traffic accidents and impairs job performance and productivity (Lavie, Pillar, & Malhotra, 2002). Taking this into consideration, the World Health Organization's (WHO) Guidelines for Community Noise (1999) recommend that in order to prevent sleep disturbances, noise levels indoors should not exceed 30 dBA for continuous noise and 45 dBA for intermittent background noise (WHO, 1999).

Communication difficulties

Background noise levels greater than 80 dBA make it difficult or impossible for people to communicate orally (Clark, 2008). Therefore the need to shout, especially in the workplace, may indicate high levels of noise masking, making speech intelligibility difficult (Dobie, 1993). Difficulties in communication compel people to speak loudly in noise levels above 80 dBA, to shout in levels over 85 dBA, and to shout from very close range in levels over 95 dBA. This can cause people to develop hoarseness, vocal nodules, and other abnormalities on the vocal cords due to excessive strain (Suter, 2002). In addition, the inability to hear warning signals and directions due to communication difficulties can lead to accidents and injuries to workers in noisy workplaces (Dalebout, 2009).

Physiological responses

There is also evidence linking high levels of noise exposure and the onset of health problems such as heart disease, high blood pressure, and higher blood cholesterol levels (Feldman & Grimes, 1985; Fritschi et al., 2011). An American health and nutrition survey found that self-reported exposure to loud noise amongst 1,236 workers was associated with an increase in coronary heart disease, angina pectoris, and myocardial infarction (Gan, Davies, & Demers, 2011).

2.2. Occupational noise-induced hearing loss (ONIHL)

Hearing loss attributed to occupational noise exposure has been widespread since the Industrial Revolution and is presently one of the most prevalent industrial problems for workers in noisy occupations (Markowitz, Sataloff, & Sataloff, 2006).

2.2.1 **History of ONIHL**

In the 18^{th} century, Bernardino Ramazzini attributed incessant noise, due to the continuous beating of newly mined copper, as the reason for hearing loss in coppersmiths (Ramazzini, 1713). This was one of the first accounts of occupational noise-induced hearing loss. The French investigator Alexandre Layet, in 1875, hypothesised that sheet-iron workers, coppersmiths, and blacksmiths, were vulnerable to hearing loss, and the risk of hearing impairment increased the longer they remained in their respective occupations (Dembe, 1996). Another study in 1881 by Gottstein and Kayser, measuring occupational deafness in 75 blacksmiths and metalworkers at a German railway yard found that 61% of workers in the study group had “bad” or “fairly bad” hearing compared to only 5% of the control group (36 bricklayers) (Atherley & Noble, 1985). Towards the end of the 1960s Passcier-Vermeer reported that increasing noise levels caused hearing damage in workers after analysing data from 4,600 workers (Pelmear, 2000). Bartlett and Myers described hearing loss to be common among airman, boilermakers, and workers in nail factories (Bartlett & Myers, 1934). Prior to the Industrial Revolution, the major source of occupational hearing loss was the sound of exploding gunpowder, which had damaging effects to the hearing of military personnel (Dembe, 1996). The field of audiology developed during and after World War II when concern grew following large numbers of military personnel developing hearing loss upon exposure to gunfire noise (Sataloff, 2006a).

Although, there was widespread evidence of occupational noise causing hearing loss in workers from the nineteenth and early twentieth century, NIHL was not considered a compensable disorder until after World War II (Dembe, 1996).

2.2.2 **Epidemiology of OHNIL**

A 2005 global burden of ONIHL study determined that exposure to occupational noise contributes to 7% and 21% (averaging 16%) of adult hearing loss around the world and males are at greater risk owing to a higher representation in noisy occupations and greater working lifetime (Nelson et al., 2005). However, there is a suggestion that there are sex differences underlying auditory sensitivity that could be responsible for the increased susceptibility in men (D. McFadden, 1998; S. L. McFadden, Henselman, & Zheng, 1999; Ward, 1966). Nelson and colleagues found that the burden of ONIHL was greatest amongst younger workers and in certain occupations such as production workers and in economic sectors such as manufacturing, mining, and construction (Nelson et al., 2005). These estimates should be viewed cautiously as there are some questions regarding the study’s methodology. For example, US data was modified to be used in all sub regions and different hearing loss definitions for age-related hearing loss and NIHL were used. These and other methodological limitations may have led to either under- or overestimation of the burden of ONIHL. However having considered the limitations and the absence of global estimates on the burden of ONIHL, this study provides reasonable estimates that can be used as a guide.

Approximately 15% of Americans (26 million) have NIHL caused by either occupational noise exposure or leisure noise (NIDCD, 2008). A National Health Interview Survey (Tak & Calvert, 2008) conducted between 1997 and 2003 involving workers aged 18 to 65 years determined that occupational noise exposure could be attributed to 24% of the overall hearing loss in the US. The survey also established that hearing impairment was most common in the railway, mining, and primary metal manufacturing industries and mechanics, machine operators, and transportation equipment operators were most at risk of acquiring NIHL (Tak & Calvert, 2008). The study relied on self-reporting; however, its findings are supported by a recent study that utilised 1,122,722 worker audiograms from 2000 to 2008 to determine ONIHL in the US (Masterson et al., 2013). The analysis of the worker audiograms determined that 18% of the sample had hearing loss and workers from mining and manufacturing had the highest prevalence and risk of developing NIHL. However, Dobie (Dobie, 2008) and Nelson (Nelson et al., 2005) suggest that less than 10% of the total burden of hearing loss in the US can be attributed to occupational noise exposure. This is supported by a recent study which found lower prevalence and severity of hearing loss in the US currently than 40 years ago (Hoffman, Dobie, Ko, Themann, & Murphy, 2010). The authors speculated that the lower burden of hearing loss might reflect a decline in NIHL due to greater enforcement of hearing protection strategies and a reduction in manufacturing activities.

These estimates are not very different for countries in Europe as described in a 2005 European Agency for Safety and Health at Work report on noise exposure and hearing loss (European Agency for Safety and Health at Work, 2005). Figures from 2000-01 indicate that approximately 29% to 35% of the workforce was exposed to high levels of noise. The sectors with a high prevalence of NIHL were agriculture; forestry and fishing; mining; utilities; manufacturing and construction. Blue-collar workers such as process and machinery personnel, particularly apprentices, reported the highest rate of hearing problems.

In Australia, occupational noise exposure is responsible for 10% of total adult hearing loss and there were about 16,500 accepted ONIHL-related compensation claims between 2002 and 2007 (Safe Work Australia, 2010). The rate of compensation increased over a nine year period (2001 to 2009) from 491 to 523 claims per million employees (Safe Work Australia, 2012). Not surprisingly, 65% of compensation claims involved workers from manufacturing, construction, and transportation industries (Safe Work Australia, 2010).

2.2.3 **NIHL in New Zealand**

It is estimated that NIHL contributes 17 to 25% of total hearing impairment cases in New Zealand (Thorne et al., 2013). The prevalence of NIHL ($\geq$25dBHL$_{Ave1,2,3,4kHz}$) was estimated to be between 62,169 and 69,613 in 2006 and a total of 22. 5 to 25. 8% of hearing-impaired people have some hearing loss from occupational noise exposure (Thorne, Welch, Grynevych, John, et al., 2011). The Accident Compensation Corporation (ACC) of New Zealand paid out $193. 82M in NIHL claims for the period 1995 to 2006 and agriculture and fisheries workers, trade workers, machine operators and assemblers were making more than half (53%) of the new claims (Figure 2.2) (Thorne et al., 2008).

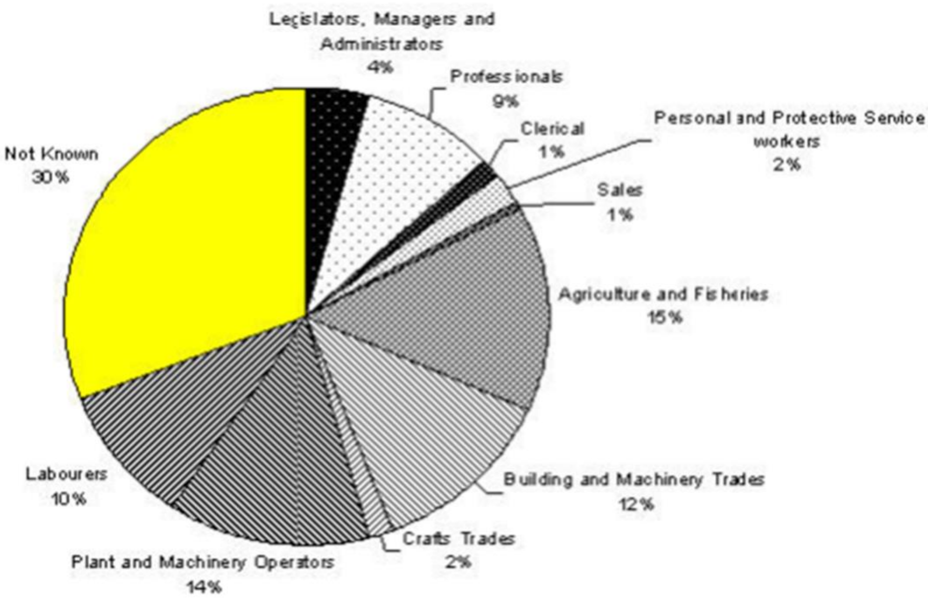

Figure 2.2 Distribution of new ACC claims by occupational categories for the period between July 1995 and June 2006 (Thorne et al., 2008).

However, these numbers have significantly dropped since 2009 after ACC amended its legislation to set a threshold of 6% hearing loss for claimants of NIHL. It is important to note that the 6% threshold of hearing loss is not reached until there has been significant damage to hearing. Pure tone measurement is used to diagnose NIHL in New Zealand and this process takes into account age, noise exposure, sex, and frequency to determine the percentage of hearing loss (OSH, 1994). This method is inconsistent because there is not a universal standard as to which frequencies make up the pure tone average (PTA). Hearing loss at low frequencies would be calculated using the lower frequencies from the audiogram (500, 1000 and 2000 Hz) and the PTA for high frequency hearing loss would be calculated using the higher frequencies from the audiogram (3000, 4000 and 6000 Hz). For hearing loss to be accepted for ACC cover:

- *The hearing loss must be caused by noise.*
- *The exposure to noise needs to be identified as having occurred at work.*
- *The exposure to injurious noise must not have occurred to a material extent away from work (material extent meaning that the non-work exposure acting alone could not have been sufficient to cause the NIHL).*
- *Workers exposed to such workplace noise must be at significantly greater risk of suffering NIHL compared with others not exposed to that environment. The comparison of risk is between people who generally perform work with such noise exposure and people in other work environments, not between the client and the general population. The fact that a client may be more at risk of suffering NIHL, due to continuous hazardous noise exposure is not relevant to this consideration.*
- *The work must be for pecuniary gain or profit. Unpaid work or work that involves only an allowance which is not subject to taxation (such as volunteer firemen, prisoners involved in work schemes) is not covered* (ACC and NZSOHNS 2011, pp. 4-5).

Importantly, this has implications for studies of hearing loss as the prevalence and incidence rates for hearing loss are influenced by how hearing loss is calculated and defined. In addition different agencies such as the Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), and International Standards Organisation (ISO) use different guidelines to specify frequencies used for PTA calculation (ISO 1999, 2013; NIOSH, 1998; OSHA, 1971). Similarly, the hearing threshold levels vary between different organisations. OSHA uses a 10 dB decrease in hearing ability as their hearing threshold level (OSHA, 1971); while New Zealand standards set a threshold of 6% hearing loss for claimants of NIHL. The 6% rated hearing disability calculation is based on hearing disability associated with losses of different levels at different frequencies and taking into account what would be expected to have occurred at those frequencies as a result of ageing (McBride, 2010).

The ACC data must be treated with caution as there was potential for bias in the dataset such as the low representation of claimants with Māori and Pacific ethnicities although these ethnicities are over-represented in noisy industries (Thorne et al., 2008). In addition, the absence of a clear demarcation between NIHL and age-related hearing loss in the process explained above highlights the limitations of the ACC's claims data on NIHL. It may be that not everyone who made a successful claim had hearing loss directly resulting from occupational noise exposure. However, in the absence of better diagnostic techniques, the ACC data has to be relied on as an indicator of NIHL in New Zealand.

The category of common claimants was also identified by another study which found that trade workers, plant and machine operators and assemblers (metal moulders, sheet metal workers) and elementary workers reported a high prevalence of exposure to loud noise more than a quarter of the time (Eng et al., 2010). The same study reported that only of 47% agricultural and fisheries workers reported using hearing protection devices. This is of concern especially when the agriculture industry is known to produce high levels of noise. McBride and colleagues (McBride, Firth, & Herbison, 2003) found that 17% of the 60 dairy and sheep farms surveyed in Southland for noise exposure exceeded 90dBA L_{eq} and approximately 78% of workers were observed to be not wearing hearing protection when working.

A recent study measuring noise exposure and hearing protection use in different sectors in New Zealand found that noise exposure levels for all workers ranged from 65 dBA to 113 dBA. On average, noise exposure levels were highest for production workers in agriculture, mining, construction, and manufacturing sectors. Ominously, dosimeter measurements established that almost 40% of production workers exceeded their total daily noise exposure limit of L_{Aeq8h} of 85 dB and 10% of these workers reported not using any hearing protection (John, Grynevych, Welch, McBride, & Thorne, 2013). Interestingly, the proportions of production workers exposed to noise levels in excess of 85 dBA L_{Aeq} in construction (67%), agriculture (58%) and manufacturing (43%) were far greater than WHO estimates of 18%, 20% and 22% respectively (Concha-Barrientos, Campbell-Lendrum, & Steenland, 2004).

2.2.4 **Standards and legislation**

The 3 dB trading rate and exposure limit of 85 dBA will be adopted in this thesis as they align with New Zealand standards. According to the equal-energy hypothesis, the allowable exposure time is reduced by half for every 3 dB increase (doubling) in noise level (SA/SNZ, 2005). Thus eight hours at 85 dB carries the same auditory risk as four hours at 88 dB, two hours at 91 dB, and so on. In other words, hearing loss caused by a sound is directly proportional to the average amount of sound energy received over time. However, the

Occupational Safety and Health Administration of the US Department of Labour (OSHA) use a trading rate of 5 dB instead of 3 dB to explain the intermittent nature of shorter exposures throughout the day. OSHA states that the 3 dB exchange is based on data reflecting zero intermittency while the 5 dB exchange rate takes into consideration intermittent noise that is common in industry (Dear, 2006). Based on the 5 dB ratings, the assumption is that 16 hours at 85 dB carries the same auditory risk as eight hours at 90 dB, four hours at 95 dB, two hours at 100 dB, and so on (Dobie, 2001). The more lenient OSHA values allow for higher exposures for longer durations and the more conservative ISO values recommend lower exposures for shorter durations.

The recommended maximum sound dose varies for the unprotected ear with the suitable dose being 85 dB (A) over eight hours (Aw et al., 2007). Regulation 11 of the Health and Safety in Employment Regulations (1995) stipulates the national standard for continuous noise exposure as ($L_{Aeq,8h}$) of 85 dB(A) with an exchange rate of 3 dB, while the maximum peak level permitted is 140 dB(C) (Department of Labour, 1995). This is in line with International standards (ISO 1999, 2013) which recommend that noise levels should not exceed 85dB(A) over an eight-hour period. This standard is based on an eight-hour workday, five days per week over a 40-year working lifetime and the assumption that no significant noise exposure occurs after work hours. However in the US, 90 dBA time weighted average (TWA) is the common minimum exposure limit and between 85 and 90 dB in Canada (Dobie, 2001).

The WHO defines disabling hearing impairment in adults as a permanent hearing threshold level of 41 dB or greater. The hearing threshold level is based on the better ear average over the 500, 1000, 2000, and 4000 Hz frequencies (WHO, 1991). The grades of hearing impairment and corresponding hearing ability are described in Table 2.3 (WHO, 2012).

The ISO Standard 1999 gives a method for calculating NIHL caused by all types of noise (continuous, intermittent, and impulse) during working hours. The relationship between noise exposure ($LA_{eq}8h$) and NIHL are given for frequencies of 500-6000 Hz for exposure times of up to 40 years. This shows that NIHL mostly occurs in the high frequency range of 3000 to 6000 Hz. However, with increased noise intensity and exposure time, NIHL can also occur at 2000 Hz (ISO, 1990).

Figure 2.3 Grades of hearing impairment

Grade of impairment	Corresponding audiometric ISO value	Performance	Recommendations
0 - No impairment	25 dB or better (better ear)	No or very slight hearing problems. Able to hear whispers.	
1 - Slight impairment	26-40 dB (better ear)	Able to hear and repeat words spoken in normal voice at 1 metre.	Counselling. Hearing aids may be needed.
2 - Moderate impairment	41-60 dB (better ear)	Able to hear and repeat words spoken in raised voice at 1 metre.	Hearing aids usually recommended.
3 - Severe impairment	61-80 dB (better ear)	Able to hear some words when shouted into better ear.	Hearing aids needed. If no hearing aids available, lip-reading and signing should be taught.
4 - Profound impairment including deafness	81 dB or greater (better ear)	Unable to hear and understand even a shouted voice.	Hearing aids may help understanding words. Additional rehabilitation needed. Lip-reading and sometimes signing essential.

Grades 2, 3 and 4 are classified as disabling hearing impairment in adults.
The audiometric ISO values are averages of values at 500, 1000, 2000, 4000 Hz. (ISO, 1990)

2.3. Prevention of NIHL in workplaces

Occupational noise exposure in workplaces needs to be controlled by engineering and administrative strategies in the first instance. This is accomplished by controlling the noise source noise path and the receiver (Suter, 2002). However, controls that protect the individual, such as the use of hearing protection devices (HPDs), takes precedence over source controls due to feasibility and cost factors (Roelofs et al., 2003).

2.3.1 **Engineering control**

Engineering controls form the primary preventive action because they reduce or eliminate noise at source most effectively, affecting everyone in the work environment (Suter, 2012). Noise sources must be identified and noise levels measured before engineering-control strategies are considered. Key considerations include the type, level, frequency, sources, and pathways of noise and room acoustics. Clearly, design modifications to machines, processes and buildings offer the best control options (Hansen & Goelzer, 2001). A number of methods are utilised to prevent noise at source as shown below (Aw et al., 2007, p. 165):

- *substitution of a quieter process, i. e. welding not riveting*
- *avoidance or cushioning of the impacts*
- *introduction of, or increase in, the amount of damping*
- *reduction of turbulence of air exhausts and jets by silencers, either of the 'absorption' type, where the attenuation (insertion loss) is achieved by the lining of absorbent material, or the 'expansion chamber' type, where the insertion loss is achieved by acoustic mismatch between the volume of the chamber and the inlet/outlet pipe (a number are now a hybrid of these two types)*
- *use of low-noise air nozzles and pneumatic ejectors*
- *matching the pressure of supplied air to the needs of the air-powered equipment*
- *avoidance of 'chapping' air streams by rotating components*
- *improved design of fans, fan casings, compressors, etc*
- *dynamic balancing of rotating parts*
- *use of better quality control in design and manufacturing procedures to obviate the need for post-hoc rectification*
- *better machine maintenance*
- *limiting the duration that a noisy machine or part of a machine is in use.*

The next most appropriate action following efforts to prevent noise at source is to minimise the transmission of noise from source to worker (Suter, 2012). A number of methods that minimise noise exposure are given below (Aw et al., 2007, pp. 165-66):

- *use of correctly chosen reflecting and absorbent barriers for the direct component*
- *use of correctly chosen absorbent material on surrounding surfaces to minimise the reflected component*
- *use of anti-vibration mountings under machines*
- *enclosure of the source*
- *provision of a noise refuge*
- *increasing the distance between the source and receiver*
- *segregation of noisy processes*
- *use of remote control*
- *use of flexible exhaust hoses to ensure that the exhaust is discharged away from the operator(s)*

- *active noise control, where the addition of a second source with the same amplitude, but with a reversed phase, causes destructive superposition.*

While engineering and administrative controls are primary noise prevention options, they are not given first priority as there appears to be a misperception that primary control methods are too difficult and expensive (Suter, 2012). In addition, lack of noise emission information for equipment and the lack of qualified acoustical personnel have acted as barriers to primary noise control in industry (Suter, 2012).

2.3.2 **Administrative controls**

Administrative controls focus on the reduction of noise exposure by limiting the time a worker spends in noisy environments. This may involve the rotation of workers out of noisy jobs to areas and tasks producing safer levels of noise. However, these administrative controls may not be practical as they could interfere with work processes and productivity (Suter, 2002). A more practical administrative control is to provide noise-free recreational areas such as lunchrooms for workers. This would ensure that workers are not constantly exposed to hazardous noise levels during breaks (Suter, Franks, National Institute for Occupational, & Health, 1990).

2.3.3 **Hearing protection devices (HPDs)**

When it is not possible to eliminate noise at source and pathway via engineering and administrative controls, HPDs are used for immediate and effective protection against occupational noise exposure. HPDs attenuate the sound at the eardrum so less energy reaches the cochlea, preventing hearing damage. The different types of HPDs include ear inserts/plugs, earmuffs, canal caps and electronic hearing protection.

Ear inserts/plugs

(Markowitz et al., 2006) describe ear inserts/plugs as formable, premoulded and custom-moulded (Figure 2.4) and are designed to fit inside the ear canal to attenuate loud sounds. They also tend to work comfortably with other protection equipment such as hard hats and goggles (for more information, please refer to Markowitz, et al. 2006). Instructional training covering demonstration of fitting and verification of correct fit, followed by earplug insertion practice sessions has the capacity to enhance the attenuation performance considerably for both formable and pre-moulded devices (Joseph et al., 2007). This is because incorrect fitting of earplugs does not achieve a good seal in the ear rendering its performance ineffective and several studies have shown that manufacturers' laboratory-based attenuation ratings are overestimates of actual attenuation in workplaces (Berger et al., 1998; Frank, Greer, & Magistro, 1997; Franks, Murphy, Johnson, & Harris, 2000; Park & Casali, 1991).

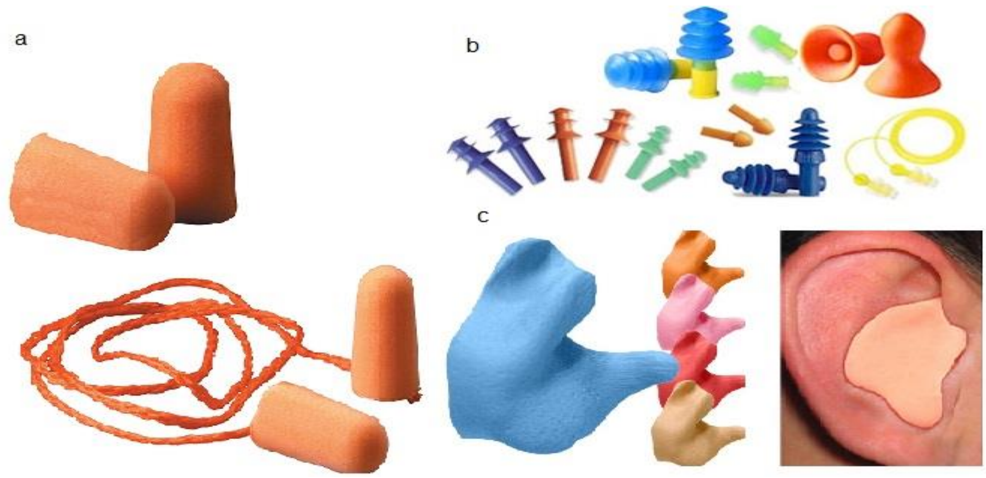

Figure 2.4 Examples of common types of earplugs: (a) formable; (b) premoulded; and (c) custom-moulded

Earmuffs

Earmuffs (Figure 2.5) are worn over the head providing an acoustic seal to reduce the level of noise reaching the inner ear and are held in place with a headband made of plastic and lined with acoustic foam (Markowitz et al., 2006). Unfortunately, the use of earmuffs in warm environments is often uncomfortable due to resulting perspiration around the ear. Furthermore, obstruction when wearing earmuffs over hair or glasses will not provide the expected attenuation due to reduced tension and inadequate seal of the ear (Action, 1977).

Figure 2.5 Examples of different types of earmuffs: (a) common passive earmuffs; (b) neck band earmuffs for welding; (c) hard hat earmuffs; and (d) foldable earmuffs

Canal caps

Canal caps (Figure 2.6) are made of two soft plastic conical caps held in place by a springy headband. Hearing protection is achieved by sealing the external opening of the ear canal. They do not provide as much attenuation as earplugs or earmuffs as they only close the ear opening without fitting deeply into the ear canal. Canal caps can be used in numerous positions and are most useful for workers who constantly remove and replace HPDs while working (Markowitz et al., 2006).

Figure 2.6 Canal caps

Electronic hearing protection

Electronic hearing protection devices (Figure 2.7), also known as active HPDs, use electronic circuitry to actively reduce noise and enable communication. These HPDs may be level-dependent where they attenuate for high-level sounds but allow low-level sound to enter the ear naturally. This is especially useful when the worker needs to hear warning signals and be able to converse with co-workers but also be protected from intermittent noise or unexpected impact sounds (Suter, 2002). This is done by the use of an amplifier built into the earmuffs that permits the passage of low- or moderate-level sounds; but at sounds above 85 dBA the amplification ceases and the earmuffs attenuate like ordinary passive HPDs. Noise-cancellation HPDs generate a signal within the protector that cancels certain incoming sounds and are most effective at reducing low-frequency noise. Electronic HPDs also have the capability to enhance communication. Some electronic HPDs use microphones mounted in the earcups that feed the signal to an amplifying circuit with built-in-limiter where the maximum output cannot exceed 85 dBA. At high frequencies, active HPDs act as passive hearing protection with good attenuation. Other types of communication earmuffs obtain their signals from an external radio source that is connected via wires or wireless systems utilising FM or Bluetooth technology (Suter, 2002). Some electronic HPDs also include FM radio and external audio input capabilities. Electronic HPDs are more expensive than passive HPDs and may fail electronically (Markowitz et al., 2006).

Figure 2.7 Electronic hearing protection devices

2.3.4 **Hearing protection attenuation**

Hearing protection attenuation can be compromised by leakage around the HPD, sound generated by HPD vibration, sound transmission via HPD material and bone and tissue conduction. The SLC80 rating of HPDs is used in New Zealand to guide the different classes (Table 2.2) of hearing protection available for different levels of noise exposure and attenuation requirements (SA/SNZ, 2002). The SLC80 rating of HPDs is a simple number and class rating derived from a test procedure as outlined in the AS/NZS 1270:2002 (SA/SNZ, 2002). It is an estimate of the amount of protection attained by 80% of the users based on laboratory testing of inexperienced users. By contrast, the noise reduction rating (NRR), a single number rating, is used in the US to describe that amount of noise that can be reduced by a particular HPD (Suter, 2002). For example, the use of a HPD with a NRR of 17 dB will permit 78 dB of noise to enter the ear in environments where the noise level is 95 dB. Despite different standards, in order to gain maximum protection from HPDs, they need to be worn 100% of the time (Gerges, Vedsmand, & Lester, 2001). When HPDs are worn for half of the exposure time, then the total exposure is reduced by half signifying a reduction equivalent to a 3 dB change in sound pressure level. For example, a worker in 94dBA noise exposure level will receive 74dBA noise exposure at the eardrum if correctly using HPDs with 30dB attenuation. However, if HPDs are not worn for 100% of the exposure time, the protective value of HPDs is compromised (W. Williams, 2009).

Table 2.2 Different classes of HPDs in New Zealand as defined by the SLC80 rating (SA/SNZ, 2002)

Class	Noise Level dB(A)	SLC $_{80}$ Range (dB)
1	less than 90	10 to 13
2	90 to less than 95	14 to 17
3	95 to less than 100	18 to 21
4	100 to less than 105	22 to 25
5	105 to less than 110	26 or greater

2.3.5 **Hearing conservation programmes (HCPs)**

HCPs are designed to protect hearing and require time and effort to establish and maintain. They consist of a number of strategies (Alberti, 2012, pp.273-86) that are aimed at eliminating unwanted noise and most importantly protecting workers against NIHL:

1. Identifying and quantifying a hazard:
   - *sound level measurements and dosimetry*
   - *clear warning signs must be posted to wear HPDs in areas where noise levels are above 85 dBA*
2. Removing, or at least reducing the hazard to a safe level:
   - *engineering controls*
   - *administrative controls*
3. Discussion with, and education of, the workforce about the problem and solutions:
   - *good educational programmes are used to motivate the workers to use HPDs for their own wellbeing*
4. Hearing screening (pre-screening, regularly during employment and on retirement):
   - *screening of hearing thresholds*
   - *detection of abnormal thresholds*
   - *detection of changes in thresholds over time in individuals*
   - *monitoring of the programme's effectiveness*
   - *Tests need to be conducted in quiet areas using calibrated equipment twelve hours after exposure to noise to avoid TTS contamination. It is important to note*

that hearing tests present opportunities to reinforce positive hearing-protection behaviour messages

5. Provision of personal hearing protectors (HPD):
   - *instruction in their use*
   - *ensuring HPDs are properly maintained and used. This can be easily undertaken during annual hearing tests and regularly throughout the year*
6. Monitoring:
   - *workplace sound*
   - *hearing tests of workforce*
   - *other hazards to hearing e. g. volatile hydrocarbons*
   - *regular analysis of sound levels, annual hearing tests, and worker practices and health will help evaluate the effectiveness of the HCP*
7. Keeping accurate records:
   - *well-maintained records help to track workers over time and assist in the early detection of failing hearing capabilities*
8. Engineering out the hazards.
9. Monitoring the effectiveness of the programme by repeated hearing testing and repeated sound level measurement.

The existence of a HCP does not guarantee the prevention of NIHL but successful HCPs would benefit both the employer and employees (Suter et al., 1990). While HCPs are designed to protect hearing (Pell, 1973), they appear to be largely ineffective as they are poorly understood and implemented (Alberti, 2012). The effectiveness of HCPs can be determined by assessing the completeness and quality of the components (Suter et al., 1990) and the evaluating audiometric results (Pell, 1973; Suter et al., 1990). It is important that audiometric data should not be used alone to assess the effectiveness of HCPs as other factors such as prior hearing loss can affect test variability (Dobie, 1995).

A 2009 review of the US hearing conservation amendment of 1981 by Suter concluded that noise regulations were outdated, there was an over-reliance on HPDs, and engineering noise-control strategies were not being enforced. In addition, most companies did not evaluate HCPs even though tools were available, and this has contributed to the failure to reduce noise exposure levels in workplaces (Suter, 2009). A Cochrane review (Verbeek et al., 2012) of interventions to prevent NIHL that included 25 studies found that there is some evidence that legislation (Joy & Middendorf, 2007) can reduce NIHL and the effectiveness of HPDs depends on their proper use. In addition, there is contradictory evidence that HCPs are effective in the long term and that they need to be better implemented and reinforced to effectively prevent NIHL (Verbeek et al., 2012). Sadly, other components of HCPs had little or no effect on reducing the risks of hearing loss in occupational settings. This review supports the findings of an earlier study by Dobie (Dobie, 1995) which found that studies assessing the effectiveness of HCPs lacked methodological rigour and failed to provide significant evidence that they were effective in preventing NIHL. While conservation programmes can be effective at identifying, monitoring, and lessening the severity of hearing loss, there is a lack of strong scientific evidence that HCPs can completely eliminate NIHL (Dobie, 1995; Verbeek et al., 2012).

2.3.6 **Legislation related to NIHL prevention for New Zealand workplaces**

The Health and Safety in Employment Act 1992 (Department of Labour, 1992), the Health And Safety in Employment Regulations 1995 (Department of Labour, 1995) and the Approved Code of Practice for the Management of Noise in the Workplace (Department of Labour, 1996) require control of the exposure of people to noise at work. Regulation 11 of the Health and Safety in Employment Regulations 1995 stipulates that no employee shall be subjected to noise levels over 85 dBA longer than eight hours. Generally, the legislation requires employers to protect employees from excessive noise exposure by:

- *the determination and identification of noise levels*
- *quietening of plant and equipment*
- *reducing the amount of time individuals spend in high-noise levels*
- *providing HPDs and appropriate training for people working in noisy areas*
- *monitoring workers' hearing through audiometric hearing tests.*

Generally, the legislation requires employees to:

- *use any noise control equipment provided in the workplace*
- *wear personal hearing protectors in noisy areas.*

The legislation and standards outline the duties of employers and employees, which complement HCP components.

2.3.7 **The use of HPDs in workplaces**

While the use of HPDs is recommended as a secondary action against hazardous noise, they are inconsistently and incorrectly used in practice reducing their utility as a preventive measure against NIHL (W. Williams, 2009). A 14-year follow-up study at an automobile plant involving 264 workers found that the proportion of time spent wearing HPDs was an important factor associated with preserving hearing at frequencies above 1000 Hz (Brink, Talbott, Burks, & Palmer, 2002). The study compared audiometric results of workers who wore HPDs less than 33% of the time with workers who wore HPDs more than 33% of the time when exposed to noise. A significant correlation was found between the percentage of time the participants wore HPDs during their working time and their total hearing loss experienced ($p<0.0001$). However, several studies found poor consistency of HPD use in workers: 27% used HPDs always when exposed to noise and 45% reported never using them (Arezes & Miguel, 2008); on average HPDs used 41% of the time when exposed to noise levels above 85dBA (Edelson et al., 2009); 50% of workers were observed to use HPDs when exposed to hazardous levels of noise (Hansia & Dickinson, 2010); reported HPD use was 34% of the time it was required (Hong, Chin, & Samo, 2013). These findings of poor hearing protection behaviour suggest that there are factors that act as barriers against consistent HPD use in noisy workplaces.

2.3.8 **Predictors of HPD use**

Several factors are associated with HPD use amongst workers. While some factors positively influence workers' HPD behaviour, other factors limit their ability to consistently and correctly use hearing protection.

Perceived benefits (value of use)

Several studies have shown that workers who understand and believe that the use of HPDs is beneficial to them are more likely to use them consistently and correctly. The benefits of using hearing protection include keeping out annoying aspects of noise and the preservation of hearing (Kim, Jeong, & Hong, 2010; Lusk, Ronis, & Hogan, 1997; Lusk, Ronis, Kerr, & Atwood, 1994; McCullagh, Lusk, & Ronis, 2002; McCullagh, Ronis, & Lusk, 2010; Melamed, Rabinowitz, Feiner, Weisberg, & Ribak, 1996; Ronis, Hong, & Lusk, 2006). These studies were based on theoretical models that were able to predict large variance in HPD use and affirm the usefulness of theoretical models in predicting hearing-protection behaviour. However, there is also evidence that some workers are fully aware of the benefits of proper and consistent use of HPDs but still hold poor attitudes that justify their non-use. Murray-Johnson and colleagues reported that older miners acknowledged the protective value of HPDs but held attitudes such as “it can be hard to teach an old dog new tricks” (Murray-Johnson et al., 2004). Therefore, it is not only important to promote usefulness of HPDs, the harmful and severe outcomes of NIHL must be advocated to change behaviour (Janz & Becker, 1984).

Risk perception

Risk perception has been assessed with items related to individual risk perception, perception of noise effects, perception of the value of HPDs on eliminating risk, safety culture and risk behaviour. Arezes and colleagues (Arezes & Miguel, 2005a) reported good reliability (0. 73-0. 87) of the items (noise source, knowledge about noise, knowledge about hearing protection, and self-efficacy) used to assess the effect of risk perception on HPD use. When workers do not believe or are not aware of the dangerous levels of noise in their workplace, they are less likely to use HPDs consistently. In addition, some workers may feel that the levels of noise they are exposed to may not harm them or that they are ‘hardened’ against noise (Arezes & Miguel, 2005a, 2005b, 2006a; Kahan & Ross, 1994; Melamed et al., 1996; Robertson, Kerr, Garcia, & Halterman, 2007). This suggests that risk perception is a good predictor of hearing protection behaviour in workers.

Interpersonal influences

Social support and positive hearing health norms within workplaces where workers remind each other to wear HPDs is likely to have a positive influence on hearing-protection behaviour (Kim et al., 2010; Tantranont et al., 2009; Torp & Grogaard, 2009; Torp, Grogaard, Moen, & Bratveit, 2005). However, two studies reported unacceptable reliability levels (theta<0. 70) for items measuring interpersonal modelling suggesting the need for further development and testing of these measures (McCullagh et al., 2002; McCullagh et al., 2010).

Communication difficulties

The use of HPDs is perceived to hinder communication by limiting the ability of workers to hear warnings regarding potential hazards and accidents in noisy workplaces (Kahan & Ross, 1994; Morata et al., 2005; Patel et al., 2001; Tantranont et al., 2009; W. Williams, 2009). The qualitative study by Patel and colleagues (Patel et al., 2001) summarised mining workers' attitudes towards HPD use with regards to communication difficulties as, *"It's hard to carry on a conversation. . . hear orders to be able to work together"* and *"I didn't wear 'em so that I could hear better my crew and the roof talk. "* These views suggest fear of being unable to hear warnings signals and feelings of vulnerability to accidents when wearing HPDs. Interestingly, workers who wore HPDs reported no such problems when using hearing protection. Contrary to beliefs that HPDs inhibit speech discrimination, HPDs have little or no effect on the ability to understand speech in moderate background noise (Berger, 1980; Howell & Martin, 1975).

Self-efficacy

Self-efficacy is the measure of workers' ability to correctly and consistently use HPDs at work. Workers generally avoid wearing HPDs when they are not confident in using them. Low self-efficacy can lead to de-motivation and discouragement leading to poor hearing-protection behaviour (Arezes & Miguel, 2005b, 2006a; Lusk et al., 1997; Lusk et al., 1994; Melamed et al., 1996). Arezes and Miguel reported that approximately 25% of workers in their study did not receive any instruction regarding the correct use of HPDs and that this could contribute to workers' limited self-efficacy to use HPDs. Self-efficacy is also related to the ability to choose appropriate HPDs to counter negative perceptions such as bulkiness, discomfort and communication problems (Arezes & Miguel, 2006a). Similarly, a stepwise analysis of HPD use found that self-efficacy was a strong predictor that explained a 42% variance in HPD use (Melamed et al., 1996).

Accessibility and availability

An important proviso to good hearing-protection behaviour is the availability of good quality, properly fitted HPDs. Positive beliefs, attitudes, and intentions will go to waste if HPDs are difficult to obtain. Furthermore the opportunity to choose from different types of HPDs positively influences HPD use as different workers have varying preferences with respect to comfort and design (Arezes & Miguel, 2005a, 2006a; McCullagh et al., 2002). A study of farmers found that greater accessibility and availability of HPDs (OR = 1. 75, p<0. 01) was positively related to HPD use suggesting that higher access and availability of HPDs increases the likelihood of HPD use. This was measured by seven items related to access/availability and rated using a 6-point scale with response options of strongly agree to strongly disagree to questions such as, “the supply of ear plugs on the farm is not close to where they are needed” (McCullagh et al., 2010). This suggests that even in the presence of increased levels of knowledge, attitudes, and the presence of barriers such as poor access and availability will limit the use of hearing protection amongst workers.

Uncomfortable nature of HPDs

HPDs, especially earmuffs, are bulky and heavy. This makes them cumbersome to use with other personal protective equipment such as hard hats and goggles. HPDs have been reported to cause discomfort after prolonged use due to factors such as size of device, shape of ear cups, irritation of skin on contact with the device, temperature rise inside the ear cup, increased perspiration, and the clamping force causing the disruption of blood pressure around the ears (Casali & Grenell, 1990; Gerges, 2012; W. Williams, 2007, 2009). The level of discomfort can increase workers’ dissatisfaction and, consequently, misuse of HPDs, which may significantly reduce the attenuation effectiveness of HPDs (Arezes & Miguel, 2002). These studies provided evidence that the provision of HPDs that are agreeable to the worker may help to increase HPD use in noisy industries.

Safety culture

An organisation’s safety culture relates to the combined characteristics and attitudes of both the organisation and individuals, concerning the protection of everyone in the organisation. It may be considered a social phenomenon reflected by shared perceptions of safety across all levels of the organisation that define an organisation’s health and safety management (Glendon, Clarke, & McKenna, 2006). The recognition and enforcement of hearing protection rules constantly reminds workers of noise as a hazard. In addition, the provision of HPDs and facilitation of training programmes aimed at promoting HPD use reinforces an organisation’s commitment to prevent NIHL (Arezes & Miguel, 2005b; Edelson et al., 2009). This is supported by findings of several studies which state that management support and influence were reflected in the implementation and enforcement of legislation and the correct and regular use of HPDs helps reduce the risk of developing hearing loss in workers (Bruhl, Ivarsson, & Toremalm, 1994; Heyer et al., 2011; Joy & Middendorf, 2007). Another crucial aspect of safety culture is that individuals and the environment exist in a state of reciprocal determinism where they influence each other to define the safety and health outcomes of the organisation (Cooper, 2000). Cooper and colleagues suggest that safety culture can be measured via safety climate questionnaires (attitudes and perceptions), behavioural checklists (actual ongoing safety-related behaviour), and safety management system audits/ inspections (situational features such as availability and quality of hearing protection). Edelson and colleagues found that safety climate affected HPD use through indirect routes such as perceived risk and the value placed on HPD use (Edelson et al., 2009). In addition, the work environment, personal motivation, and perception of workplace physical strain, that underline the safety climate, have also been found to be strong predictors of HPD use amongst workers (Arezes & Miguel, 2008). These findings suggest that management support for HPD use, motivation training and workers' perceived safety climate appear to be important factors in influencing HPD use.

This section has highlighted several factors that act as predictors of HPD use. These factors are either internal influences or external influences that shape hearing protection use amongst workers. It appears that these influences vary for each person and work setting. Therefore it is important to identify these influences and target them to promote hearing protection behaviour in workplaces.

2.3.9 **NIHL prevention intervention studies**

Similar to health promotion intervention studies aimed at preventing and controlling communicable diseases (Angus et al., 2013), most NIHL prevention intervention studies focus on the individual and intrapersonal factors that influence behaviour (Laird, McBride, et al., 2011). Several studies have targeted intrapersonal predictors of HPD use to develop interventions to promote hearing-protection behaviour (Gates & Jones, 2007; Hong, Ronis, Lusk, & Kee, 2006; Kerr, Savik, Monsen, & Lusk, 2007; Lusk, Eakin, Kazanis, & McCullagh, 2004; Lusk et al., 1999; Lusk et al., 2003; Neitzel et al., 2008; Ronis et al., 2006). It was reported that value of use; barriers; self-efficacy; situational factors; gender; and age were significant predictors of factory workers' use of HPDs and that value of use; barriers; self-efficacy; perceived health competence; age; and gender were significant predictors of construction workers' use of HPDs (Kerr, Lusk, & Ronis, 2002; Lusk et al., 1997; Lusk et al., 1994; Raymond, Hong, Lusk, & Ronis, 2006). While some studies detected improvement in reported consistent use of HPDs; 29 to 57% of the time at eight weeks post-intervention (Neitzel et al., 2008); 42 to 50% of the time at one year (Kerr et al., 2007); 51 to 58% of the time at one year (Hong et al., 2006); 79 to 84% of the time at 18 months (Lusk et al., 2003); 44 to 53% of the time at 10 to 12 months (Lusk et al., 1999); these improvements were minimal and insufficient to prevent NIHL.

(Lusk et al., 1999) conducted a randomised controlled trial to assess the effectiveness of an intervention that used a 20-minute video, pamphlets, and guided practice session to increase HPD use among construction workers and a sample of plumber/pipe fitter trainers. The intervention was responsible for improving HPD use from 44% to 53% of the time they should be used. While this study reported a significant increase in HPD use, the improvements are inadequate considering they did not achieve 100% use of HPD in high noise exposure. In addition, the there was a high risk of attrition bias due to a high withdrawal rate of 24% in this study. This may suggest that only highly motivated workers participated in post-intervention measurements and that these workers already had good hearing protection behaviour. Similarly, another study carried out in the USA in a large automatic factory had a dropout rate of 47% (Lusk et al., 2003). A randomized controlled design was used to compare an intervention tailored to each worker's specific responses to survey items with a non-tailored predictor-based intervention and standard control video intervention. The interventions were worker-imitated and delivered via computers. Workers who received the tailored intervention reported significant post-test increases in their use of hearing protection. However, there was a small improvement in HPD use of 4% increasing from 79% pre-test to 83% post-test. The study demonstrated that tailored intervention were more effective in improving HPD use amongst workers.

Subjective norms (co-worker, supervisor and spousal support for HPD use) have also been found to be the significant factors associated with HPD use in workplaces (Quick et al., 2008). However, this study had a high degree of bias, as the response rate post-intervention was only 28%. This may suggest that workers who participated at follow-up were those who acknowledged interpersonal influences and had reasonably better hearing protection behaviour. A few studies have also investigated the effect of legislations and regulations related to noise control and hearing conservation (Brink et al., 2002; Davies, Marion, & Teschke, 2008; Joy & Middendorf, 2007). These studies showed that the implementation of hearing loss prevention programmes improved HPD use from 72% to 91% over 18 years (Davies et al., 2008); 61% to 89% over 17 years (Joy & Middendorf, 2007); and 5% to 100% over 17 years (Brink et al., 2002). In addition, the daily monitoring of at-ear exposure along with regular feedback on noise exposure from supervisors improved the effectiveness of hearing conservation programmes by controlling further increment in high-frequency hearing loss in workers (Rabinowitz et al., 2011). However, (Daniell et al., 2006) reported that most companies were not compliant with noise regulations and that there were significant gaps in implementing hearing loss prevention programmes. This suggests that poor implementation, and enforcement of legislative strategies and programmes hinder hearing conservation efforts in workplaces (Dobie, 1995) and organisational support and efficiency is required to effectively prevent NIHL (Leinster, Baum, Tong, & Whitehead, 1994).

One study looked at removing the communication barrier to HPD use where average temporary threshold shift was found to be lower (5. 8 dB HL) for workers using active noise cancellation hearing protectors than conventional protectors at 4 kHz over four hours in a noisy working environment (Horie, 2002). This could suggest that workers with the active protectors worn their HPDs continuously, as they did not need to remove them to communicate. However, the workers reported the active protectors as heavy and cumbersome. Despite this design flaw, active hearing protectors appear to offer promising intervention opportunities.

Multi-factorial interventions that have combined strategies such as noise monitoring, screening, and training that target supervisors and employees may offer better NIHL-prevention outcomes. Hughson and colleagues (Hughson, Mulholland, & Cowie, 2002) designed interventions to improve various factors influencing workers' hearing-protection behaviour. These participatory and interactive interventions included basic noise awareness training, provision of alternative types of HPDs, and facilitating feedback and communication training for managers to encourage workers towards positive hearing-protection behaviour. Another multi-factorial study assessing the effect of daily monitoring of noise exposure inside HPDs found that workers receiving daily exposure feedback had reduced rates of hearing loss, suggesting improvement in NIHL strategies over time (Rabinowitz et al., 2011). Since this four-year study was mandatory, supervisor engagement and increased enforcement of rules could be other factors besides the use of the monitoring device that were responsible for the improvement in hearing-protection behaviour. However, even if all these factors were responsible for improved hearing-protection behaviour, it appears that regular noise exposure monitoring motivates both employers and employees towards positive hearing-protection behaviour.

Gates and colleagues (Gates & Jones, 2007) also used a multi-factorial approach consisting of educational sessions, mailed reminders, noise assessment with feedback and provision of

HPDs in a study involving 25 farmers. The intervention was effective in improving HPD use one and two months after the implementation of the programme; however, this was not sustained at the three-month time point. The study had a very small intervention group of five due to a large dropout rate (37%). Similarly, Seixas and colleagues (Seixas et al., 2011) measured the effect of a multi-component intervention utilising baseline training, follow-up booster 'toolbox' reinforcement and the use of personal noise-level indicators. They found that the group receiving all three components improved hearing-protection behaviour by 25% from the baseline and that this group was twice as likely to use HPDs as the group receiving only baseline training. However, the improvements in post-intervention meant that HPD use was neither statistically significant nor large enough (36% to 50%) to prevent NIHL in any group at the four-month follow-up.

The implementation of interventions and programmes may involve multiple strategies, such as education and advocacy. Communication has an essential role in delivering health-promoting messages but effectiveness depends on how the target audience acts and responds to the messages (Corcoran, 2007). An effective workplace health promotion intervention should incorporate a range of educational strategies at the individual level, while empowering the organisational level support to reinforce and encourage positive health actions. In addition, there should be potential for the dissemination of health-promoting messages by workers to their families and social networks at the community level (Harden, Peersman, Oliver, Mauthner, & Oakley, 1999; Wilson, 1996). Furthermore, active methods of training, such as hands-on demonstration, are more effective than passive methods of delivery such as lectures and flyer distribution. Although they may be more expensive in the short term, they are potentially less costly and more effective in the long term in ensuring healthy workplaces (Burke et al., 2006).

An interesting training method utilised an invisible ink exercise and 3D slide reels to increase knowledge about hearing and hearing protection amongst drillers (Barrett & Calhoun, 2007). The invisible ink exercise allowed the worker to answer questions and then use a special ink pen to reveal correct answers and feedback regarding noise and hearing protection. This method allowed for a more interactive session than standard lectures and was less technology dependent than computer-based exercises. The 3D slide reel was a self-teaching exercise demonstrating the correct use of HPDs and could be used anytime, especially before starting a workday. These training exercises improved knowledge on how to use hearing protection properly after the intervention. The mean score of correct responses on the pre-test was 6.13

(SD: 0.998) and the mean score in the post-test was 7.24 (SD: 0.978). The change in scores was statistically significant ($t = 9.38$) ($p < 0.001$). The interactive nature of the intervention appears to be a promising strategy to improve hearing protection behaviour and the prevention of NIHL in workplaces.

An informal face-to-face training session with emphasis placed on noise as a particular workplace hazard increased perceived susceptibility to hearing loss but did not elicit changes in self-efficacy, barriers, and benefits of HPD use post-training (W. Williams, Purdy, Storey, Nakhla, & Boon, 2007). The training session was a trainer-facilitated session that encouraged input from participants relating to their experiences regarding noise, hearing protection and legislation. The authors agreed that training programmes that just focus on attitudes and perceptions are not sufficient to improve hearing-protection behaviour.

While training methods may differ, the focus of the message delivered to promote safety behaviour is also very important. Stephenson and colleagues (Stephenson et al., 2005) found that positive messages were more effective in improving intrapersonal influences such as intentions, attitudes, and behaviour towards hearing protection than neutral and negative messages. Conversely, persuasive messages presenting threat of hearing loss and illustrating the use of HPDs to avert the threat can motivate workers to improve hearing-protection behaviour (S. W. Smith et al., 2008). In addition, these messages can act as a cue to action or a boost towards HPD use even in workers who had high efficacy and perceived threat levels before intervention (S. W. Smith et al., 2008).

Most interventions described above focussed on raising awareness regarding noise and hearing protection. In addition, the main outcome for most of the interventions was self-reported or intended use of HPDs. A few studies measured the effect of intervention on the predictors of HPD. These studies however, did not find significant changes in the predictors of hearing-protection behaviour. Most interventions reported improvements in short-term outcomes but these were not sustained in the long term. While multi-factorial studies have not provided definite evidence of long-term behaviour change due to limitations in study design, they appear to be relevant to industry and offer alternate intervention strategies to prevent NIHL. In addition, booster techniques applied at different time points post-intervention may sustain behaviour change in the long term. It appears that any intervention must be grounded in a theoretical framework and its components need to be assessed as predictors of hearing-protection behaviour. There is a need to shift from interventions that focus only on the workers to include all levels of the organisation to promote hearing health in workplaces. This would suggest the need for using ecological approaches, designed to influence all levels of the organisation, in behaviour change interventions to prevent NIHL in workplaces.

2.4. The principles for effective behaviour change interventions

Behaviour plays an important role in people's health by affecting the health of the person engaging in that behaviour (personal health behaviour), the health of other people (health-related behaviour), or intentionally improving health (heath-protective behaviour). Personal health behaviour not only concerns individual choices but is also influenced by environmental factors (B. G. Simons-Morton, McLeroy, & Wendel, 2012). For example, people engage in greater physical activity when the environment is adequately resourced to promote physical exercise such as walking and biking (Sallis et al., 2009). In addition, individual behaviour is also influenced by social influences, for example, passengers are more likely to wear seatbelts if the driver does (A. F. Williams, McCartt, & Geary, 2003) and young people are more likely to smoke if their friends do (B. G. Simons-Morton, Chen, Abroms, & Haynie, 2004). It is important to note that personal health behaviour is not always intentional as its existence may be attributed to other factors. For example, people who exercise may not do it for health reasons, but instead the desire to maintain a good appearance may be responsible for the behaviour (B. G. Simons-Morton et al., 2012). Furthermore, the WHO defines health promotion as, "the process of enabling people to increase control over, and to improve, their health. It moves beyond a focus on individual behaviour towards a wide range of social and environmental interventions" (WHO, 2013).

Health promotion programmes have three main goals (B. G. Simons-Morton et al., 2012, p 24):

1. *Providing services and activities that improve behaviour and health.*
2. *Strengthening the environment to support personal health behaviour.*
3. *Facilitating healthful behaviour.*

Health promotion is also about identifying changeable factors associated with the likelihood of behaviour change. These behaviour-change factors can be either cognitive in nature (knowledge, beliefs, attitudes related to behaviour) or environmental (concerned with the environmental influences on behaviour) (B. G. Simons-Morton et al., 2012). The environment influences the behaviour and the behaviour influences the environment and there are also interrelationships between the person, the behaviour, and the environment (Bandura, 1986), which is described as reciprocal determinism (Figure 2.8). Personal factors include personality attributes and cognitive processes of the individual. The environment includes physical and social aspects of influence (norms, structures, policies, practices, economic factors, and social influences), and behaviour is any resulting action undertaken by the individual. Reciprocal determinism is when the person, environment, and behaviour interact constantly (B. G. Simons-Morton et al., 2012). The personal and environmental influences can either support or hinder behaviour.

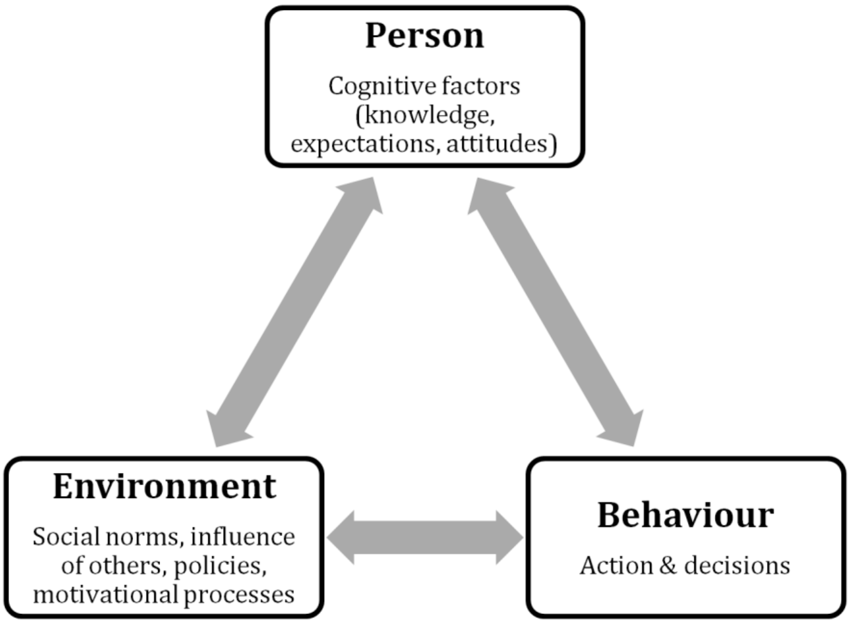

Figure 2.8 Reciprocal determinism, adapted from (Bandura, 1986).

The interaction of the individual and environmental influences has been conceptualised as occurring at multiple levels. These conceptualisations describe multilevel influences of behaviour and help to develop effective interventions at multiple levels. Importantly, many theories and principles of behaviour change can be applied at multiple levels to influence health-related behaviour (B. G. Simons-Morton et al., 2012). A recent review examining evidence for effective interventions using theories of behaviour change found that the most commonly applied behaviour change theories were those that intended to modify individual-level behaviour and that there was a need for more interventions using ecological models that incorporated more than one theory to effectively achieve the desired impact (Angus et al., 2013).

2.4.1 **Social ecological models**

The social ecological model is a framework that examines the multiple effects of behaviour affecting, and being affected by, the social and physical environment (Sallis, Owen, & Fisher, 2008). The first social ecological model was developed by Urie Bronfenbrenner and is called the Ecological Systems Theory (Bronfenbrenner, 1979). It proposed four types of behavioural influence:

- *microsystem: immediate environments (individual's knowledge, skills, attitudes, values, interpersonal relations)*
- *mesosystem: a system of connections between immediate environments (such as relations between the home and workplace)*
- *exosystem: external environmental settings, which only indirectly affect development (e. g. a parent's workplace); and*
- *macrosystem: the wider cultural context (broader social and cultural influences).*

According to Bronfenbrenner, people develop positive and negative behaviours through their interactions (direct and indirect) with these systems. The Ecological Model for Health Promotion (McLeroy, Bibeau, Steckler, & Glanz, 1988) is an extension of Bronfenbrenner's theory and is conceptualised by five societal levels (Figure 2.9) that correspond to Bronfenbrenner's levels which include:

1. *intrapersonal level (the individual and individual's characteristics such as knowledge, attitudes, values, and skills)*
2. *interpersonal level (social relationships, including family, peers, and colleague networks)*
3. *organisational level (organisational norms, policies and support)*
4. *community level (community norms, standards, and social networks); and*
5. *policy level (health-promoting policies and legislation and their regulation, interpretation, and enforcement).*

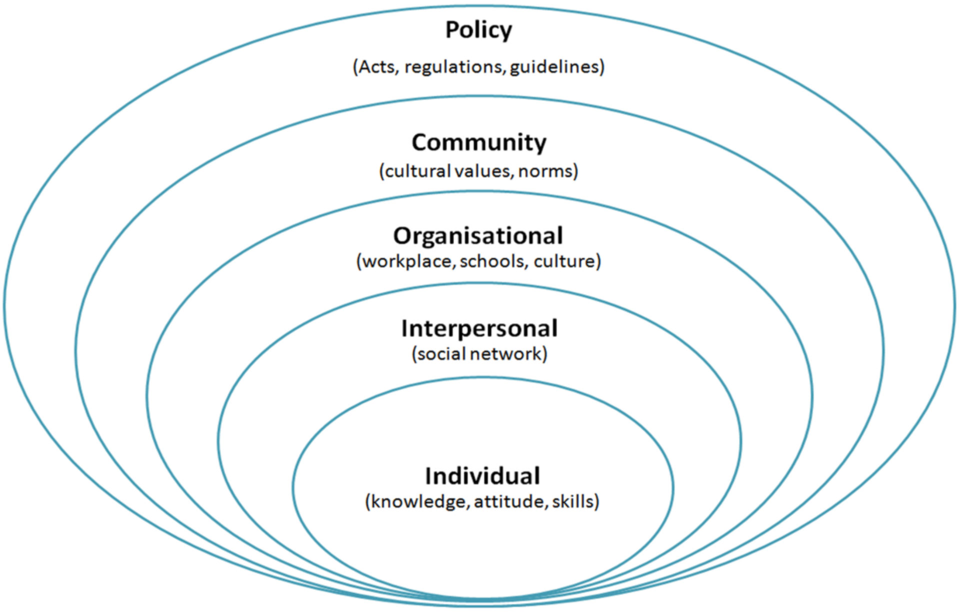

Figure 2.9 The Social Ecological Model of Health Promotion, adapted from (McLeroy et al., 1988).

The following discussion examines each societal level, followed by descriptions of how each is part of a larger interactive system. An ecological approach to health promotion requires examination of each societal level, and across each level to understand the factors that influence behaviour and health and the interrelationships between the levels (B. G. Simons-Morton et al., 2012).

Intrapersonal (individual) level

Analysis at the intrapersonal level is concerned with identifying important cognitions such as knowledge, attitudes, skills, or intentions to comply with behavioural norms. Individual level theories such as value expectancy, social learning theory, contingency management, and personality theories identify key cognitive variables and describe relationships among variables and how they are linked to behaviour (B. G. Simons-Morton et al., 2012). Personal factors at the intrapersonal level can then be targeted through appropriately developed interventions to facilitate behaviour change (McLeroy et al., 1988). For example, knowledge, attitudes, and beliefs towards smoking will have an effect on smoking behaviour. Interventions that highlight the harmful effects of smoking may help change knowledge, attitudes, and beliefs regarding smoking and thus facilitate behaviour change.

Interpersonal level

Interpersonal relationships and networks such as family members, peers, and work contacts are important sources of influence on health behaviour. Health behaviour is influenced by an individual's relationship with others and others' attitudes and behaviour. In addition, individuals are influenced by social norms that exist within their respective settings. A number of theories explain determinants of interpersonal influences such as network theory, social support theories, role theory, and social influence models (B. G. Simons-Morton et al., 2012). For example, adolescents are more likely to smoke if their parents smoke and it is an accepted norm in their household. Therefore, it is also important for intervention strategies to focus on changing societal norms regarding health-related behaviour at the interpersonal level (McLeroy et al., 1988).

Organisational level

The third level of the ecological model is characterised by how organisational influences can be used to support behavioural changes, health promotion activities targeting organisational change, and the importance of organisations in facilitating health promotion programmes. Organisations such as schools and workplaces play an important role in health promotion, as this is where individuals spend considerable amounts of time (McLeroy et al., 1988). For example, workplaces may offer smoking cessation services to their workers or adopt standards such as no smoking policies at the worksite. In addition, health promotion programmes in workplace settings may target individuals and their families and promote employee health-related behaviours (O'Donnell, 2001). Theories such as diffusion of innovations, stage theories, and organisational change may be useful in promoting the adoption of changes within an organisation. The leadership support of organisations is also crucial in providing resources to ensure the long-term sustainability of health promotion programmes. Importantly, the ability to work effectively with, and within organisations is swayed by influences at the intra- and interpersonal level of the ecological model (B. G. Simons-Morton et al., 2012).

Community level

Community is viewed as having three distinct meanings. It refers to groups belonging to individuals such as families, friends, and neighbourhoods. Community is also referred to as the relationship between organisations such as local agencies, health providers, and schools.

Finally, community is defined in geographical and political terms such as cultural or regional groups that exude a sense of power over their members. Community influence that includes family, informal social networks, and churches may be important sources of social resources and social identity (B. G. Simons-Morton et al., 2012). Some theories that may help explain influences and develop interventions at the community level include cultural change, social change, community development, diffusion of innovation, and participatory research.

Public policy level

The public policy level advocates the use of regulatory policies, procedures, and laws to protect the health of communities. Policies are developed and implemented to address health risks, which include restricting behaviours such as smoking in public places, introduction of positive and negative incentives such as increased taxes on tobacco, and policies that pledge funding towards behaviour change research such as funding smoking cessation projects (B. G. Simons-Morton et al., 2012). Policy level influences also encourage individuals and communities to participate in the political process of voting and lobbying to support issues related to health policy. Furthermore, it is important to recognise the role of mediating structures at the community level in advocating policy level changes (McLeroy et al., 1988). The development, implementation, evaluation and changes in policies is generally framed within the perspectives of theories and models such as political change, theories of democratic action, and citizen participation (B. G. Simons-Morton et al., 2012).

2.4.2 **Interrelationship between different levels of the ecological model**

The different levels of influence not only affect behaviour but also are part of a larger system in which each level affects the other. For example, behaviour is not only affected by personal factors but also through networks of relationships that are part of the greater community and organisations. These levels of influence are also guided by or guide policies related to their health behaviour. This relationship has important implications concerning multilevel interventions aimed at changing health-related behaviours. Multilevel planning and intervention not only concern the behaviour of individuals but also the influences at other levels of the ecological model. This suggests that interventions may be affected by, "what we know about what works, with whom, and under what conditions" (B. G. Simons-Morton et al., 2012, p 65). The models and theories that target individuals' health-related behaviour appear to be the most commonly used in health promotion intervention. However, evidence supports the use of more than one theory across different levels of behavioural influence in behaviour change interventions (Angus et al., 2013; Painter, Borba, Hynes, Mays, & Glanz, 2008).

2.4.3 **Behaviour-change theories at different levels of the ecological model**

Intrapersonal level

Health Belief Model

The Health Belief Model (HBM) (Rosenstock, 1966) is one of the most widely used behavioural models used to predict health behaviour. The model is based on five constructs of the core beliefs of individuals with regard to health behaviour and conditions, according to their perceptions.

- *Perceived susceptibility – a person's view of their risk of getting the condition.*
- *Perceived severity – a person's view of the seriousness of the condition and the consequences.*
- *Perceived barriers – a person's view of the factors that facilitate or discourage adopting the promoted behaviour.*
- *Perceived benefits – a person's view of the positive consequences of adopting the behaviour.*
- *Perceived self-efficacy – ability to successfully adopt the behaviour.*

Theory of Reasoned Action

The Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980) proposes that people tend to behave according to their intentions when opportunity allows and those intentions are based on beliefs and attitudes. The theoretical construct is that behaviour is predicted by intentions, intentions are predicted by attitudes, and attitudes are made up of beliefs.

Theory of Planned Behaviour

The Theory of Planned Behaviour (TBA) adds to the TRA a third key construct: perceived behavioural control (Ajzen, 2002). The TBA posits that human behaviour is governed by three kinds of consideration: behavioural beliefs, normative beliefs and control beliefs where behavioural beliefs produce a positive or negative attitude towards behaviour, normative beliefs result in subjective norm, and control beliefs give rise to perceived behavioural control. A combination of attitude toward the behaviour, subjective norm, and perceived behavioural control leads to the formation of a behavioural intention.

Transtheoretical Model/Stages of Change

The Transtheoretical Model (TTM) evolved from concepts, strategies and methods from a number of theories and focuses on decision-making of the individual and the natural process of change (Prochaska, Diclemente, & Norcross, 1992). The TTM assumes that behavioural change is not instantaneous but is a process that unfolds over time though a cycle of stages. The five stages of the TTM are: pre-contemplation; contemplation; preparation for action; action; and maintenance. The contemplation stage is when individuals are aware of the benefits of health behaviour and are considering it, while individuals prevent relapse and consolidate the adopted behaviour at the maintenance stage. This theory is also focussed on the individual and ignores the social context in which changes occur. However, the use of fixed periods that distinguish between the different stages does not consider the model's premise that behaviour change is gradual and that the time it takes for change can vary (Povey, Conner, Sparks, James, & Shepherd, 1999).

Health Promotion Model

The Health Promotion Model (HPM) (Pender & Pender, 1987) derives its theory from the expectancy value theory (individuals engage in actions that they perceive as possible and that result in valued outcomes) and the social cognitive theory (thoughts, behaviour and environment interact). The model attempts to explain individuals' participation in health-promoting behaviours and theorises that cognitive-perceptual factors influence health-promoting behaviour. The cognitive-perceptual factors consist of: importance of health; perceived control of health; perceived self-efficacy; definition of health; perceived health status; and perceived benefits of, and perceived barriers to, health-promoting behaviours. Modifying factors include demographic and biologic characteristics, interpersonal influences, and situational and behavioural factors. The HPM is based on the following theoretical propositions:

- *Prior behaviour – inherited and acquired characteristics influence beliefs regarding health-promoting behaviour.*
- *People engage in behaviours they perceive as beneficial.*

- *Perceived barriers hinder health-promoting behaviour.*
- *Perceived competency or self-efficacy increases the likelihood of carrying out a behaviour.*
- *Greater perceived self-efficacy results in fewer perceived barriers to health behaviour.*
- *Positive emotions towards a particular health behaviour results in greater self-efficacy and the likelihood of a behaviour change is increased.*
- *People are more likely to carry out behaviour when influential networks (peers, family, and colleagues) also carry out the behaviour.*
- *Situational (environmental) influences can greatly affect health-promoting behaviour.*
- *The greater the commitment to a specific plan, the more likely it is that health-promoting behaviours are maintained over time.*
- *People can modify cognitions, interpersonal and situational influences to create incentives for health-promoting behaviour.*

A weakness of the HPM is that its constructs focus on the individual and do not incorporate reciprocal relationships where personal and environmental factors interact to influence behaviour (King, 1994).

Extended Parallel Process Model

The Extended Parallel Process Model (EPPM) theorises that people who are threatened will take one of two courses of action: danger control or fear control (Witte, 1992). Danger control seeks to reduce the risk. Fear control seeks to reduce the perception of the risk. Danger control is outer-focused and towards a solution. Fear control is inner-focused and away from a solution. For danger control to be selected, a person needs to perceive that an effective response is available (response efficacy) and that they are capable of utilising this response to reduce the risk (self-efficacy). If danger control is not selected, then action defaults to fear control. The EPPM utilises the protection motivation theory linkages among perceived levels of severity, susceptibility, response efficacy, and self-efficacy that lead to message acceptance and, ultimately, attitude, intention and behaviour changes.

Interpersonal level

Social Cognitive Theory

The Social Cognitive Theory (SCT) explains how people regulate their behaviour and describes the interrelationships of self-regulatory processes involved in goal-directed behaviour (Bandura, 1986). The theory proposes that people learn by watching what others do, with environment, behaviour, and cognition as key factors in influencing development. There are five core concepts associated with the SCT framework. These core concepts are observational learning/modelling, outcome expectations, self-efficacy, goal setting, and self-regulation. Reciprocal interaction (the interplay of factors) between personal, behavioural, and environmental influences is a key focus of the theory. Self-efficacy theory (the perceived ability to perform a behaviour) is also an important contributor to SCT.

Organisational level

Diffusion of Innovations Theory

The Diffusion of Innovation Theory is concerned with how ideas and practices are adopted over time and how innovations (an idea, practice or object that is perceived as new) spread through social systems through formal and informal communications and processes (Rogers, 1962). It seeks to explain how, why and at what rate innovations spread throughout societies. Diffusion of an innovation occurs through a five-step adoption process:

- *Knowledge – In this stage, the individual is first exposed to an innovation but lacks information about the innovation. During this stage of the process, the individual has not been inspired to find more information about the innovation.*
- *Persuasion – In this stage, the individual is interested in the innovation and actively seeks information/detail about the innovation.*
- *Decision – in this stage, the individual takes the concept of the change, weighs the advantages/disadvantages of using the innovation, and decides whether to adopt or reject the innovation. Due to the individualistic nature of this stage, Rogers notes that it is the most difficult stage to acquire empirical evidence.*
- *Implementation – in this stage, the individual employs the innovation to a varying degree depending on the situation. During this stage, the individual determines the usefulness of the innovation and may search for further information about it.*

- *Confirmation – In this stage, the individual finalises his/her decision to continue using the innovation. This stage is both intrapersonal and interpersonal confirming that the group has made the right decision.*

Behaviour change theories help understand the causes of health issues such as NIHL, and inform the development of interventions to address the identified factors. The theories described above are common theories that have been successfully used in the development of health promoting interventions. In addition, different theories can be applied at different levels of behavioural influence. As such, this gives researchers and health promoters an opportunity to apply different theories to target several factors influencing behaviour and health outcomes.

2.5. The utility of an ecological approach in workplace health promotion

Workplace behavioural interventions have mostly focused on changing personal health factors rather than also addressing environmental and organisational factors that influence workers' well-being (Harden et al., 1999; Stokols, 1996). Workplace interventions that are developed with narrowly focussed models are inadequate and a broader ecological perspective that views the workplace as a larger community system is required to promote health and well-being in occupational settings effectively (Stokols, Pelletier, & Fielding, 1996). It has been shown that workplace programmes that include organisational and management support and buy-in are more effective than those that focussed on personal factors influencing workers behaviour. (Pratt et al., 2007). Furthermore, there is evidence that the visible support and involvement of management and employee input in the planning, development and implementation of interventions results in effective workplace health promotion (Harden et al., 1999). An ecological approach helps identify and target personal and environmental factors across different levels of behavioural influence (McLeroy et al., 1988) and this may be useful in developing effective health promotion programmes for workplaces.

2.6. Theoretical framework for thesis

The Ecological Model for Health Promotion presents opportunities to identify gaps in NIHL. It can also be utilised to develop interventions targeting different levels of influence concerning hearing-conservation behaviour. In addition, as discussed previously, different behaviour change theories can be applied at different levels to promote hearing-protection behaviour in workers. While only two qualitative studies have used a social ecological model to explain hearing-protection behaviour amongst workers (Robertson et al., 2007; Tantranont et al., 2009), this model has been used in other areas of public health such as adolescent behaviour (Mason, Cauce, Gonzales, Hiraga, & Grove, 1994), HIV-risk behaviours (Larios et al., 2009), smoking behaviour (Baron-Epel, Satran, Cohen, Drach-Zehavi, & Hovell, 2012; Wen, Van Duker, & Olson, 2009), and physical activity studies (Adams et al., 2006; Langille & Rodgers, 2010; Lee, Ho, & Keung, 2010). Intervening at multiple levels is an important concept in health promotion and may be useful in developing strategies to prevent NIHL. In terms of NIHL, we are concerned about at-risk workers (high-noise exposure) and their hearing-protection behaviour at the individual level. We are also concerned about all the networks (family, peers, and workmates) at the societal level whose influence can prevent NIHL. In addition, we want to establish policies, norms, and values at the organisational level that support the worker. Finally, there needs to be properly enforced national and local legislation at the policy level that oversees noise-prevention effort in workplaces. As such, the Ecological Model for Health Promotion (McLeroy et al., 1988) is chosen as the theoretical framework for this thesis.

Chapter 3. Overview of Research Plan and Methodology

The theoretical framework of this research was guided by the Ecological Model for Health Promotion that focuses attention on both individual and social environmental factors as targets for health promoting interventions (McLeroy et al., 1988). The model theorises that behaviour is determined by factors that exist at different levels of influence and interact with each other.

The research used a mixed methods design: semi-structured interviews (qualitative), a cross sectional survey (quantitative), and a pilot intervention implementation and evaluation. The key outcome measures were changes in barriers, supports, knowledge, attitude, and behaviour towards hearing protection behaviour. A mixed methods design was adopted to allow for a detailed understanding and identification of factors that influence hearing protection behaviour in workers. Mixed methods research represents an integrative investigation of qualitative and quantitative data gathering, analysis, and interpretation to provide a better understanding of the research problem (Creswell & Clark, 2011). This approach offers deep insights into a subject area through a research plan that is flexible and exploratory without the restrictions of pre-determined research designs (Andrew & Halcomb, 2008). Qualitative research seeks to understand values, opinions, behaviours, and social context regarding a particular research problem from the perspectives of the target population (Mack, Woodsong, MacQueen, Guest, & Namey, 2005). Quantitative research focuses on gathering numerical data and generalising it across groups of people (Field, 2005). This thesis was based on the premise that quantitative and qualitative methods are complementary and that qualitative data from semi-structured interviews is useful in informing the design of the quantitative survey questionnaire, while quantitative data provide more-easily measured indices of changes in behaviour. Detailed information regarding the sample, data collection, data analysis, and ethical issues is provided separately in Chapters 4, 5, 6, 7, and 8. The results reported throughout the thesis are based on self-reported data.

3.1. Research questions

The primary purpose of this research was to understand factors influencing hearing protection behaviour in workers and to develop an intervention that promotes hearing health in workplaces.

The research aimed to answer the following research questions:

1. What factors influence hearing protection behaviour in workers from noisy workplaces in New Zealand?

- *How do workers' individual characteristics influence their hearing protection behaviour?*
- *How do factors other than individual characteristics influence hearing protection behaviour?*
- *What is a useful theoretical framework that helps understand hearing protection behaviour in workers?*

Methodology: Semi-structured interviews were conducted to develop an understanding of factors that influence hearing protection behaviour in workers. Questions were asked regarding workers' perception of noise levels in their workplaces, HPD use, motivation for wearing HPDs and barriers against hearing protection behaviour. A purposive sample (Guarte & Barrios, 2006) of 25 workers was interviewed from noisy workplaces, to provide a sample of workers exposed to hazardous noise. Purposive sampling allow for the selection of subjects believed to represent the characteristics of the target population (Guarte & Barrios, 2006). The interview sample size was determined on the basis of theoretical saturation (Mack et al., 2005), where no new information or insight was being recorded. A qualitative content analysis was used utilising a systematic classification process of coding and identifying themes. Conventional content analysis (Hsieh & Shannon, 2005) was used to let the data reveal information and avoid preconceived ideas forming themes about hearing protection. This method allowed the use of open-ended questions and probing to explore all possible influences of hearing protection behaviour. This helped inform the development of a questionnaire to assess hearing protection behaviour.

2. Can a quantitative instrument to measure hearing protection behaviour be developed?

- *What sub-scales reflect influences on hearing protection behaviour?*
- *Can these sub-scales be explained according to the ecological model?*

Methodology: A number of personal and environmental factors (barriers and supports to hearing protection behaviour) were identified in the qualitative study. These barriers and supports formed the items related to hearing protection behaviour in the hearing protection assessment questionnaire (HPA-2). In addition, the 2-page questionnaire was designed to collect data on the characteristics of the workers (gender, age, and ethnicity). As a study of the questionnaire's applicability, convenience sampling was utilised to carry out a cross sectional survey of people working in noisy environments. The recruitment process relied heavily on volunteer participation, both by companies and workers. Despite the disadvantages of bias due to convenience sampling, this method provided the only logical and practical way to administer the questionnaires to as many workers as possible. The questionnaire items were assessed for reliability and validity and factor analysis was undertaken to describe significant influences of hearing protection behaviour in the sample. This allowed for the identification of subscales the barriers and supports scales, and allowed their relationship to the ecological model to be investigated.

3. Can an intervention be effective in targeting factors that influence HPD use to promote hearing health behaviour in workplaces?

- *Which behaviour change theories are useful to target factors that influence hearing protection behaviour?*
- *What are the key components of the intervention programme aimed at preventing noise induced hearing loss?*
- *How can these components be effectively communicated to the target audience?*
- *Is the intervention programme effective in changing behavioural measures (barriers, supports, knowledge, attitude, and behaviour) from pre to post intervention and over a longer (two month) period?*
- *Can the training be enhanced to improve effectiveness over time?*

Methodology: The Multilevel Approach to Community Health (MATCH) ecological model (B. G. Simons-Morton et al., 2012) was used as a planning model to develop an intervention informed by theories to explain and address problems associated with hearing protection behaviour. The Health Belief Model (HBM) and the Social Cognitive Theory (SCT) were the behaviour change theories used to inform the development of the training programme (Bandura, 1986; Janz & Becker, 1984). The HBM was chosen because it theorises that modifying variables (age, gender, ethnicity, knowledge, motivation), cues to action, and self-efficacy influence behaviour by affecting perception of susceptibility, severity, benefits and barriers (Rosenstock, Strecher, & Becker, 1988). The training programme included interactive components that were aimed at raising awareness and improving knowledge regarding noise and NIHL. In addition, the programme endeavoured to emphasise the correct way to wear HPDs and its subsequent maintenance to ensure its protective utility. The HBM guided the programme development in that it provided the basis to include relevant motivating information to improve knowledge, create noise awareness, and improve self-efficacy to ultimately influence hearing protection behaviour. The SCT was chosen because of its success in informing the development of successful health related interventions and its consideration of the reflexive relationship between people and their environment (Bandura, 2004). In addition, the theory posits that people learn from observing others and also have an influence on others through their own behaviour. This was particularly important for the intervention programme, promoting workplace interpersonal support and modelling aimed at promoting hearing health behaviour across different levels of the organisation. This would also drive an organisation's culture towards health promotion, in particular hearing health.

The Dangerous Decibels programme (Martin et al., 2006) was selected as the programme to adapt to a workplace setting because of closeness to the aims of the current research and overarching objective to prevent NIHL. The adapted training programme was piloted and evaluated for its effectiveness. The key outcome measures were changes in perceptions of barrier, supports, knowledge, attitude, and behaviour. The knowledge, attitude and behaviour measures were adapted from the Dangerous Decibels evaluation study questionnaire (Griest et al., 2007). Items were adapted for workplace relevance and integrated with the HPA-2 questionnaire. The evaluation questionnaire assessing the five measures was called HPA-5. A repeated measures design was utilised to evaluate changes in the measures from pre to post intervention and to allow for the workers to act as their own controls. The adapted workplace-training programme was piloted in five workplaces. Fifty-six workers were trained but three dropped out post intervention. Fifty-three workers were therefore analysed for outcome measures before the intervention, 1 week after, and at 2-months follow-up.

3.2. Summary

The study began with a semi-structured interview phase. The results from this phase informed the development of the data collection tool (HPA-2) for the survey phase. The survey phase then helped inform the development of the intervention. The intervention was adapted from the 'Dangerous Decibels' classroom NIHL prevention programme to a workplace setting. The workplace programme was piloted in five workplaces and was evaluated for effectiveness. The different research phases, guided by an ecological model, helped understand factors influencing hearing protection behaviour and develop a hearing conservation programme in workplaces. This was done by investigating the following three key questions related to hearing conservation and behaviour.

1. *What factors influence hearing protection behaviour in workers from noisy workplaces in New Zealand?*
2. *Can a quantitative instrument to measure hearing protection behaviour be developed?*
3. *Can an intervention be effective in targeting factors that influence HPD use to promote hearing health behaviour in workplaces?*

Chapter 4 provides details of the study undertaken in phase 1 of this research.

Chapter 4. Hearing Protection Use in Manufacturing Workers – A Qualitative Study

This chapter has been published in Noise and Health; Reddy RK, Welch D, Thorne P, Ameratunga S. *Hearing protection use in manufacturing workers: A qualitative study*. Noise & Health 2012; 14:202-209

4.1. Abstract

Occupational noise is a significant contributor to disabling hearing loss worldwide. Noise induced hearing loss (NIHL) has resulted in huge human and economic consequences costing New Zealand approximately $53M annually and rising. A high proportion of hearing loss claims are made by workers in the manufacturing sector. Hearing protection devices (HPDs) are used together with engineering and administrative controls to minimise noise exposure and prevent hearing loss. Unfortunately, inconsistent and improper use of HPDs has hindered efforts to prevent NIHL. The purpose of this study was to understand the factors that influence the use of HPDs amongst a group of manufacturing workers in New Zealand. A purposive sample of twenty-five workers was recruited to take part in semi-structured interviews. The open-ended questions were aimed at exploring the participants' knowledge, attitude, beliefs and behaviour towards noise and HPDs. The data were analysed using conventional content analysis and key themes emerged in relation to HPD use. Themes that emerged from the interviews either supported good hearing protection behaviour or acted as barriers against it. Five major themes, (perception of noise, hearing preservation, reluctance to use HPDs, workplace interaction and value of hearing) and sub-themes described various factors that influence hearing protection use. Both personal and environmental factors influence the use of HPDs. Based on this study, personal and environmental factors need to be targets for further research using ecological models to develop interventions that promote HPD use amongst workers.

4.2. Introduction

Occupational noise induced hearing loss (NIHL) costs people many years of healthy life. Worldwide, 7-21% of disabling hearing loss is estimated to be caused by occupational noise (Nelson et al., 2005) and it is considered to affect approximately 17% in the New Zealand population. This has a high personal and societal cost. For example, in New Zealand, claims for occupational NIHL rehabilitation (provision of hearing aids) is costing the Accident Compensation Corporation approximately $53M annually (Thorne et al., 2008). Further, given that the overall direct burden of hearing loss is estimated at 1.6-3% of GDP, (Access Economics, 2006) the impact of occupational noise exposure is a significant cost to society.

Engineering and administrative controls, such as eliminating noise at source and isolating workers from noise source, are primary measures to reduce noise exposure. These measures must be encouraged to reduce noise levels at work. However, hearing protection devices (HPDs) are also used in addition to these controls. However, improper and inconsistent use of HPDs has been of concern to preventive approaches to NIHL (Fausti, Wilmington, Helt, Helt, & Konrad-Martin, 2005). Several factors are reported to influence the wearing of hearing protection: health beliefs, perceived risk, perceived probability of risk, perceived benefits and comfort of wearing the device (Arezes & Miguel, 2002; Kerr et al., 2002; Kim et al., 2010; Melamed et al., 1996). New Zealand data suggest that a high proportion of hearing loss claims come from the manufacturing sector and plant and machine operators (Thorne et al., 2008).

Previous New Zealand research into of occupational exposure found that just half the plant and machine operators, assemblers, and elementary workers who worked in noisy environments reported hearing protection use (Eng et al., 2010). Although international studies have looked at factors that influence the use of HPDs (Arezes & Miguel, 2006a; Hong, Samo, Hulea, & Eakin, 2008; Patel et al., 2001; W. Williams et al., 2007), no such study has been found in New Zealand manufacturing workers. The purpose of this study was to understand the factors that influence the use of HPDs amongst a group of manufacturing workers in New Zealand.

4.3. Subjects and Methods

Ethics approval was obtained from the University of Auckland Human Participants Ethics Committee (Ref: 2010/214). Companies defined as “manufacturing” by The Australian and New Zealand Standard Industrial Classification (ANZSIC) (ANZSIC06, 2006) were approached. A purposive sample of twenty-five workers was recruited from 11 companies to take part in semi-structured face-to-face interviews in August, 2010. The participants were plant and machine operators and assembly line workers from factories in Auckland, New Zealand. Regulation 11 of the Health and Safety in the New Zealand Employment

Regulations 1995 require employers to take all practicable steps to ensure that no employee is exposed to noise above 85dBA for an 8-hour period (Department of Labour, 1995). Participants were recruited from workers who reported noise levels greater than 85dBA for an 8-hour period. They predominantly conducted moulding works, sheet metal fabrication and joinery. This sample included one female participant. Demographics were not the focus of this research, however one participant was female, age ranged between 19 and 60, and 17 were New Zealanders, 8 were immigrants of whom 6 were Pacific Islanders, 1 was European and 1 was South American. Four workers approached refused to be interviewed. The interview questions were developed from a literature review of NIHL and the use of HPDs. The semi-structured interview consisted of five items. The open-ended questions (Table 4.1) were aimed at exploring the participants' knowledge, attitude, beliefs and behaviour towards noise and HPDs. In addition, the interviews aimed to establish supports for and barriers against HPD use.

Table 4.1 Semi-structured interview questions

1. What do you think of noise levels at your workplace?
2. Do you think high levels of noise are bad for you? Why?
3. Do you wear hearing protection at work? Why?
4. Why don't people wear hearing protection at work?
5. What can be done to encourage workers to wear HPD more often?

Permission was sought from employers to engage their workers in this study (Appendix 1). Recruitment of participants for this study ceased after the twenty-fifth participant was interviewed. This was the point of saturation where no new information was being recorded. Six workers from five different companies were recruited at a training workshop organised by the local workers union. All participants were informed that participation was voluntary and given a participant information sheet outlining information about the research (Appendix 2). Each participant was asked to sign a letter of consent (Appendix 3). Interviews took approximately 10 minutes to complete and the participants were gifted a $10 voucher for their time and assistance. The interviews were digitally recorded using an Olympus digital voice recorder and transcribed verbatim (RKR). The data were exported to QSR NVivo 8 software for analysis. The data were analysed using conventional content analysis (Hsieh & Shannon, 2005).

Conventional content analysis aims to describe a phenomenon without having preconceived themes, instead allowing themes to emerge from raw data (Hsieh & Shannon, 2005). Transcripts were read thoroughly, words that described a concept related to workers and their views were highlighted. Notes were made to capture a keyword that described the highlighted texts. After coding six transcripts, a set of codes based on emerging themes were determined. The rest of the transcripts were read and key ideas were assigned to preliminary codes. Data that did not fit existing codes were assigned to new codes. Once the coding was completed, the data were checked in each code and a review was undertaken to decide if some codes could be collapsed or expanded. There were further discussions between the investigators about the order of the categories and sub-categories. These discussions led to changes in the make-up of categories and themes and its hierarchy.

4.4. Results

Themes that emerged from the interviews either supported good hearing protection behaviour or acted as barriers against it. Some themes are further divided into sub-themes to explain different views and concepts.

4.4.1 **Theme 1: Perception of noise in the workplace:**

Sub-theme: Acceptance of noise as part of work – fatalism

A theme of fatalistic acceptance was observed. There is the suggestion of accepting noise as part of work and that work could not be done without making noise.

> *"You can't work and not make noise so it's just part of the job."*

> *"Because of the nature of the work, they (noise levels) are very high."*

Because of this belief, noise was regarded as something that has to be accepted.

> *"You can't really help it (noise). Welding makes noise, fabricating makes noise and cutting makes noise."*

> *"But it (noise) is unavoidable...it is the nature of our machinery...it (noise) is just one of those things you've got to live with."*

Even though all participants worked in places where noise would be considered to be hazardous (i.e. greater than 85 dB Leq for an eight-hour shift) under the Health and Safety in

Employment Regulations (Department of Labour, 1995) some workers described noise levels as low. This could be taken as further evidence of the acceptance and normalisation of high noise levels within this workforce. There is also the suggestion that some workers may feel that they have become used to being in noisy environments.

"It's (the noise level) not that loud..."

"I have got quite accustomed (to noise)."

Sub-theme: Noise annoyance:

Noise was reported to be annoying, and that it causes undue stress and discomfort. Some participants view noise to be bothering and frustrating and that working in constant noise had a negative effect on their mood, level of attention and health. They also report that noise causes them to experience headaches and migraines.

"It (noise) can stress you out. It is frustrating sometimes being in all the noise."

"Sometimes you get a migraine…headaches."

"It (noise) can start to get on your nerves after a while…all the banging and hammering."

Sub-theme: Fear of Hearing Loss:

There was knowledge that high levels of noise can damage ears and cause hearing loss. Part of this knowledge was the understanding that hearing loss is gradual and damage to hearing may not be felt until later in life.

"It (noise) makes you deaf."

"You may not see it (hearing loss) straight away but in time…"

"Loud noise all day will affect your hearing in the long run."

4.4.2 **Theme 2: Hearing protection use**

Sub-theme: Hearing preservation

The participants discussed reasons why workers used HPDs at work. They acknowledged that HPDs help prevent damage to hearing. They talked about how loud levels of noise can damage their ears if unprotected.

> *"To (wear HPD) obviously protect my ears from damage."*

> *"It (HPD) protects my ear drums."*

Sub-theme: Work Requirement

Interestingly, some participants also reported that they use hearing protection because it is the law and a company requirement. This demonstrates an acceptance of HPDs, an attitude similar to noise acceptance, due to enforcement of rules and regulations. There is suggestion that HPD use is part of their work process similar to punching in their time cards when they start and finish work.

> *"Because it is law, we have to wear hearing protection."*

> *"It's (to wear HPD) an employee requirement by the company."*

> *"I wear ear muffs because the rules in the factory you have to wear your safety gear."*

These responses suggest an acceptance of instructions about HPDs by employers or health and safety officials. However, they may also indicate lack of thought given to why hearing preservation is important to an individual.

This is highlighted by the suggestion that even though there are company rules, the workers may choose not to wear them.

> *"It (wearing HPD's) really comes down to the own person. You cannot force it."*

> *"I know it is put on us to wear hearing protection, it is supplied to us, but it is up to us."*

Sub-theme: Reduce noise annoyance

Some participants used HPDs to counter the annoying effects of occupational noise. They described relief and concentration to carry out work in a less noisy environment.

"To keep the noise out. It gets very noisy in the workshop"

"I wear the ear muff...when it is too loud, I feel unhappy"

The suggestion that HPDs help workers experience some peace in frustrating conditions is seen as another strong motivator for HPD use.

"You want a little bit of peace and quiet."

4.4.3 **Theme 3: Reluctance to use HPDs**

The participants accept the use of HPDs to protect hearing, avoid noise annoyance and conform to workplace rules. However, they report unwillingness to use HPDs for varying reasons. These include the mechanics of HPDs and the inability to communicate when using HPDs.

Sub-theme: Bulky

The participants described earmuffs as being bulky and inconvenient to use. Some workers found it difficult to wear earmuffs with other safety equipment such as helmets, safety shields and goggles.

"If you have the earmuffs, you cannot get the helmets on. You cannot get your goggles, your glasses, you cannot get anything on."

Sub-theme: Uncomfortable

In addition to being a problem to wear with other safety equipment, the participants reported a degree of discomfort when wearing HPDs particularly given the hot and humid conditions of most manufacturing workshops. Some workers also find earplugs to be painful when inserted in the ear canal.

"It's (HPD) uncomfortable. You know if you use the plugs, it tends to hurt the inside of your ears when it expands. And when we use the earmuffs, it tends to press against your head and it sweats."

“They get sweaty around their ears. Just feels uncomfortable.”

Sub-theme: Communication problems

The participants felt that the wearing of hearing protection blocked off sounds, and it was difficult to communicate with other workers or hear what was going around in their work environment.

“You know you cannot hear the other co-workers and you cannot communicate properly with them.”

In addition, the need to communicate can make workers to constantly remove hearing protection devices. This can be frustrating and workers may abandon wearing hearing protection altogether.

“Every time you got to talk to someone, it’s (HPD) in out in out.”

Furthermore, there is suggestion that workers value communication and interaction with each other. Their inability to carry this out makes them feel demoralised and unhappy.

“I’ve got to wear hearing protection at work and when you are wearing ear muffs, basically you are in your own little world.”

“You can’t really talk to anybody so you are by yourself sort of. It makes a long shift.”

Sub-theme: Quality and Availability

There were suggestions from the workers that the type of HPDs provided are of inferior quality and thus workers are not keen on wearing them.

“…the company provided a cheap one (HPD)…they (workers) do not want to use it.”

It was also suggested that workers have different preferences about which HPD to use. Some workers prefer earplugs while others liked earmuffs. However, in the absence of their preferred type of HPD, workers may be unmotivated to use the available HPD.

“We have to wear them (ear plugs) because we don’t have ear muffs. Ear muffs would be lot better.”

Sub-theme: Habits

The participants also suggested that some workers are habitual non-users of HPD and that those workers who have not regularly used HPDs are more likely not to regard HPD use as an important protective behaviour.

"They have worked here for 30 plus years and think that it (noise) does not do any damage."

"Probably habits…It is like old dog, new tricks sort of thing. Like my father for instance, builder for years, he is deaf as a door post…If only he had worn hearing protection. He never did, still does not."

4.4.4 **Theme 4: Workplace influence**

Sub-theme: Peer Mentality

It was reported that some workers may find the wearing of HPDs as a ridiculous and socially inappropriate behaviour. The workers as a group may not necessarily value the importance of HPDs and find wearing them funny. While this may all be light-hearted workplace banter, some workers may be discouraged from using HPDs.

"The way I'm thinking they make fun of me. Especially when I put the green ear plug, it looks funny to me."

Sub-theme: Peer Modelling

On the other hand, co-workers support each other at work and remind them of safety practices. This gives workers added encouragement and motivation to adopt positive HPD use behaviour.

"Everyone is treated the same so we all support each other. Remind each other (to wear HPD)."

Sub-theme: Self image

Some participants thought that some workers considered themselves as stronger and not vulnerable to the harmful effects of high levels of noise. This may also mean that some workers think that this bravado earns them the respect of their peers.

"Maybe they are too staunch and think it (noise) doesn't hurt them."

"Some of the guys got, 'I'm the man' type of attitude, you know. 'It's not going to hurt me', but it will in the long run."

Sub-theme: Proper enforcement of rules

Some participants reported that the practice of wearing hearing protection was encouraged when employers effectively enforced policies and regulations.

"My boss is also our safety inspector and makes sure that we do wear them (HPDs)."

"I think the boss can make people wear it (HPD)."

Sub-theme: Training

The participants thought regular training at workplaces on noise and hearing protection encouraged workers to wear HPDs and increased workers' awareness of issues around noise and hearing protection.

"We have regular courses at work that remind us; refresh us about hazards at work and why we should wear hearing protection."

4.4.5 **Theme 5: Value of hearing**

There is a suggestion that good hearing ensures a normal life with loved ones and being able to appreciate the everyday joys of life. The idea moves beyond just protecting ears. It is about valuing hearing as an important part of life.

"I love going out to the beach. I do a lot of diving. My hearing is very precious to me.

I love the sound of my grandkids."

On the other hand, it appears that some workers may not see noise as an issue at all whether at or away from work. This may imply that noise is not regarded as a serious hazard in the community: an attitude which may produce a barrier against safety behaviour.

"I have got 2 subwoofers (for loud music) at the back of my car so I don't really care."

4.5. Discussion and conclusion

The findings suggest that a combination of factors influence the use of HPDs. Five major themes: perception of noise, hearing protection use, reluctance to use HPDs, workplace interaction, and value of hearing, influence hearing protection use.

There is a fatalist belief among workers that noise is an acceptable and unavoidable part of the job. This attitude suggests that workers feel that noise is a given and will always be present in their line of work. A possible consequence of this may be acceptance of hearing loss as an unavoidable condition of the work environment. Fatalistic beliefs such as this can influence workers' risk perception and make them ignore safety procedures (Kouabenan, 2009). In addition, noise levels were reported to be low by some workers. Since it was known that, according to an external (legal) frame of reference, the noise levels were high for all those interviewed; the presence of an opposing theme may be taken to represent an acceptance and internalisation of the idea that, within the manufacturing sector, noise levels cannot be avoided. The presence of the contrary theme, that noise was high and continuous, suggests that workers may not have completely accepted high-level noise as the norm. If workers are able to identify noise as a hazard, it will support the idea of the importance of HPD to keep out noise. Previous research showing that those who felt they were exposed to high levels of noise wore hearing protection more often supports this idea (W. Williams, Purdy, Murray, LePage, & Challinor, 2004). This implies that workers' attitudes to noise may be influenced by the perspective from which they perceive it. For example, a worker who views the noise in his factory as being average for his industry may not be careful around it. On the other hand, another worker who views the noise level as high in comparison to the rest of the world may take more care in noise.

Exposure to noise in industrial settings is known to annoy workers (Tantranont et al., 2009) and evidence suggests that workers who accept noise as part of everyday work are less likely to be annoyed by noise (Singh et al., 2010). In addition, noise can also cause annoyance indirectly by interfering with performance and communication as well as impairing hearing (Vandijk, 1986). However, workers' perceived susceptibility to NIHL and the perceived severity of NIHL varies (Svensson, Morata, Nylen, Krieg, & Johnson, 2004).

The participants indicated that HPDs were beneficial in efforts to protect hearing. However, there was a contrary theme that company requirements are the primary reason to wear hearing protection; not a personal desire for hearing protection. This may indicate that the workers possibly do not understand the benefits of HPDs. Furthermore, the workers reported using HPDs to reduce the annoying effects of noise. It is not uncommon for workers to use HPDs to reduce the annoying aspects of noise (McCullagh & Robertson, 2009; Melamed et al., 1996). This belief can be seen as a motivator to use hearing protection in noisy workplaces. While the use of HPDs was acknowledged as a means of preventing hearing loss and reducing noise annoyance, there were barriers that hindered this protective behaviour. HPDs are known to be uncomfortable (Davis, 2008) and workers in this study described them to be bulky, painful and sweaty. The workers also found HPDs to interfere with other safety equipment. In addition, workers reported having different preferences in relation to the type of hearing protection they choose to use. When there is limited choice, workers could start developing unfavourable attitudes towards HPDs. These factors may cause dissatisfaction and frustration that could lead to the compromised use of HPDs. Ineffective and improper use of HPDs will in turn reduce hearing protection (Arezes & Miguel, 2006a). The use of hearing protection is further impacted by the inability of workers to communicate effectively when using them (Morata et al., 2005; Patel et al., 2001). The workers felt that using HPDs cut them off from others and made them lonely. In addition, it was difficult and a hassle to remove hearing protection every time to communicate and then put them back on. It may also be necessary to hear machine sounds for workers to carry out their tasks properly (Horie, 2002).

Peers can be seen to exhibit behaviour that either can act as support for or barriers against HPD use. An earlier study did not find any evidence of people being ridiculed or joked at for wearing hearing protectors but the authors accept that it did not mean peer pressure did not exist but operated rather subtly (Leinster et al., 1994) A more recent study involving construction workers did however provide evidence that workers did not wear personal protective equipment because they feared being teased by their peers (Choudhry & Fang, 2008). There were suggestions by workers in this study that HPDs may become the subject of jokes in workplaces. On the other hand, it has been shown that workers were motivated to wear HPDs after seeing co-workers carry out this behaviour. There is evidence that collective behaviour of a work group may function as a social modelling stimulus for HPD use (Olson, Grosshuesch, Schmidt, Gray, & Wipfli, 2009). This study also found that workers were motivated to wear hearing protection because they reminded each other to wear HPDs at work.

Participants believed that some workers thought that noise was not a problem for them, and that they were tough enough to negate the effects of noise. The idea that some workers may not feel the need to wear HPDs because they can physically cope with noise is interesting. It contains an implicit assumption that invulnerability is a manly trait, and implies that this view is believed to be misguided. It may be that an 'ideal' man would be invulnerable, but it is acknowledged that nobody meets this ideal. In terms of developing intervention, this ideal man image may be a useful straw man. This finding is consistent with the findings of another study where workers did not wear HPDs to appear strong and macho for their peers and employers (Robertson et al., 2007). This kind of attitude may also be driven by the need to be popular among peers. It is likely that some workers think that by demonstrating negative safety behaviour they will earn the respect of peers of being a tough worker.

Poor enforcement of safety law and rules can make the workers complacent and possibly trivialise the importance of HPD use. The workers acknowledge that enforcement of HPD use helps them sustain this behaviour. While, rules and regulations alone cannot influence behaviour, they are important to observe and when combined with strategies at other levels should have a positive influence on HPD use behaviour. The attitude of being an ideal worker who follows company rules can be viewed as an added motivation to observe workplace safety procedures. It appears that workers who think that they are provided with inferior quality HPDs are not raising this with their employers. However, the suggestion that the HPDs provided are of inferior quality could just be a justification to not wear them. In addition, training is an important organisational factor that increases workers' ability to use HPDs effectively. It raises the question about the effectiveness of training methods on how to use earplugs. Improper use of earplugs will most likely cause discomfort to the ears of workers. Training needs to be effective to facilitate any increase in knowledge and initiate the process of behavioural change. Training needs to go further than the fact that HPDs help protect hearing. It must scratch beyond the surface and stimulate thinking about why hearing is precious and how it would affect different aspects of workers lives.

Social support networks such as family and peers influence HPD use behaviour. Preservation of hearing to maintain a good quality of life was reported as one of the reasons to wear HPDs. Hearing loss may contribute to isolation, loss of intimacy, communication impairment, self-pity, and diminished quality of life (Chia et al., 2007; Noble, 2009). The thought that hearing is necessary to maintain and enjoy the little joys in life with family members is a very powerful driver to support HPD use. On the other hand, of concern is the attitude demonstrated by the worker who appears to be fond of loud sounds, *("...subwoofer at the back of the car...")*, and is not bothered by noise at work. This suggests a culture of accepting loud sounds and noise in our communities, and could explain the relaxed attitude to noise in the workplace. Workers may not relate to the hazardous nature of noise because they have not experienced hearing loss and possibly have an internal belief of low susceptibility to hearing loss. Future research may consider investigating possible association between community perception of loud sounds and noise and its subsequent influence on workers' hearing protection behaviour.

These findings suggest that two types of factor influence hearing protection behaviour: personal and environmental. Both are important to consider when looking at hearing protection behaviour. The themes of this study fit in well with the Ecological Model for Health Promotion (Table 4.2) (McLeroy et al., 1988). The model theorises that there are different levels of influence (intrapersonal, interpersonal, organisational, community and public policy) that interact with each other and that personal, socio-cultural and physical environmental factors cut across each level to influence behaviour (Sallis et al., 2008). The personal and environmental factors in this study cut across different levels of the ecological model suggesting that factors in each level and across levels of influence interact with each other to impact HPD use (Table 4.2). This supports findings of other studies that have used ecological models to explain hearing protection behaviour amongst workers (Robertson et al., 2007; Tantranont et al., 2009). An important consideration for an ecological model is the community level. There were suggestions in this study that workers did not care about noise and enjoyed loud sounds outside of work suggesting a community culture of not thinking of noise as a hazard. However, a contrary theme of valuing hearing to enjoy life, the environment and family is seen as a motivator for HPD use at work. These two themes suggest that how noise is perceived in the community may influence hearing protection behaviour at work.

Table 4.2 Personal and environmental factors that influence the use of HPDs at different levels of the ecological model

Level of the ecological model	**Themes (personal factors)**	**Themes (environmental factors)**
Intrapersonal	Perception of noise in the workplace (fatalism) • *Acceptance of noise as part of work (fatalism)* • *Noise annoyance* • *Fear of hearing loss* Hearing protection use • *Hearing preservation* • *Reduce noise annoyance* Reluctance to use HPDs • *Habit* • *Self-image (machismo)*	Hearing protection use • *Work requirement* Reluctance to use HPDs • *Bulky,* • *Uncomfortable* • *Communication problems,* • *Quality and availability*
Interpersonal	Workplace interaction • *Self-image (impress peers)*	Workplace interaction • *Peer mentality* • *Peer modelling*
Organisational		Reluctance to use HPDs • *Quality & availability* Workplace interaction • *Enforcement of rules* • *Training* • *Availability of HPDs*
Community	Value of hearing	
Policy	The health and safety in employment regulations 1995	

This study has some limitations. While workers from manufacturing companies were recruited, this study is qualitative and exploratory, with limited generalisability. This study was not designed to consider demographic factors, but to understand underlying motivations and barriers to HPD use amongst manufacturing workers. The findings strengthen the need for ecological models to be used as a theoretical framework in developing health-promoting interventions. Future research using a mixed methodology (quantitative questionnaires and focus group discussions) would provide important context-dependent information that informs the development of focused and targeted interventions. This study provides baseline information that will be used to inform the formulation of a quantitative questionnaire as part of a larger study looking to develop targeted intervention aimed at positively influencing the behaviour of workers towards the use of HPDs.

Chapter 5. Development of the Hearing Protection Assessment (HPA-2) Questionnaire

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5.1. Abstract

Background: Noise-induced hearing loss (NIHL) remains an important occupational health issue given it is the second-most common self-reported occupational injury or illness. The incorrect and inconsistent use of hearing protection devices (HPDs) compromises their effectiveness in preventing NIHL.

Aim: To describe the development of an easily administered yet robust questionnaire to investigate factors that influence HPD use according to an ecological model.

Methods: A hearing protection assessment (HPA-2) questionnaire was developed using items based on themes identified in the previous chapter. These themes fell into two classes: supports and barriers to wearing HPD, and these formed two scales within the questionnaire. The questionnaire, which also included demographic items, was administered to workers from thirty-four manufacturing companies, yielding a response rate of 53%. The internal consistency of the scales was tested and factor analysis was conducted to investigate the underlying structure of the scales.

Results: The Cronbach's alpha for the barriers scale (α=0.740) and supports scale (α=0.771) indicated strong internal reliability of the questionnaire. The supports and barriers were further described as five key factors (risk justification, HPD constraints, hazard recognition, behaviour motivation and safety culture) that influence hearing protection behaviour. Workers who reported always using HPDs had more supports across these factors while those who did not always wear HPDs reported more barriers.

Conclusions: The HPA-2 questionnaire may be useful in both research and interventions to understand and motivate hearing protection behaviour by identifying and targeting supports and barriers to HPD use at different levels of the ecological model.

5.2. Introduction

Noise exposure is an occupational health hazard causing hearing loss. Noise-induced hearing loss (NIHL) is the second-most common self-reported occupational injury or illness, accounting for 7% of the total hearing loss in developed countries and 21% in developing countries (Nelson et al., 2005). It is estimated that between 13.5% and 17.5% of the hearing impaired population in New Zealand have an occupational noise induced hearing loss and up to 26% of hearing impaired people have some hearing loss caused by excessive occupational noise exposure (Thorne, Welch, Grynevych, & al, 2011). Hearing loss significantly impacts communication causing personal, professional and social problems for those affected (Morata, 2006). In addition, NIHL imposes a large financial burden. For example, claims for NIHL compensation and rehabilitation in New Zealand was reported to be approximately 44M USD for the year ending 2006 (Thorne et al., 2008).

New Zealand regulations limit unprotected noise in occupational settings to 85dBA over an 8-hour day with the requirement that preventive measures are employed to protect workers' hearing where noise levels exceeded this threshold (Department of Labour, 1996). The use of engineering (reducing noise at source) and administrative (removing worker from excessive noise) controls is the most effective way to prevent NIHL but unfortunately, hearing protection devices (HPDs) are often solely relied on to control noise exposure (Morata, 2006). While the use of hearing protection has shown to reduce NIHL (Heyer et al., 2011; Rabinowitz, Galusha, Dixon-Ernst, Slade, & Cullen, 2007), incorrect and inconsistent use of HPDs compromises their effectiveness in preventing hearing loss (Earshen, 2006; Morata, 2006).

The previous qualitative study identified personal and environmental factors as supports or barriers to hearing protection use (Reddy, Welch, Thorne, & Ameratunga, 2012). The Ecological Model for Health Promotion formed the theoretical basis for a classification of the factors into intrapersonal, interpersonal, and organisational levels (McLeroy et al., 1988). It was further theorised that personal, socio-cultural, and physical environmental factors cut across each level to influence behaviour (Sallis et al., 2008).

Previous studies have used questionnaires aimed at understanding intrapersonal factors related to hearing protection behaviour (Arezes & Miguel, 2006a; Purdy & Williams, 2002) and others have utilised the Health Promotion Model (HPM) (Pender & Pender, 1987) to develop questionnaire items eliciting predictors of HPD use with varying results (Edelson et al., 2009; Lusk et al., 1997; Lusk et al., 1994; Raymond et al., 2006). The HPM focuses on individual factors and fails to acknowledge the interrelationship of factors that may influence behaviour (King, 1994). Purdy and Williams (2002) developed a reliable Noise at Work questionnaire for assessing the effectiveness of workplace training in hearing loss prevention. However, the questionnaire described in this study was designed to identify a range of personal and environmental factors drawing on the ecological model to understand hearing protection behaviour. The levels of influence (intrapersonal, interpersonal, organisational, community and policy) reflect the idea that personal and environmental factors at each level are interrelated (B. G. Simons-Morton et al., 2012). This is important because the interwoven link between individuals and their environment is crucial to the concept of health promotion (King, 1994).

The first three levels of the ecological model were investigated in this study in relation to the behaviour of workers towards HPD use. The factors present at the *intrapersonal level* of the model are influenced by knowledge, attitudes, values, and skills relating to noise and HPD use. The *interpersonal level* of the ecological model focus on the influence of family and co-workers and the social norms prevalent in the workplace (B. G. Simons-Morton et al., 2012). Factors at the *organisational level* are shaped by the values, policies, and action of companies in respect to noise and hearing protection. This provides a multi-level perspective and a basis for developing interventions that promote hearing protection behaviour. Drawing on this knowledge, this study describes the development of a quantitative questionnaire to measure the factors that influence self-reported HPD use that were identified by the previous study (Reddy et al., 2012), and its use with a sample of workers in noisy industries. This allowed for the identification of a range of supports and barriers to HPD use in workers who always used HPDs and those that did not.

5.3. Methods

A questionnaire made up of items pertaining to factors identified in the previous research (Reddy et al., 2012) was developed with instructions to respondents to endorse ‘yes’ or ‘no’ for each item as a reason that they would, or would not, wear HPDs when exposed to noise at work. The questionnaire also included demographic items such as gender and age; two items describing attitudes to safety behaviour at work; and one item to capture the self-reported frequency of hearing protection use.

It was important to develop a questionnaire that could be easily administered in the workplace and therefore a two-page self-administered hearing protection assessment (HPA-2) questionnaire focusing on supports and barriers to HPD use was developed (Appendix 7). Draft versions of the questionnaire was pre-tested in two workplaces to obtain worker feedback on design issues and determine suitability of items. This process helped confirm the items and format of the final version of the questionnaire. The study was approved by the University of Auckland Human Participants Ethics Committee (Ref: 2010/214).

Convenience sampling was used to recruit thirty-four manufacturing companies. Twenty-six of these were contacted via the telephone directory while the remainder were recruited through a health and safety training company. Most (N=24) were in the Auckland City region. As the primary interest was understanding workers' perceptions regarding supports and barriers to HPD use, actual noise levels in the different workplaces were not measured. The aim was to recruit companies in the manufacturing industry that regarded themselves as a 'high noise level' environment and where employees were required to use HPDs in accordance with health and safety regulations (Department of Labour, 1995). The companies recruited were sheet metal fabricators, joiners, cement factories and foundries.

Employers were given a company participant information sheet (PIS) and the details of the study were explained to them. The employers and in some cases, occupational health and safety personnel, then explained the purpose of the study to the workers and invited interested workers to participate. The workers were also given a subject PIS. The anonymous questionnaires were collected within two weeks of distribution. Data collection lasted from July 2011 to March 2012.

An alpha level of 0.05 was adopted for all inferential statistical tests. As HPD use is most effective when worn all the time in excessive noise (W. Williams, 2009), the study compared factors influencing HPD use in workers who always reported to use hearing protection with those who did not. The chi-squared test was used to test for differences in reported supports and barriers to HPD use between workers who reported always using HPDs and those who did not always use them. Differences in the number of supports and barriers sub-scales between groups were assessed with the non-parametric Mann–Whitney U test. The reliability analysis using Cronbach's alpha was used to measure internal consistency (reliability) of the questionnaire scales. Factor analysis with an oblique rotation was conducted to investigate underlying structure of the scales. An examination of the Kaiser-Meyer Olkin measure of sampling adequacy suggested that the sample was factorable (KMO=0.808).

5.4. Results

Of the 1053 questionnaires distributed, 555 completed questionnaires were received, a response rate of 53%. The mean age of participants was 42.6 years (SD=12.5, *N*=545, missing data=10) and 96% were male. Fifty percent of workers reported New Zealand European ethnicity, 10 % Māori, 16% Samoan and 7% Cook Island Māori. There was a wide range in reported HPD use when exposed to noise, with 46% of the participants indicating they always wore HPDs and 54% reported not always using HPDs (22% almost always, 12% usually, 4% often, 12% sometimes and 4% rarely or never). Many respondents (74%) indicated that safety was at the forefront of their mind when working while 25% thought that other factors limited their ability to work safely even though they considered safety as important. Those who indicated high safety awareness (80%) were more likely to report using HPDs, $\chi 2$ (1,549) = 7.15, $p = 0.007$. About half the participants believed that injuries occur because people do not take safety seriously (52%), and the other half believed that injuries will always occur no matter how hard people try to prevent them (47%). There was no difference in the reported use of HPDs in these two groups.

All but two participants in this study endorsed at least one support for reported HPD use (reasons for wearing HPDs). The three most common reasons for wearing HPDs when it was noisy (Table 5.1) were to protect hearing, when doing a noisy job, and preserving hearing to maintain quality of life with family. Less than half of the workers in this study (N= 228) reported receiving training to use HPDs. A greater percentage of workers who reportedly always wore HPDs indicated wanting to preserve hearing for family, recognition and adherence to company rules, and receipt of training as supports for their hearing protection behaviour. In contrast, a greater percentage of workers who reportedly did not always use HPDs indicated noise created by tasks performed by them or by other workers as their reasons for using hearing protection.

Table 5.1 Reasons for wearing HPDs at work (supports)

Supports	**Freq (%)** n = 549[a]	**Always wear HPD,** n=252 Freq (%)	**Don't always wear HPD,** n=297 Freq (%)	**Chi-Sq** X^2	**df**	***P* value**
You want your hearing to be good to live a good life with your family	426 (78)	209 **(83)**	217 (73)	7.64	1	**
It is company rules	376 (69)	194 **(77)**	182 (61)	15.58	1	***
You have received training to wear them	228 (42)	122 **(48)**	106 (36)	9.03	1	**
Wear it all the time, even when it is quiet	124 (23)	103 **(41)**	21 (7)	89.09	1	***
You want to protect your hearing	497 (91)	234 (93)	263 (89)	2.95	1	NS
You are annoyed by the noise	321 (59)	147 (58)	174 (59)	0.004	1	NS
Your boss tells you to	181 (33)	88 (35)	93 (31)	0.80	1	NS
Your workmates remind you to wear them	128 (23)	65 (26)	63 (21)	1.60	1	NS
You are doing a noisy job	449 (82)	183 (73)	266 **(90)**	26.27	1	***
Others workers are doing a noisy job	421 (77)	178 (71)	243 **(82)**	9.54	1	**

[a] Missing data – 6 (1%). NS, non-significant. Significantly greater % of supports in either group is indicated in bold. Significance: ***P < 0.001, **P < 0.01, *P < 0.05

Almost two-thirds (355) of the participants reported at least one barrier against HPD use. Of the 200 who did not endorse any barriers, 61% reported using HPDs always. The three most common reasons for reportedly not wearing HPDs were someone else doing a noisy job without warning, communication difficulties, and inability to hear warning signals and work process sounds (Table 5.2).

Table 5.2 Reasons for not wearing HPDs when exposed to noise at work (barriers)

Barriers	**Freq (%)** n = 549[a]	**Always wear HPD,** n=252 Freq (%)	**Don't always wear HPD,** n=297 Freq (%)	**Chi-Sq** X^2	**df**	***P* value**
Someone else does something noisy without warning	144 (26)	54 (22)	90 **(30)**	5.42	1	**
They are uncomfortable	108 (20)	39 (16)	69 **(23)**	5.19	1	*
You can't communicate properly with other workers	211 (38)	87 (35)	124 (42)	3.01	1	NS
You can't hear properly to do your work	132 (24)	51 (20)	81 (28)	3.96	1	NS
They get in the way of other safety equipment	63 (12)	28 (11)	35 (12)	0.05	1	NS
You are used to noise at work	48 (9)	23 (9)	25 (8)	0.09	1	NS
Your co-workers often don't wear them	36 (7)	21 (8)	15 (5)	2.40	1	NS
You are not clear as to when you should wear them	34 (6)	23 **(9)**	11 (4)	6.90	1	**
Your co-workers find it funny when you wear them	19 (4)	14 **(6)**	5 (2)	6.08	1	*

[a] Missing data – 6 (1%). NS, non-significant. Significantly greater % of supports in either group is indicated in bold. Significance: ***P < 0.001, **P < 0.01, *P < 0.05

Self- reported wearing of HPDs was significantly associated with some barriers against hearing protection behaviour (Table 5.2). A greater percentage of workers who reportedly did not always wear HPDs found other workers doing a noisy job without warning and HPDs being uncomfortable as reasons for not wearing hearing protection when noisy. Interestingly, a greater percentage of workers who reported always using HPDs indicated not being clear about when to use HPDs and co-workers finding them funny as barriers to wearing hearing protection. A marginally (p=0.055) greater proportion of workers who reportedly did not always wear HPDs regarded their inability to hear warning signals as reason for not wearing HPDs.

In order to identify key factors that describe the supports and barriers to HPD use as per the ecological model, factor analysis with an oblique rotation was conducted. When loadings less than 0.25 were excluded, the supports and barriers to HPD use loaded onto five factors (Table 5.3). Eight items loaded onto Factor 1. These items may be regarded as 'excuses' workers make for their inconsistent use of HPDs and this factor was labelled, "Risk

Justification". Items loaded for Factor 2, labelled "HPD Constraints" related to difficulties faced by workers when wearing HPDs that negatively influenced HPD use in workers. Three items loaded onto a third factor ("Hazard Recognition") related to workers reported use of hearing protection when exposed to noise and using HPDs to avoid noise annoyance. The four items that loaded onto Factor 4 ("Behaviour Motivation") related to influences that acted as a stimulus for reported hearing protection behaviour. The influence of workplace policies and encouragement towards hearing protection behaviour at Factor 5 was labelled "Safety Culture". The item 'wear all the time' was loaded in a reasonably balanced way across the five factors. The loading of 0.26 on factor 1 was highest, but the others ranged from -0.11 to -0.20.

Table 5.3 Obliquely rotated component loadings for factors influencing hearing protection behaviour [a]

Sub-scales of supports and barriers

1. Risk justification	Co-workers find HPDs funny	0.878
	Co-workers don't wear HPDs	0.719
	Not clear when to wear	0.643
	Used to not wearing HPDs	0.528
	HPDs are uncomfortable	0.344
	HPDs get in the way of safety gear	0.323
	Co-workers doing a noisy job without warning	0.294
	Wear all the time	0.258
2. HPD constraints	Can't hear machine	0.672
	Communication	0.588
	HPDs get in the way of safety gear	0.281
3. Hazard recognition	Other workers doing noisy jobs	0.817
	Workers doing a noisy job	0.790
	Noise is causing annoyance	0.453
4. Behaviour motivation	Hearing preservation to maintain healthy family life	-0.626
	To protect hearing	-0.593
	Workplace rules	-0.331
	Receipt of training	-0.342
5. Safety Culture	Boss reminds to wear HPDs	-0.729
	Workmates remind to wear HPDs	-0.693
	Workplace rules	-0.413
	Receipt of training	-0.386

A Mann-Whitney U test was performed to test the relationship between reported HPD use with each supports and barriers sub-scale. The results (Table 5.4) indicate greater influence of supports (behaviour motivation and safety culture) on those who always wore HPDs and a greater influence of barriers (risk justification and HPD constraints) for those who did not always wear hearing protection.

Table 5.4 The relationship between supports and barriers sub-scales and HPD use (Mann-Whitney U Test)

	HPD use (n=549)[a]	**Mean rank**	**Mann-Whitney U**	***Z***	***P***
Supports	Not always	265	34569	-1.55	NS
	Always	286			
Behaviour Motivation	Not always	250	29912	-4.22	***
	Always	305			
Safety Culture	Not always	257	31933	-3.04	**
	Always	297			
Hazard Recognition	Not always	285	34407	-1.79	NS
	Always	263			
Barriers	Not always	301	29684	-4.34	***
	Always	244			
Risk Justification	Not always	298	30695	-4.01	***
	Always	248			
HPD Constraints	Not always	288	33653	-2.23	*
	Always	260			

[a] Not always n=287 (54%), always n=252 (46%), missing data 6 (1%). NS, non-significant.
Significance: ***P < 0.001, **P < 0.01, *P < 0.05

The reliability of the two scales "supports" scale and "barriers" scale for self-reported HPD use was tested. Items from the supports scale (α=0.77) had good internal consistency as did items in the barriers scale (α=0.74). All items except one appeared to be worthy of retention. The greatest increase in alpha would come from deleting item; "wear all the time" (Table 5.5). This item had a low item-total correlation of 0.19, whereas others were in the range 0.31 to 0.55. On this basis and because of its unreliable factor loading, the item 'wear all the time' was dropped from the questionnaire.

Table 5.5 Corrected item-total correlation of items describing influence on hearing protection behaviour

Reasons for wearing HPDs at work (supports to HPD use) (Cronbach's Alpha = 0.771)	**Corrected Item-Total Correlation**
Your boss tells you to	0.45
When you are doing a noisy job	0.47
When other workers are doing noisy jobs	0.49
You want to protect your hearing	0.31
You are annoyed by the noise	0.45
You want your hearing to be good for your family	0.49
Your workmates remind you to wear them	0.49
It is company rules	0.48
You have received training to wear them	0.54
You wear them all the time, even when it is quiet	**0.19**
Reasons for not wearing HPDs at work (barriers against HPD use (Cronbach's Alpha = 0.740)	**Corrected Item-Total Correlation**
You are not clear when to wear them	0.51
You can't hear properly to do your work	0.46
You can't communicate properly with other workers	0.37
They are uncomfortable	0.43
They get in the way of other safety equipment	0.47
You are used to noise at work	0.49
Your co-workers often don't wear them	0.55
Your co-workers find it funny when you wear them	0.61
Someone else is doing something noisy without warning	0.26

Cronbach's Alpha for subscales: Hazard Recognition (0.748); Behaviour Motivation (0.661); Safety Culture (0.722); Risk Justification (0.685); HPD Constraints (0.592).

5.5. Discussion

The HPA-2 Questionnaire represents an easily administered instrument that can measure supports and barriers to HPD use in workers. Cronbach's alpha values close to 0.80 for a given scale are considered reliable (Field, 2005). The Cronbach's alpha for the barriers scale

(α=0.74) and supports scale (α=0.77) indicated strong internal reliability of the questionnaire. The questionnaire also demonstrated statistically significant differences in supports, barriers, and respective sub-scales to HPD use in workers. In addition, supports and barriers exist across different levels of the ecological model and interact with each other to influence hearing protection behaviour.

The finding that only 46% of workers reported always wearing HPDs when exposed to noise is of concern, especially considering that HPDs are most effective when worn all the time in excessive noise (W. Williams, 2009). Not surprisingly, workers with a reported positive attitude to safety were more likely to practice hearing protection behaviour than those with negative attitudes. However, it is alarming that almost half the respondents suggested workplace injuries to always occur despite preventive efforts given that workers' perceptions of safety and risk influence personal protective behaviour such as the use of HPDs (Arezes & Miguel, 2006b).

The five factors describing the supports and barriers (risk justification, HPD constraints, hazard recognition, behaviour motivation, and safety culture) exist within different levels of the ecological model interacting with each other to influence hearing protection behaviour (Figure5.1). This study shows that behaviour motivation and safety culture are supports that influence workers who always wear HPDs more than workers who do not (Table 5.4). Conversely, those who reported not always wearing HPDs indicated perceived barriers (risk justification and HPD constraints) more than those who always did.

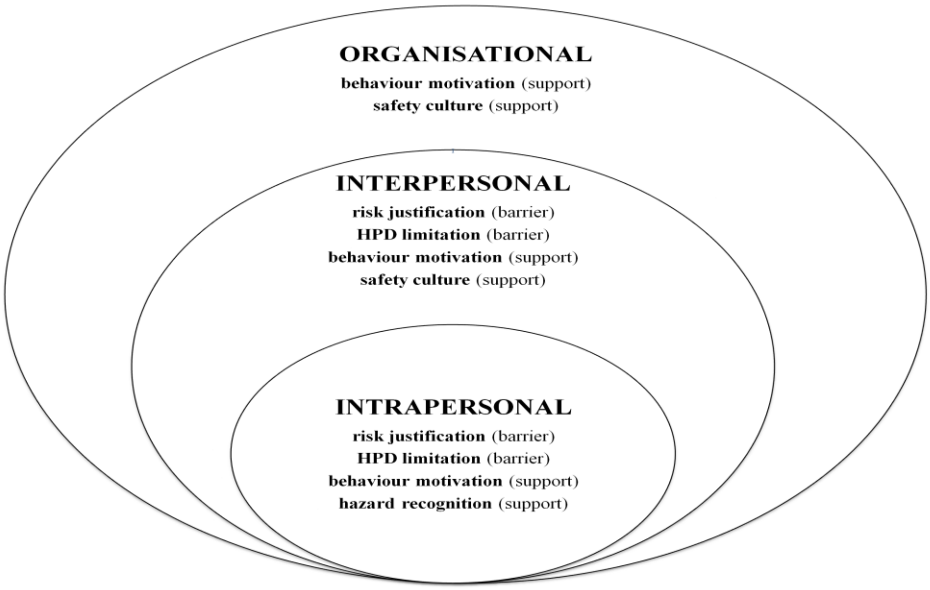

Figure 5.1 The five factors acting as supports and barriers to HPD use interacting across three levels of a modified version of the ecological model for hearing protection behaviour

Risk Justification underlies the intra- and inter-personal levels of the model that is formed by individual attributes and external influences. These attributes provide workers with justification for not wearing HPDs when exposed to noise, and appear to reflect shared attitudes across the workforce. Furthermore, workers with perceived low frustration-tolerance towards HPD use may be more likely to magnify the discomfort and not tolerate it despite the long-term benefits (Branch & Willson, 2010), thus negatively influencing hearing protection behaviour (Kushnir et al., 2006). The marginal effects of the perceived inability to hear machine signals and not wearing HPDs highlight intrapersonal influences associated with HPDs. On the other hand, the perception of noise as a debilitating hazard and nuisance is a supporting influence to hearing protection behaviour at the intra-personal level. The enforcement of workplace safety rules and facilitation of safety training by management (organisational level) is an important factor influencing hearing protection behaviour (Edelson et al., 2009). This, together with peer and management support/modelling (interpersonal level) help form a positive safety culture. Behaviour motivation is reflected at each level supporting positive hearing protection behaviour. For example, at the interpersonal level, social networks and the provision of social support such as friends and family affect the health and behaviour of individuals through direct and indirect interactions (B. G. Simons-Morton et al., 2012).

There appears to be reciprocal determinism whereby interactions between the worker and the environment across different levels of the model influence behaviour (B. G. Simons-Morton et al., 2012). For example, encouraging safety culture (training, rules, and support) at the organisational level positively affects behaviour motivation and hazard recognition at the intrapersonal and interpersonal levels while mitigating risk justification and HPD constraints to influence positive hearing protection behaviour in workers.

This research involved convenience sampling and voluntary participation. This may have led to selection bias in the types of company (level of enforcement, size) and worker who volunteered to take part. On the other hand, research involving coercion (for example by enforcement authorities) would not necessarily produce more accurate data, because people would fear the repercussions of saying that they did not conform to noise regulations.

Noise level measurements for each company were not conducted, instead basing the inclusion criterion on the companies' requirements for workers to wear HPDs at work upon noise exposure. Importantly, the focus of the research was to understand why workers did not wear HPD when they were expected to do so.

The study relied on self-reporting of HPD use and people are known to over-report hearing protection behaviour (Griffin, Neitzel, Daniell, & Seixas, 2009; Hansia & Dickinson, 2010; Neitzel & Seixas, 2005). In addition, self reported HPD use in variable noise is not as accurate as data from steady noise exposure (Griffin et al., 2009). However, by designing the scale measuring HPD use with multiple options that was subsequently categorised as 'not all the time', it was hoped to mitigate this bias to some extent. Previous research has indicated that responses to scales are affected by the number of alternatives available (Maydeu-Olivares, Kramp, Garcia-Forero, Gallardo-Pujol, & Coffman, 2009), so this scale should perform better than a simple yes/no question. A general measure for HPD use was utilised instead of a more specific variable such as a given day/week as reported elsewhere (Griffin et al., 2009).

Only three levels of the ecological model were investigated. The community level needs further investigation concerning social norms regarding noise acceptability. This can be incorporated with findings from this study to target future intervention programs. The policy level is covered by the code of practice for management of noise in workplaces (Department of Labour, 1996) but current and future research will inform the re-evaluation of policies and practices.

A practical strength of the HPA-2 questionnaire is that it is time-efficient and appropriate for respondents of most educational levels. Furthermore, the relatively clear concepts made it easy to translate this questionnaire to four different languages commonly used in New Zealand (Samoan, Tongan, Cook Island Māori, and Niuean) although the non-English translations were not required in practice since all participants elected to complete the questionnaire in English.

This research drew on factors that influence hearing protection behaviour at different levels of the ecological model to form a quantitative questionnaire measuring the supports and barriers to HPD use. Reliability and validity of the supports and barriers to HPD use were good. Furthermore, the validity of the supports and barriers incorporated in this questionnaire is supported by previous research undertaken by the authors (Reddy et al., 2012). The HPA-2 questionnaire may be useful in both research and interventions to understand and motivate hearing protection behaviour. In addition, the questionnaire allows identification of supports and barriers at different levels of the ecological model that may be targeted when developing hearing protection interventions.

Chapter 6. Influences of Hearing Conservation Behaviour in Workers of Different Ethnicities and Immigrant Status

6.1. Introduction

New Zealand has a multicultural society and workforce (Jones, Pringle, & Shepherd, 2000; Watts & Trlin, 2000). The resident population in the 2013 New Zealand Census was 4,242,048; representing a 5.3% increase from 2006. People identifying with the NZ European ethnicity represented 74% of the population, 15% were Māori, and 7% were of Pacific Island ethnicities. According to the 2013 Census, almost a quarter of people living in New Zealand were born overseas with the three most common countries of birth being England (215,589 people), The People's Republic of China (89,121 people), and India (67,176 people). Furthermore, there were 151,515 people born in Pacific Island countries such as Samoa, Tonga, Fiji, Cook Islands and Niue (Statistics New Zealand, 2013). Statistics New Zealand has projected that Māori, Asian, and Pacific populations will grow as proportions of the overall New Zealand population (Statistics New Zealand, 2010). This gives rise to a large population of immigrant and ethnic minority workers. The health and wellbeing of immigrant and ethnic minority workers around the world is a significant public health issue especially considering that they mostly work in high-risk industries such as construction and manufacturing (McCauley, 2005; Pransky et al., 2002). There is evidence internationally that ethnic minorities and immigrant workers are over-represented in high-risk occupations and have higher rates of work-related injuries, morbidity, and mortality (Anderson, Hunting, & Welch, 2000; Friedman-Jimenez, 1989; Loh, 2004; Premji, Duguay, Messing, & Lippel, 2010; Strong & Zimmerman, 2005).

Given the growing diversity in the New Zealand population and having described ethnicity characteristics in Chapter 5, it was of interest to determine whether supports and barriers to hearing protection differ by ethnicity and immigrant status. This has implications for the development of interventions to improve hearing protective behaviour, as significant ethnic differences would require tailoring of interventions to specific groups. Although there are a few New Zealand studies looking at HPD use in general, (Eng et al., 2010; Firth, Herbison, & McBride, 2006; John et al., 2013; McBride et al., 2003), there are no studies describing ethnicity and immigrant status in relation to hearing protection behaviour in New Zealand. However, there are a few international studies explaining HPD use amongst immigrant workers (Rabinowitz, Sircar, Tarabar, Galusha, & Slade, 2005; Robertson et al., 2007). The purpose of this chapter was to describe the factors influencing hearing protection behaviour in workers of different ethnicities and immigrant status.

6.2. Methods

The questionnaire data obtained from 555 respondents were analysed to assess ethnic and immigrancy differences in respect to hearing protection behaviour. Descriptive analysis was conducted for self-reported HPD use and common supports and barriers for ethnic and immigrant groups. These analyses were conducted separately for four ethnic groups: NZ European, Māori, Pacific Island, and Others. The Pacific Island ethnicity consisted of workers who indicated they were Samoan, Tongan, Cook Island Māori, Niuean or other Pacific Islands ethnicities.

One of the difficulties associated with the measurement of ethnicity is that people may possess multiple ethnicities, which may result in responses and results exceeding the total sample. Since one ethnicity was not compared to another, multiple ethnicities were accepted and data were analysed according to the total responses for each ethnicity. The Pearson's chi-square test was used to discover if there was a significant difference between NZ born workers and workers born overseas in relation to HPD use when exposed to noise. Comparison of supports and barriers between workers born in NZ and those born overseas was conducted. An alpha level of 0.05 was adopted for all inferential statistical tests.

6.3. Results

The mean age of participants was 42.6 years (SD=12.5, N=545, missing data=10) Most of the participants in this sample were male (96%) (Table 6.1). New Zealand European (NZE) ethnicity was the most common (50%), followed by Pacific Island ethnicities (29%); Other ethnicities (16%); and Māori (10%). There was a wide range of other ethnicities (n=35), including British, South African, Chinese and Indian workers. Workers born in NZ made up 57% of the sample, while workers of Pacific Island ethnicities made up 50% (n=120) of the immigrant worker group in this study (Table 6.1).

Table 6.1 Baseline characteristics of workers in the study

Characteristics	**n = 555** **n (%)**
<u>Gender</u>	
Male	534 (96)
Female	21 (4)
<u>Ethnicity</u>	
NZ European	279 (50)
Māori	55 (10)
Pacific Island	161 (29)
Other	90 (16)
<u>Place of birth</u>	
NZ born	316 (57)
Born overseas	239 (43)
NZ European	39 (16)
Pacific Island	120 (50)
Other	81 (34)

The self-reported consistent use of hearing protection was poor, with 47% of workers across the different ethnicities reporting using HPDs always when exposed to noise (Figure 1). Only 38% of workers born in NZ and 56% of workers born overseas reported using hearing protection always when exposed to noise (Figure 6.1). There was a significant difference in self-reported use of HPDs between immigrant and NZ born workers; X^2 (1) =17.4, p=<0.001.

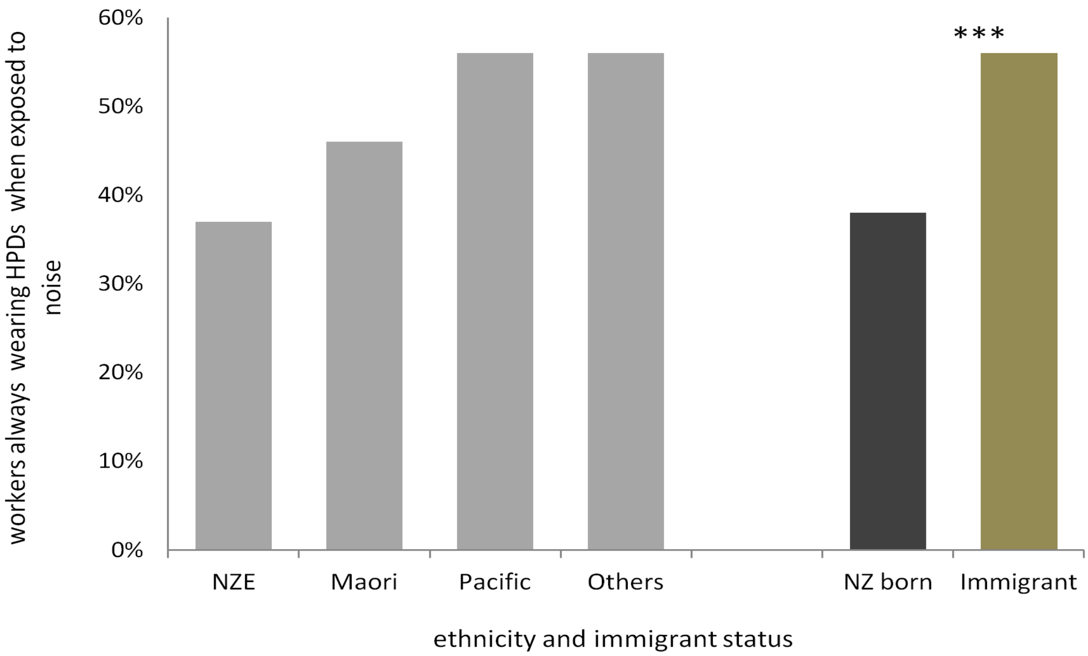

Figure 6.1 Percentage of workers reporting using HPDs always when exposed to noise across different ethnicities. Ethnicity not prioritised and a worker could have indicated more than one ethnicity. ***P < 0.001

6.3.1 **NZ European**

The most common reasons for wearing HPDs when it was noisy for workers of NZE ethnicity were for the prevention of hearing loss, when they or other workers were doing a noisy job, to preserve hearing to enjoy quality of life with family, adherence to company rules, and to block out the annoying aspect of excessive noise. Co-workers undertaking a noisy job without warning, communication difficulties, and inability to hear work processes were the three most common reason indicated by workers of NZE ethnicity for not wearing hearing protection when noisy (Figure 6.2).

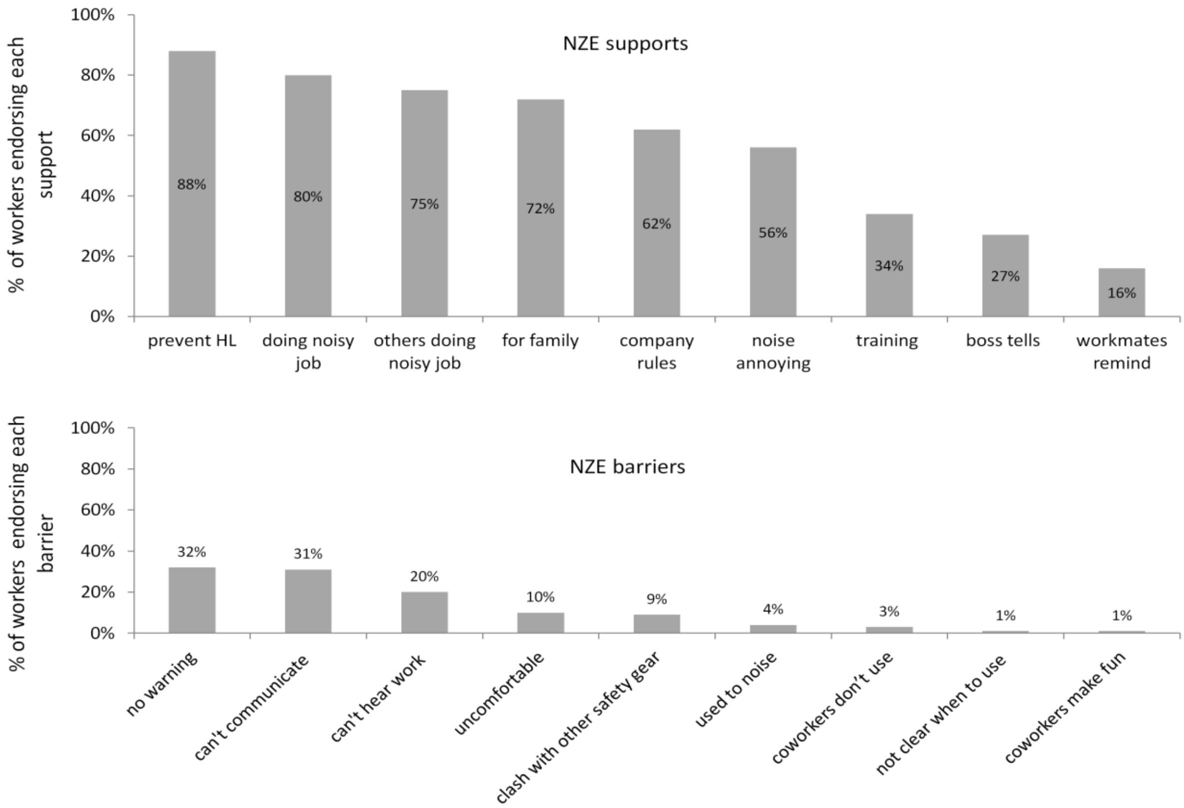

Figure 6.2 Supports and barriers to hearing protection behaviour in workers of NZE ethnicity when exposed to noise (n=279)

6.3.2 **Māori**

Māori workers reported similar common supports to HPD use as NZE workers. In addition to the common barriers identified by NZE workers, Māori workers indicated the uncomfortable nature of HPDs as their second most common reason of non-use (Figure 6.3).

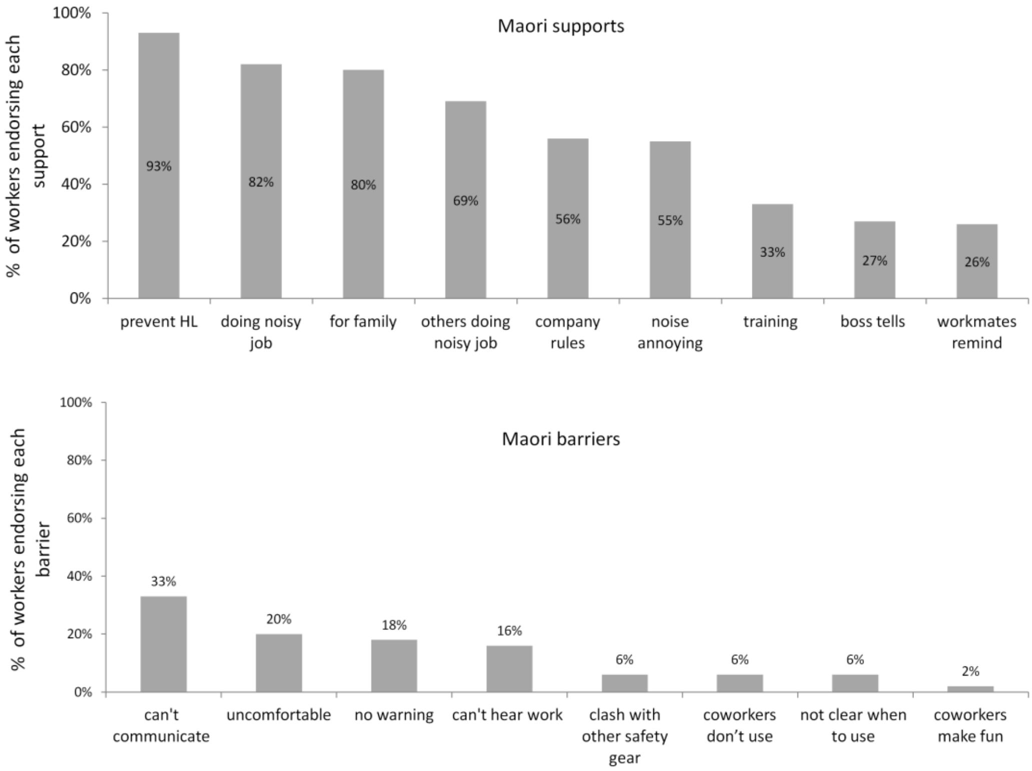

Figure 6.3 Supports and barriers to hearing protection behaviour in workers of Māori ethnicity when exposed to noise (n=55)

6.3.3 **Pacific Island workers**

Pacific Island workers reported similar common barriers and supports to NZE and Māori workers. However, a fifth of Pacific Island workers indicated being used to noise as a reason for not wearing HPDs when noisy (Figure 6.4). In addition, 10-16% of the these workers reported co-workers finding their use of HPDs funny, co-workers not wearing hearing protection and not being clear when to use HPDs barriers.

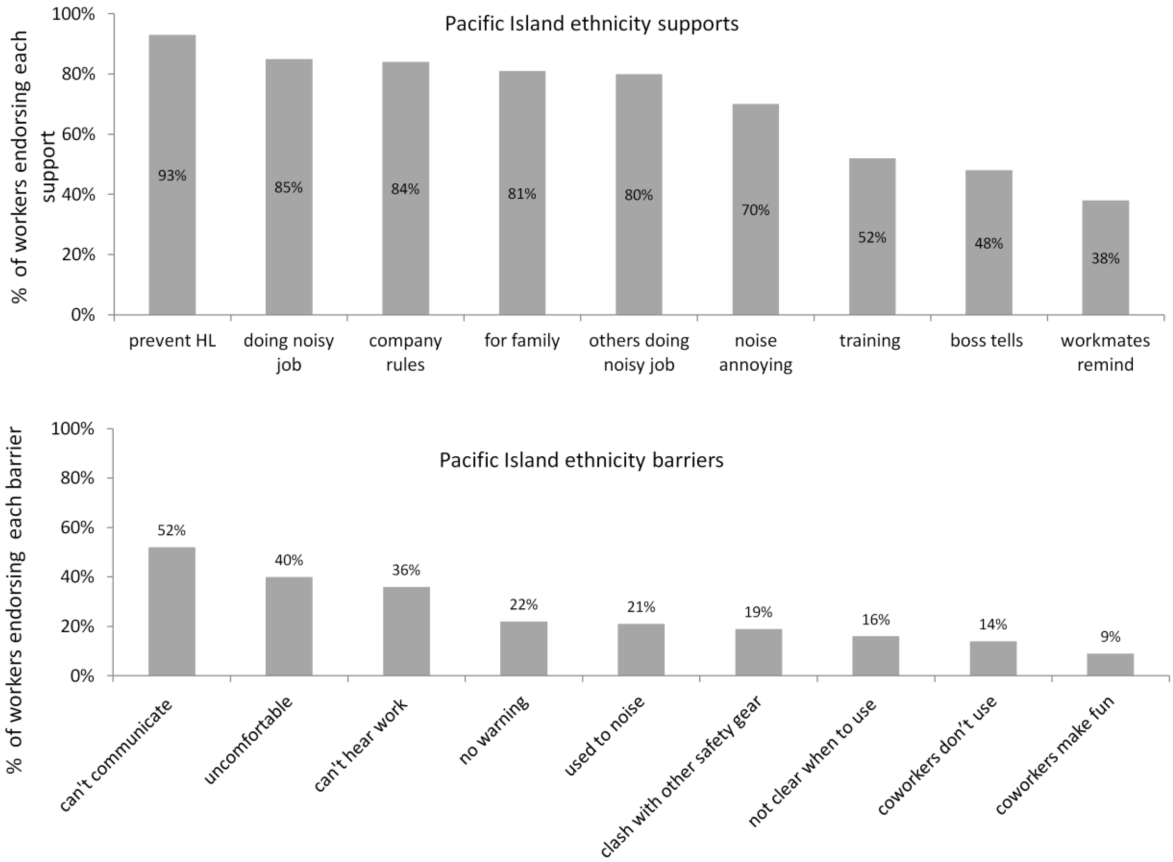

Figure 6.4 Supports and barriers to hearing protection behaviour in workers of Pacific Island ethnicity when exposed to noise (n=161)

6.3.4 **Other Ethnicities**

Workers of Other ethnicities reported similar common supports and barriers to HPD use as NZE, Māori, and Pacific Island workers (Figure 6.5). However, 66% of workers of Other ethnicities reported receipt of training as a motivator for hearing protection behaviour.

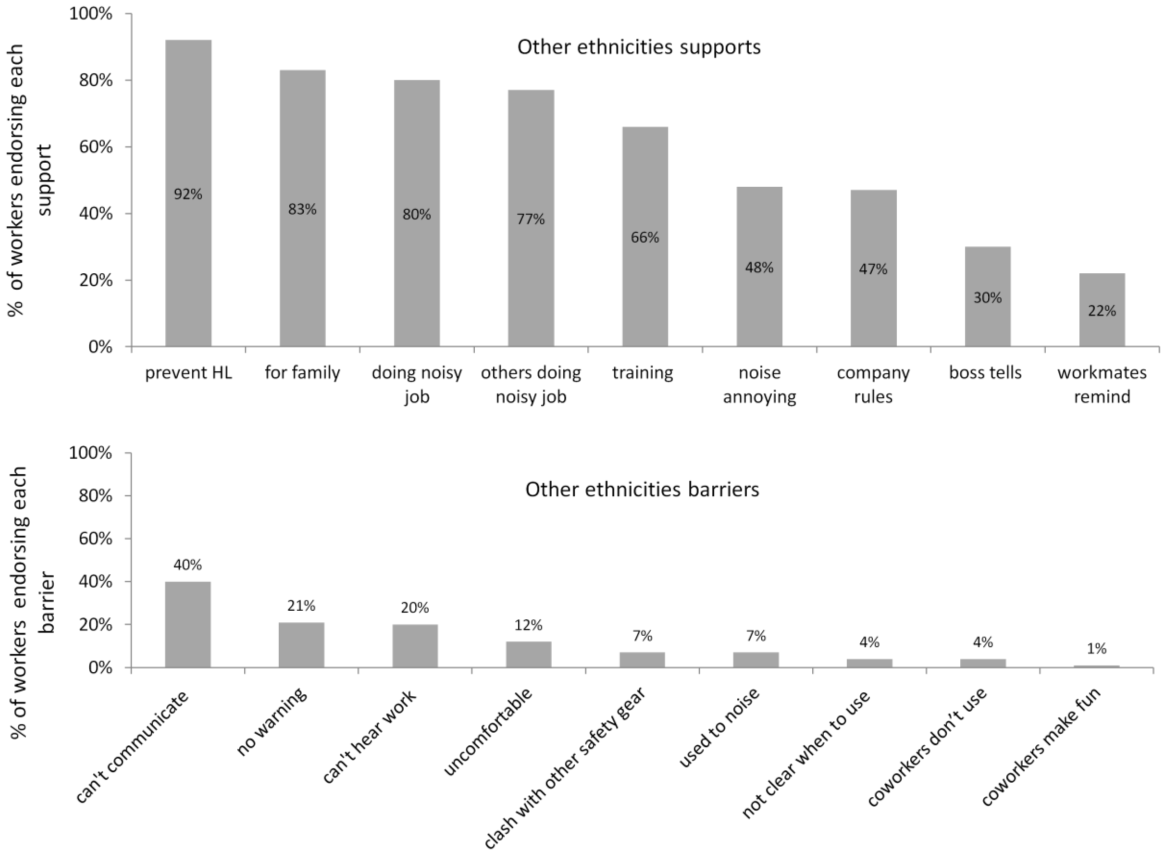

Figure 6.5 Supports and barriers to hearing protection behaviour in workers of Other ethnicities when exposed to noise (n=90)

6.3.5 **Immigrant workers**

Immigrant and NZ born workers indicated similar common reasons for and against wearing HPDs when exposed to noise (Figure 6.6). The common supports for HPD use were for the prevention of hearing loss, when noisy work was being carried out, to maintain a good quality of life with family, and adherence to company rules. Common barriers to self-reported HPD use were communications difficulties experienced, other workers doing a noisy job without warning and discomfort caused when wearing HPDs. Three-quarters of workers identifying with Pacific Island ethnicities were born overseas and made up 50% of immigrant workers in this study. Immigrant Pacific Island workers were more likely to indicate doing a noisy job (88%) as reason for wearing HPDs than NZ born workers of Pacific Island ethnicities (76%); X^2 (1)= 3.9, p=0.05. Furthermore, immigrant Pacific Island workers (42%) were also more likely than NZ born Pacific Island workers (17%) to indicate the inability to hear machine noise and work processes as reasons for not wearing HPDs when exposed to noise; X^2 (1)= 8.6, p=0.003.

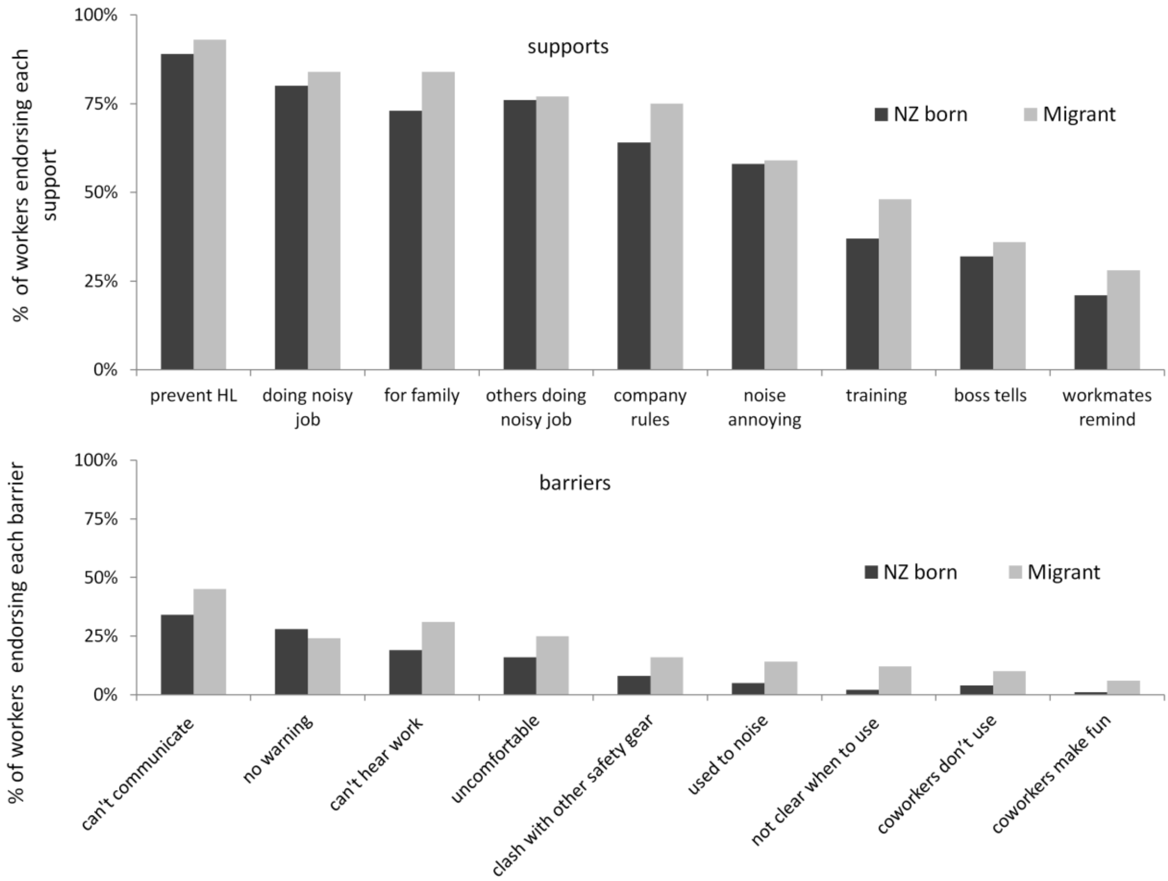

Figure 6.6 Supports and barriers to hearing protection behaviour in NZ born workers and migrant workers

6.4. Discussion

The findings provide a preliminary understanding of factors influencing self-reported HPD use amongst workers of different ethnicities and immigrant status. Self-reported consistent use of HPDs was poor in all workers regardless of ethnicity and immigrancy. However, the results suggest that workers born overseas reported always using HPDs significantly more than NZ born workers in this study. The separate ethnic subgroup analyses provided insights into the supports and barriers to HPD use. Common supports and barriers to self-reported HPD use were similar across all ethnic groups in this study. Common supports and barriers to HPD use identified in other populations (e.g., communication difficulties and impact on job performance (Kahan & Ross, 1994; Morata et al., 2005); uncomfortable nature of HPDs (Patel et al., 2001), and perceived value of HPDs in preventing NIHL (Arezes & Miguel, 2005a) were also endorsed by workers across different ethnic groups in the current sample.

Only about 30-60% of the workers in each group indicated receipt of training as a support to their hearing protection behaviour. This is of concern since adequately trained workers develop increased efficacy in observing safety procedures and managing hazards (Becker & Morawetz, 2004; Duffy, 2003; Leiter, Zanaletti, & Argentero, 2009). This could mean that they have not received training at all, they could not recall receiving training, or the training they received was not effective in influencing hearing conservation behaviour. It has been reported that non-English speaking workers have difficulties understanding oral and written health and safety related information (Premji, Messing, & Lippel, 2008). This suggests that passive training techniques such as lectures, flyers, and pamphlets do not effectively communicate health and safety messages in diverse work groups. Furthermore, a New Zealand health and safety report found that Pacific Island workers preferred hands-on, small group training sessions with demonstrations as an effective method of workplace training (Department of Labour, 2012). This emphasises the need for training sessions to be simple, interactive, and motivational rather than primarily used as a means to tell workers what to do.

The finding that immigrant workers report better hearing protection behaviour than NZ born workers may be indicative of cultural differences related to rules and hearing conservation. Immigrant workers appear to be aware of noise related risks and practice hearing protection behaviour as they may feel the need to ‘prove themselves’ as hardworking employees and avoid being construed as a ‘troublemaker’ (Robertson et al., 2007). A culture of respect, humility, loyalty, and hard work among Pacific Island workers in New Zealand has been suggested as reasons for under-reporting of injuries and hazardous conditions in workplaces (Department of Labour, 2012). This could have contributed to immigrant workers over-estimating their hearing protection behaviour. The idea of “fitting in” can also explain poor protective behaviour in immigrant workers, as they may choose to appear strong in front of their peers and supervisors in order to exhibit their false sense of value (Robertson, Kerr et al. 2007).

It was possible to compare NZ-born Pacific Island workers with immigrant Pacific Island workers, thereby keeping ethnicity constant while comparing immigrants with non-immigrants. Compared to NZ born Pacific Islanders, significantly more immigrant Pacific

Islanders endorsed one support (wearing HPDs when doing a noisy job) and one barrier (HPDs were not used due to the inability to listen to machine noise and work processes). It was only possible to treat Pacific ethnicities in this way because they comprised 50% of the immigrants in this study; the remaining 50% were of 30 different ethnicities and thus numbers of any one were too few to allow analysis. The differences between immigrant Pacific workers and NZ born Pacific workers again raise the issue of "fitting in". Immigrant Pacific Island workers appear to be very careful with their work and may not want to make mistakes for fear of losing their jobs or upsetting management. This could explain why difficulties in listening to work processes and machine sounds were a significant barrier to reported hearing protection behaviour among immigrant Pacific Island workers.

The study was limited by the convenience nature of the sample. Since the entire population was not included, it is possible that some degree of selection bias occurred, and that the results of the survey are not representative, though there is no special reason to suppose that they were not. However, given the changing backdrop of the New Zealand population, this study provides useful insights into the hearing protection behaviour of workers and the role of ethnicity and immigrant status. Cultural variations in knowledge, attitudes, and beliefs regarding noise and hearing loss also need to be investigated at the community level. This will allow for a greater understanding of cultural norms that could be targeted in interventions to prevent NIHL in New Zealand. In addition, self-reported data does not allow for generalising conclusions to all groups in all manufacturing workplaces in New Zealand.

The findings reported in this chapter encourage the development of a simple, interactive, and motivational hearing conservation programme targeted at noisy workplaces. There were similar common supports and barriers to hearing protection behaviour reported across each group. These influences of hearing protection behaviour must form the core of future training programmes. However, given the poor endorsement of training as motivation for hearing conservation behaviour and acknowledging New Zealand's diverse workforce, it may be necessary to incorporate multiple training strategies such as audio and visual techniques (Bust, Gibb, & Pink, 2008), and emotional motivation (Keller & Lehmann, 2008) to enhance the effectiveness of hearing health communication for workers. The development of such a training programme is described in the next chapter.

Chapter 7. Development of A NIHL Prevention Intervention Using an Ecological Approach

7.1. Introduction

This chapter provides a description of the development of the intervention piloted and described in Chapter 8. The intervention development was informed by the qualitative (Chapter 4) and quantitative (Chapter 5 & 6) phases of the research. The Ecological Model for Health Promotion (McLeroy et al., 1988) helped identify several factors related to hearing health promotion across different levels of behavioural influence. Research described in Chapters 4, 5, and 6 identified several factors which influence hearing health across different levels of the ecological model. The purpose of the intervention was to target these factors across different levels through a workplace-based interactive training programme. In addition, since communication barriers were found to be major constraints to hearing conservation, part of the training intervention group received electronic HPDs to investigate whether they improved the effectiveness of the programme. The process of identifying and selecting the electronic HPDs has been described in Appendix 4. This chapter provides an account of how the training programme intervention was selected and adapted using the multi-level approach to community health (MATCH) model (B. G. Simons-Morton et al., 2012).

The MATCH ecological planning model was used to adapt a classroom hearing loss prevention programme, titled “Dangerous Decibels,” originally developed and shown to be effective for children in Oregon and Washington schools (Griest et al., 2007; Martin et al., 2006). The multi-disciplinary nature, ecological perspective, and audience-centred philosophy of public health communication (Bernhardt, 2004) may be useful in developing effective NIHL prevention interventions. While it is important to retain the core principles of successful programmes, consideration of relevance to the target population is important when adapting a programme to a new community (Tortolero et al., 2005).

MATCH (D. G. Simons-Morton, Simons-Morton, Parcel, & Bunker, 1988) is a process for developing theory and evidence-based health education programmes consisting of five phases: goals selection, intervention planning, programme development, implementation planning/facilitation, and evaluation. It takes an ecological approach that considers the interrelationship between the behavioural aspects of the individual and the physical, social, and cultural aspects of the environment (B. G. Simons-Morton et al., 2012). The MATCH model can be applied to a wide variety of health topics, settings, and target groups by integrating a selection of intervention methods and theories at different levels of behavioural influence (D. G. Simons-Morton et al., 1988). Therefore, the MATCH model was used to provide a practical framework to guide the adaptation and development of an effective health promotion intervention.

7.2. Application of the MATCH model in the adaptation and development process

A New Zealand Dangerous Decibels group comprising academics, audiologists, and industry personnel were trained by the original American Dangerous Decibels team to conduct the educational programme in New Zealand schools. As a result of interest in the programme, the NZ group also presented the Dangerous Decibels programme to industry personnel (occupational health nurses, ACC programme managers, government officials, workplace managers, workers' union members, and workplace health and safety representatives) in its school-based form. These industry personnel regularly interacted with workers of different demographics, educational levels, areas, and company sizes as their work requirement. The response from the industry personnel was supportive of the programme's key messages, simplicity, concreteness, and delivery methods. However, they indicated the need to adapt the programme to reflect industry-relevant content. The programme also needed to include elements of interpersonal and organisational influence described in Chapters 4 and 5 for an effective hearing health promotion intervention in workplaces. Taking the feedback of the industry personnel into consideration and targeting different levels of the ecological model, the programme in its school-based form was adapted to a workplace setting. The adapted programme retained the nine components of the classroom-based programme. However, the programme was adapted using a MATCH model to guide the intervention goals, content, relevance, and theory relevant to workplaces.

7.2.1 **Dangerous Decibels - The original programme**

The Dangerous Decibels classroom programme was developed in 1999 as a public health campaign designed to educate adolescents about hearing loss. The programme primarily targeted school children but was also delivered to adults (parents and teachers) in the same form. The goal of the programme is to improve knowledge, attitudes, and behaviours of children regarding noise exposure and hearing protection strategies. An interactive approach is used to deliver the classroom training rather than relying on passive methods such as flyers and posters (Martin et al., 2006). Active methods of training, such as hands on demonstration, are more effective than passive methods of delivery and while they may be more expensive in the short-term, they are potentially less costly and more effective in the long-term in ensuring healthy outcomes (Burke et al., 2006).

The programme was informed by the constructs of the Theory of Reasoned Action (TRA) with the aim of changing attitudes for positive hearing health behaviour. Evaluation of the Dangerous Decibels programme showed that the training was effective in increasing students' knowledge about sources of hazardous sounds, how loud sounds damage hearing, and strategies to protect hearing from loud noise exposure as well as attitudes and intended behaviour towards hearing protection (Griest et al., 2007). The Dangerous Decibels programme for schools was therefore an effective programme but needed to be adapted to be relevant for workplace settings. Revision of examples to more workplace-relevant situations and the addition of a component aimed at interpersonal influences needed to be incorporated in the workplace programme.

7.2.2 **The workplace programme adaptation: MATCH model**

MATCH Phase 1: Health and behaviour goals selection

The first phase was to determine the key targets and goals of the training. This included identifying the at-risk population, who were workers in noisy workplaces. The prevention of NIHL through a hearing conservation programme was prioritised. The programme goals focussed on improving and strengthening personal and environmental influences related to hearing health behaviour. Research described in Chapters 4 to 6 informed the selection of the steps in phase 1 (Table 7.1).

Table 7.1 Workplace-based NIHL prevention programme goals

Phase 1	Programme Goals	
Step 1:	At-risk population:	Workers in noisy workplaces
Step 2:	Health status goals:	Prevention of NIHL in workers exposed to hazardous levels of noise
Step 3:	Health behaviour goals:	Improve HPD use and create hearing health promotion norms
Step 4:	Environmental goals:	Create positive workplace safety culture

MATCH Phase 2: Intervention planning

This phase of the MATCH model concerns looking further into the health and behaviour of the at-risk population. As per the Ecological Model for Health Promotion (McLeroy et al., 1988), personal and environmental factors influence health and behaviour across different levels. Phase 2 underlines the importance of selecting intervention goals, targets, approaches, and theory at these different levels to ensure the development of an effective behaviour change programme (B. G. Simons-Morton et al., 2012).

The workplace programme intervention goals and objectives were ‘matched’ with intervention targets and strategies across different levels of the ecological model, which were identified in Chapters 4 and 5 (Table 7.2). The intervention objective was to consider influences on hearing protection behaviour at multiple levels and provide a hearing health communication programme that effected influences at these levels. At the intrapersonal level, the goal was to improve workers’ knowledge, attitudes, and self-efficacy regarding hearing protection. At the interpersonal level, the goal was to foster co-worker support and positive hearing protection behaviour modelling. In addition, we wanted to establish the emotional connection with family members and the role of good hearing in workers’ quality of life. At the organisational level, the goal was to provide a comprehensive, yet simple, training programme that advocates safety culture and support for hearing protection behaviour.

Table 7.2 Workplace NIHL prevention programme as per Phase 2 of the MATCH planning model

Phase 2		**Ecological level**	
Intervention planning	Intrapersonal	Interpersonal	Organisation
• *targets*	Workers/managers	Co-workers/family	Management/workers
• *goals*	Knowledge, attitudes, behaviour	Peer support/modelling, family influence	Resources, support/modelling and safety culture
• *approach & theory*	Interactive training, health belief model	Interactive training, social cognitive theory	Interactive training, social cognitive theory

An important part of the intervention planning phase is the identification and selection of channels of intervention delivery, intervention approach, theory, and methods. Channels of intervention may be direct (person-to-person) or indirect (media). The approach refers to how the intervention is delivered and varies according to channels and methods. This could be in the form of counselling, training, media and communication, consulting, organisational change, lobbying, etc. The appropriate approach depends on the target audience, resources, and channels of communication (B. G. Simons-Morton et al., 2012).

Therefore, having identified workers as the at-risk population for the intervention, the channel of intervention was selected to be direct with an educational, communicative, and training approach. This would allow person-to-person interaction with the workers and managers of noisy workplaces and the delivery of the hearing conservation programme.

The MATCH model views theory as a guide to understanding the likely influences on behaviour that help develop the intervention. The theories may also drive the methods or strategies for intervention. For example, the Social Cognitive Theory (SCT) methods involve interactive learning and modelling, while the Health Belief Model (HBM) uses persuasive methods to emphasise perceived risks and benefits (B. G. Simons-Morton et al., 2012).

The theoretical framework comprised of two behaviour change theories to guide the development of the workplace hearing conservation. The HBM and SCT helped inform the development of content aimed at targeting different levels of influence (Figure 7.1). The HBM posits that health behaviour is determined by factors such as perceived susceptibility and severity of disease, benefits of health behaviour, barriers against health behaviour, modifying factors, cues to action and self-efficacy (Janz & Becker, 1984). It suggests that persons' behaviour is based on their wish to remain or become healthy, and that the prescribed behaviour will help them achieve their goals (B. G. Simons-Morton et al., 2012). The constructs of the HBM helped understand and target individual level influences in the workplace programme. The SCT explains human behaviour as a three-way, reciprocal model where personal factors, environmental influences, and behaviour interact (Bandura, 1986). The reciprocal influence of actual behaviour and situational constraints may explain the safety culture of an organisation in relation to safety behaviour (Cooper, 2000). The SCT theorises that people not only learn from their own experiences but also through experiences and observations of others (Bandura, 1986). This is relevant to the workplace programme, as peer/supervisor modelling and role models within and outside the workplace influence workers. Another concept of the SCT is that self-efficacy is likely to be poor where people are unmotivated and without active involvement in what they are doing (Bandura, 1988).

The SCT acknowledges the importance of management guidance, motivation, and feedback at the organisational level when promoting healthy behaviours.

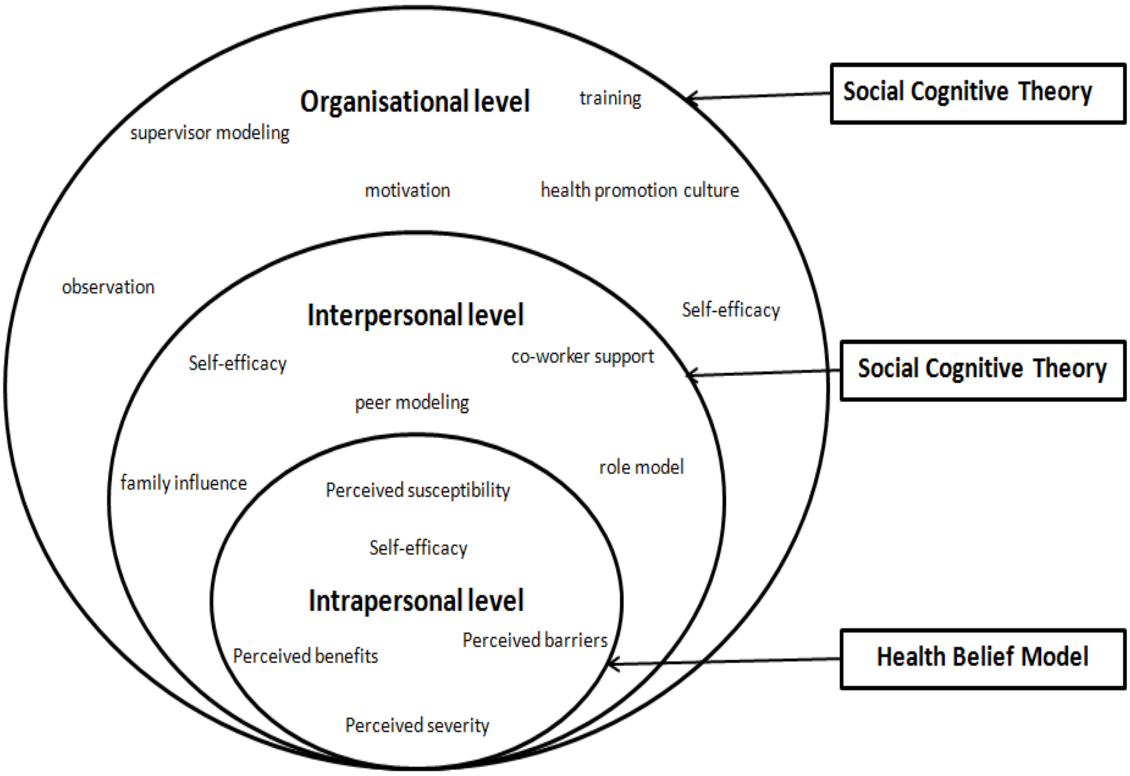

Figure 7.1 The utility of the HBM and SCT in targeting factors, across different levels of influence

MATCH Phase 3: Programme development

The programme development phase (Table 7.3), as per the MATCH model, includes three steps: (1) create components, (2) develop objectives and learning activities, and (3) develop user manual, curriculum, or guide.

There could be several programme components aimed at each level of behavioural influence. These components share the common goal of improving health and behavioural outcomes. However, they would be separate components delivered at different levels of influence, such as a training programme for individuals, a video session for their families, and the adoption of new policies at the organisational level (B. G. Simons-Morton et al., 2012). However, the workplace training programme in this thesis is a single component intervention that is aimed at influencing factors across multiple levels of behavioural influence related to hearing conservation. The HBM and SCT guide the training programme to: (1) improve knowledge, attitudes, beliefs, and skills at the individual level; (2) facilitate learning through experience, facilitate improvement in workers' self-efficacy; encourage peer support and modelling, enable emotional connection with family members and quality of life related to good hearing at the interpersonal level; and (3) encourage positive hearing health norms, foster management support and motivation, and create hearing health promotion culture at the organisational level. The management involvement is important as this shows their commitment to the programme and to their workers. Therefore, the programme content is relevant to the workers and their managers.

Table 7.3 Workplace NIHL prevention programme adaptation described by Phase 3 of the MATCH planning model

Phase 3	**Ecological level**		
	Intrapersonal	Interpersonal	Organisation
Programme development			
• *Component objectives*	Workplace training programme Susceptibility, severity, perceived threat, benefits, barriers, cues to action, and self-efficacy to prevent NIHL.	Observational learning, co-worker support to promote hearing protection	Organisational support and fostering of positive hearing health norms to reinforce safety culture.
• *methods and activities*	Positive interaction, 'hands on' demonstration, industry relevant noise level examples, audio, visual resources, skills training, reinforcement.	Modelling and support Emotional connection for family and quality of life Audio resource. Reinforcement and motivation	Reinforcement, feedback and motivation Persuasive communication
• *user manual*	Workplace NIHL prevention training script		

Effective training strategies involve the: (a) delivery of relevant information and concepts; (b) demonstration of knowledge, attitudes, and skills being taught; (c) opportunity to practice skills learnt; and (d) facilitation of feedback between trainer and trainee (Salas & Cannon-Bowers, 2001). The workplace programme used similar training strategies where workers were made aware of workplace-relevant concepts, shown pictures and microscopic images, props were used for demonstrations, technology-incorporated demonstrations of using HPDs were conducted, and practice sessions were facilitated.

The programme content and curriculum were adapted from the school-based programme. Nine modules have been modified to reflect workplace relevance and are described below.

Module 1: Purpose and introduction of training programme

The objective of this component was to establish rapport with the audience and explain the relevance and purpose of the programme. The workplace programme followed a similar approach to the school-based programme but included more industry-specific information, such as the high prevalence of NIHL affecting workers and increasing economic and societal costs. The major change in this component was placing more emphasis on workplace strategies of controlling noise such as engineering, administrative, and hearing protection use. In addition to programme messages of "walk away," "protect your ears," and "turn it down," industry messages such as "eliminate," "isolate," and "minimise" were emphasised. Messages such as "hearing loss is gradual," "it has severe consequences," and "everyone exposed to hazardous noise is susceptible" were retained. Caution signs and display cards about the dangerous level of sound sources were used to communicate these messages (Figure 7.2).

Figure 7.2 Caution cards

Module 2: The physics of sound and energy

This part of the programme was retained in its entirety from the school-based programme. The workers were encouraged to take part in an activity where tuning forks and ping-pong balls fixed to a piece of string were used as props to demonstrate how vibrations have energy and create sound waves. The objective was to involve the workers and give concrete examples that would help in understanding the concept of sound energy as something that has power to cause damage.

Module 3: The hearing process

An ear anatomy poster was used to explain how the sound waves explained in the previous component reach the ear and to provide a basic explanation of the processes that take place for the sound to be heard (Figure 7.3). This included understanding the hair cell physiology and transduction at a basic level. The component was also retained from the school-based programme. This explanation of a complicated concept in a simple yet concrete way was important in helping to demystify the hearing system for workers.

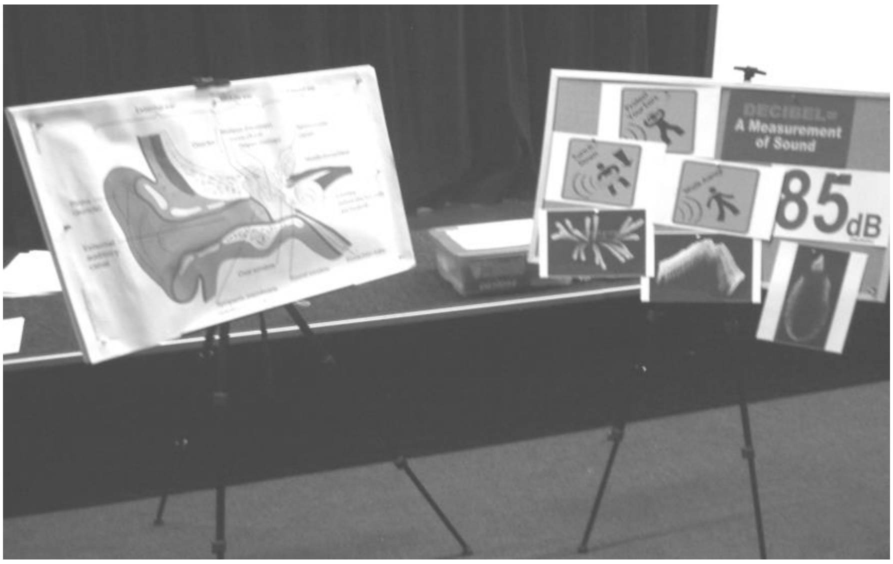

Figure 7.3 Poster of a cross section of the ear anatomy and other displays

Module 4: The process of hearing loss

The objective of this component was to demonstrate how the energy in loud sounds damages hair cells in the ear. This part builds on the earlier components, describing vibrations and how the stereocilia of hair cells are involved in the hearing process. Pipe cleaners are used as props to demonstrate how, with exposure to loud sounds, inner ear hair bundles become damaged and are unable to be restored, causing permanent hearing loss. In addition, microscopic images of the hair bundles in their normal and damaged states were shown to the workers. This helped reinforce the messages related to susceptibility and the severity of hazardous noise on human hearing. This component used an interactive story-telling activity and the concreteness of the pipe-cleaners to communicate the information.

Module 5: The consequences of hearing loss

A hearing loss demonstrator (Huckvale, 2010) was used to demonstrate the effects of hearing loss. The “HearLoss” simulator is an electronic application played on a computer that has three sound wave files (movie dialogue, music, and sport commentary) playing in a hearing loss form and in normal form. The school-based programme used an online virtual exhibit which had several activities for children, including matching different sound sources, filtered to mimic high-frequency hearing loss, to a montage of images on the screen. The sounds included child-relevant examples such as a telephone ringing, baby crying, cat meowing, birds chirping, etc. The workplace programme placed emotional and reflective emphasis on the consequences of hearing loss and its effect on the quality of life. The workers were encouraged to discuss how they spent time with family and friends and it was demonstrated to them through the simulator how social activities and interactions relevant to them could be diminished by hearing loss. It served the purpose of using social relationships as a motivator for hearing protection behaviour.

Module 6: Loudness of workplace sounds

The decibel scale was introduced with emphasis placed on the 85dB limit as the threshold of safe sounds. The concept of decreasing exposure time as noise levels increase was also discussed. The workers were encouraged to take part in an activity involving several flash cards displaying images of common workplace tools and activities. The other workers would guess noise levels and the upper limits of safe duration of exposure to them. Preventive measures to prevent excessive noise such as turning off the unattended noisy machines, wearing HPDs, moving away, and reminding fellow workers before beginning a noisy task were emphasised. The workplace programme included industry-specific examples such as power tools and heavy machinery along with the classroom programme examples such as tractor noise, washing machine noise, and rock concerts, etc. However, the focus of the component remained the same, whereby workers were made aware of different sources of loud noise in their environment, how much exposure would be dangerous, and how best to avoid them.

Module 7: Sound measurement

Workers were shown the measurement of sound using sound level meters. A power drill was used as a sound source to demonstrate noise level readings. The concept of reducing noise exposure by moving away from the sound source was then demonstrated and discussed. In addition, there was discussion related to machinery creating different levels of noise when applied to different materials such as timber, glass, or steel.

Module 8: Proper use and maintenance of hearing protection devices (HPDs)

The correct method of inserting earplugs and ensuring adequate protection was demonstrated. The workers were also encouraged to practise the correct procedure with their workmates.

This is similar to the classroom programme approach. The objective was to improve self-efficacy of workers to implement hearing protection behaviour. The workplace programme also emphasised the importance of correctly wearing earmuffs and that obstructions such as caps, beanies and long hair compromised the protective utility of HPDs. The maintenance of HPDs was emphasised and workers were encouraged to seek management assistance to ensure a high standard of HPDs.

Module 9: Peer modelling and promotion of workplace hearing health

This component was used by the classroom programme to gauge the intrapersonal and interpersonal behavioural intention of children when they were exposed to high levels of noise such as rock concerts. The workplace programme used this component to encourage peer modelling and support for hearing protection in their settings. There was emphasis to create a healthy hearing work environment that takes hearing health promotion seriously. The workplace programme was summarised by reinforcing key messages to improve and motivate hearing health behaviour in workers.

A trainers' workplace hearing protection programme script was developed (Appendix 5). It included complete training instructions on how to approach each component of the programme and how to deliver it. The script encouraged trainers to include or generate discussion regarding examples relevant to training participants. In addition, a summarised version of the script was developed as a series of nine index cards reflecting each module (Appendix 6).

MATCH Phase 4 & 5: Implementation and evaluation

Planning and effort is required to ensure the effectiveness of any programme by ensuring adoption, quality implementation, and widespread dissemination. This needs to be done by providing evidence of acceptability, evidence of efficacy, stakeholder involvement, training, reinforcement, and dissemination. This is followed by evaluation that comprises of process, impact, and outcome evaluation (B. G. Simons-Morton et al., 2012). The revised NIHL prevention programme (30-minute, single session) for workplaces adapted from the school-based "Dangerous Decibels" programme was piloted and evaluated for effectiveness. The findings of the evaluation of the workplace programme and the use of electronic HPDs (selection process described in Appendix 4) is reported in the next chapter.

7.3. Conclusion

The MATCH approach has been a useful framework to adapt the school-based Dangerous Decibels programme to a workplace-based NIHL prevention programme. MATCH provided a socio-ecologic perspective and a basis for developing the NIHL prevention programme for workplaces to address personal and environmental influences at different levels. In addition, it allowed sound theoretical frameworks to inform the content and delivery of the programme.

Chapter 8. Effectiveness of a Workplace Hearing Loss Prevention Programme – A Pilot Study

8.1. Introduction

The workplace hearing conservation programme was piloted and evaluated to gather evidence of acceptability and efficacy. The successful uptake of programmes depends on its compatibility with existing practices; not being too complex, disruptive, and expensive; and having outcomes that produce observable effects (B. G. Simons-Morton et al., 2012).

The workplace training programme, informed by two behavioural theories (Health Belief Model and Social Cognitive Theory), was developed to promote hearing health promotion in the workplace (Chapter 7). These theories guide the programme to focus on beliefs about susceptibility to and severity of hearing loss, highlight the utility of hearing protection devices (HPDs), encourage peer support and modelling, and create hearing health promoting norms in the workplace. In addition, the training programme was developed to be interactive and informative, rather than passive and instructional, as the active involvement of participants and utilisation of various training techniques help to effectively communicate key messages (Bandura, 1986; Janz & Becker, 1984). This is important because when values, norms, and behaviours are accepted and internalised, self-determined motivation for related behaviour increases (Kelman, 1961).

Small manufacturing companies, defined as having fewer than 20 workers (Ministry of Business Innovation and Employment, 2013), were targeted for two reasons. Firstly, about 97% of companies in New Zealand have fewer than 20 employees and employ approximately 30% of the workforce (Ministry of Business Innovation and Employment, 2013). Secondly, these companies are reported to have poorer adherence to hearing protection protocols than larger companies (Laird, Thorne, Welch, & Legg, 2011).

A common perceived barrier to self-reported hearing protection reported in Chapters 4, 5, and 6 was communication difficulties associated with wearing HPDs. Therefore, it was important to know if addressing this barrier directly would enhance the training programme. Electronic hearing protection devices, also known as sound restoration hearing protection devices, are designed to amplify sounds below 85dBA to improve audibility, while maintaining protection from hazardous levels of noise. They have been found to be most effective for workers exposed to intermittent noise (Azman & Hudak, 2011). Workers in intermittent noise tend to remove their hearing protection when conditions are not noisy in order to communicate. However, electronic HPDs would allow workers to continue wearing hearing protection while enabling communication and providing protection from sudden impact noise.

The aim of the study was thus to pilot and evaluate a training intervention programme that was guided by an ecological model and behaviour change theories. The Ecological Model for Health Promotion (McLeroy et al., 1988) was used as a planning model to identify factors at different levels and the behavioural theories were used to inform the development of the programme to address these factors and influence hearing health promotion. Training effectiveness was assessed by measures (perceived barriers, perceived supports, knowledge, attitude, and behaviour) before and after the delivery of the training intervention using a hearing protection assessment questionnaire. Furthermore, the potential of electronic HPDs to enhance the effectiveness of the training intervention was investigated. The acceptability of the programme was investigated by talking to workers and managers following the completion of the training.

8.2. Methods

8.2.1 **Sample**

The intervention sample consisted of 56 workers from five manufacturing companies where employees were required to use HPDs in accordance with health and safety regulations. The companies were purposefully identified and contacted via the telephone directory. The companies recruited were involved in steel metal fabrication, foundry works, and steel and timber joinery. These were small companies employing fewer than 20 workers, with two being owner-operated. Only 53 workers were included for analysis purposes as three workers who had received the intervention did not participate in the evaluation process (dropout rate: 5%): two of these workers had left the participating companies and one refused to continue participation in the research.

8.2.2 **Procedure**

Employers were given information sheets and the details of the study were explained to them. The employers then explained the purpose of the study to the workers and allocated time for all workers to receive the training intervention on-site. The workers also gave informed consent for participation. All participants were asked to complete a hearing protection assessment questionnaire (HPA-5) designed to assess five measures related to hearing protection behaviour (Appendix 8: HPA-5 questionnaire). This was administered immediately before the training intervention, one week after training, and again two months after training. The study was approved by the University of Auckland Human Participants Ethics Committee (Ref: 2010/214).

8.2.3 **Assessment instrument**

The hearing protection assessment questionnaire assessing five measures is an extension of the two-measures (HPA-2) questionnaire developed and previously described in Chapter 5 (Appendix 7: HPA-2 questionnaire). The HPA-2 assessed barriers and supports to HPD use. Three more sets of questions were added to assess knowledge, attitudes, and behaviour towards hearing protection. These three measures were adapted from a questionnaire used to assess the effectiveness of a similar training intervention in school children in the United States of America (Griest et al., 2007). There were nine listed items each for barriers and supports measures and participants endorsed as many items as they wished. The knowledge, attitudes, and behaviour scales had multiple-choice questions, each of which had only one correct answer. There were five questions for the knowledge scale about the science of sound, hearing loss, and hearing conservation; there were two questions related to attitudes towards noise and hearing protection; and there were three questions about hearing protection behaviour. The questionnaire also included demographic items such as gender and age; two items describing attitudes to safety behaviour at work; one item to capture the self-reported frequency of individual HPD use and one item to capture the self-reported frequency of co-worker hearing protection behaviour. All three questionnaires (pre-training, one week post, and two months post) included the same questions.

8.2.4 **Intervention**

The workplace programme was conducted on-site where the participants worked and took approximately 30 minutes to complete. The training programme was adapted from the 'Dangerous Decibels' school-based education programme (Griest et al., 2007) to target workers from noisy workplaces. The adaptation and content of the programme is described in detail in Chapter 7.

In addition to the training programme, 27 workers from the sample were also given electronic HPDs aimed at minimising the communication barrier. The ‘Protector inTouch’ is a Class 5 HPD with active listening capability equipped with microphones to allow communication at close range. The methodology for the selection of the ‘Protector inTouch’ electronic HPD is described in Appendix 4. These electronic HPDs were given to all the workers from two companies immediately after the delivery of the training programme, while all workers at other companies received Class 5 passive HPDs. It was decided to give the electronic HPDs to all workers at the two companies rather than just distributing them at random because their effectiveness in reducing communication difficulties depends upon their use by all workers in the same noise environment.

8.2.5 **Statistical Analysis**

The five scales of the HPA-5 had different numbers of items, so to allow comparability between them scores were converted to percentages of items endorsed (for barriers and supports) and percentages of items answered correctly (for knowledge, attitudes, and behaviour).

An alpha level of 0.05 was adopted for all inferential statistical tests. Analyses of variance (ANOVA) were conducted separately for the five HPA-5 scales, HPD group (passive and electronic HPD) as a between-subjects factor, and time (pre-intervention, one week post, and two months post) as a within-subjects factor. Effects of ‘time’ would indicate the influence of training. In addition, ANOVA was conducted to detect changes in the subscale of supports and barriers and mean supports to barriers ratio, pre-intervention to post-intervention. Five subscales describing the supports and barriers (risk justification, HPD constraints, hazard recognition, behaviour motivation, and safety culture) were identified in Chapter 5. An interaction effect between the HPD group and time would show a different effect of electronic HPDs compared to passive HPDs, and would be evidence that electronic HPDs would be a useful supplement to training. Data were examined for outliers and other departures from test assumptions. When Mauchly’s Test of Sphericity indicated that the assumption of sphericity had been violated, either the Greenhouse-Geisser (when sphericity estimates < 0.75) or Huynh-Feldt (when sphericity estimates > 0.75) correction was used (Field, 2005). Data were analysed using IBM SPSS Statistics (version 21.0).

8.3. Results

The mean age of participants was 39.7 years (SD=14.3, N=53). The workers identified the most with the New Zealand European ethnicity and 96.2% were male (Table 8.1). Ethnicities were not prioritised and two participants reported multiple ethnicities.

Table 8.1 Baseline characteristics of workers in the study

Characteristics	**n = 53** n (%)
Gender	
Male	51 (96)
Female	2 (4)
Ethnicity	
NZ European	31 (59)
Māori	2 (4)
Pacific Island	11(21)
Other	12 (23)

8.3.1 **Supports and barriers**

The findings show a significant improvement ($F (2,102) = 4.9, p=0.01$) in the perceived supports to barriers ratio over time (pre-intervention: 76%; 1 week: 83%; 8 weeks: 84%). This suggested that there were more supports than barriers to hearing protection over time. However, there was no significant effect on barriers ($F (2, 102) = 0.8, p=0.41$) or supports ($F (1.8, 93) = 2.4, p=0.10$) over time following the intervention, though the non-significant trends were towards a reduction in perceived barriers and an increase in perceived supports to hearing protection behaviour from pre-training to post-training (Figure 8.1).

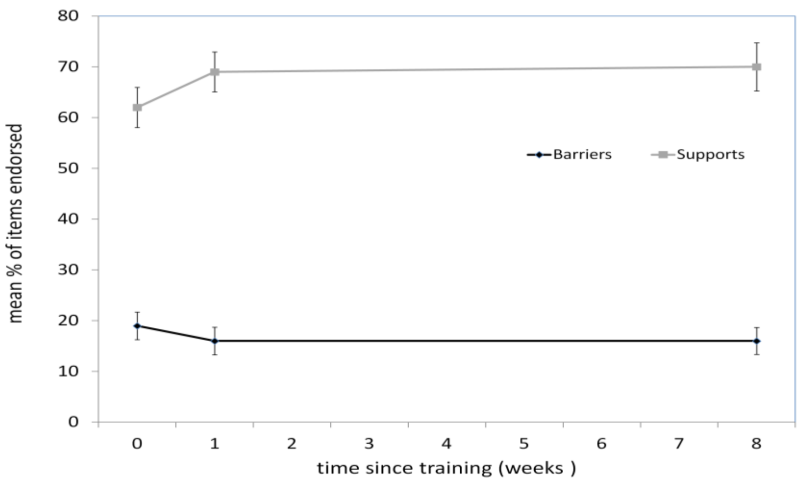

Figure 8.1 Mean percentage of barriers (nine items) and supports (nine items) endorsed pre-training, one week afterwards, and after two months

There was no significant effect on the perceived barriers subscales, risk justification ($F(2, 102) = 0.17$, $p=0.80$) and HPD constraints ($F(2, 102) = 0.7$, $p=0.50$), over time. The perceived supports subscale hazard recognition ($F(2, 102) = 1.2$, $p=0.30$) also did not show an effect over time following the intervention. The results show a significant effect of the intervention on perceived supports subscales ‘behaviour motivation’ ($F(1.73, 83.9) = 5.64$, $p = 0.01$) and ‘safety culture’ ($F(1.79, 91.1) = 3.52$, $p = 0.04$) measures over time. These results indicated that ‘behaviour motivation’ and ‘safety culture’ measures significantly improved post-intervention (Figure 8.2).

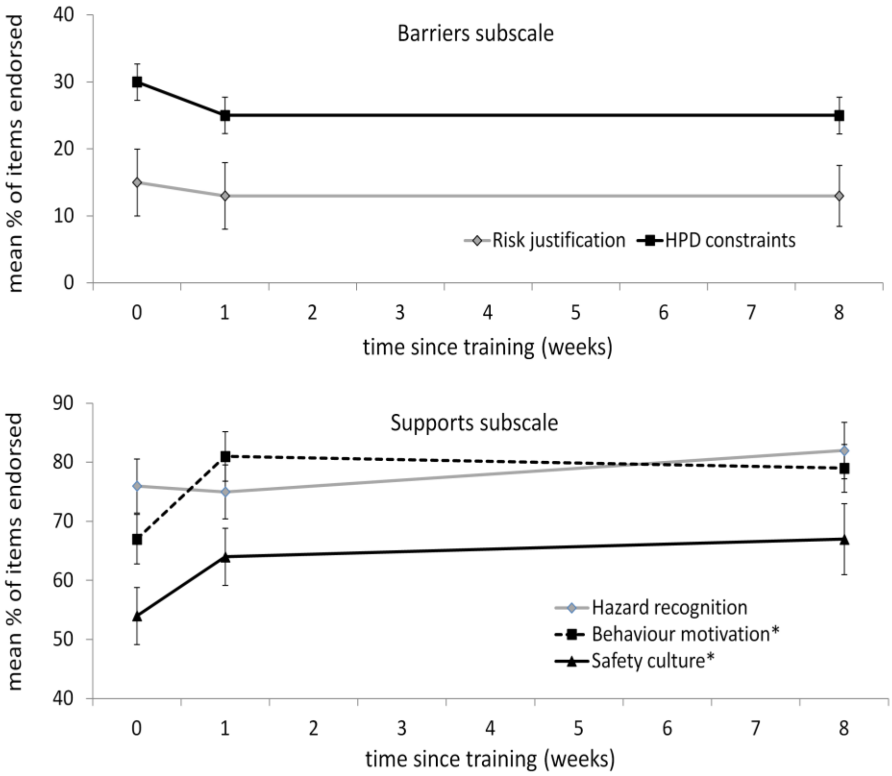

Figure 8.2 Mean percentage of barriers and supports subscales endorsed pre-training, one week afterwards, and after two months. * $p < 0.05$

8.3.2 **Knowledge, attitudes, and behaviour**

The results show a significant effect of the intervention on knowledge ($F(2, 102) = 94.5$, $p<0.001$), attitudes ($F(1.3, 65) = 9.1$, $p=0.002$), and behaviour ($F(2, 102) = 7.4$, $p=0.001$) measures over time, indicating that these measures significantly improved post- intervention (Figure 8.3).

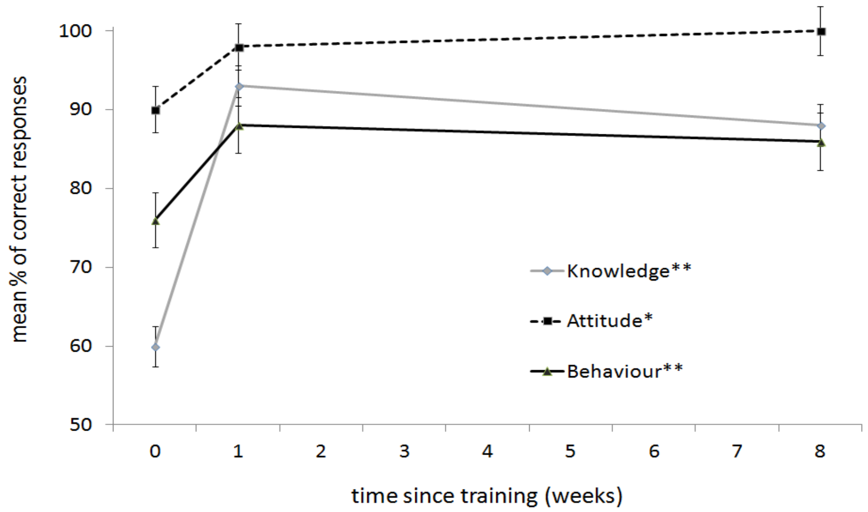

Figure 8.3 Mean percentage of knowledge, attitude, and behaviour measures endorsed pre-training, one week afterwards, and after two months. * $p < 0.01$, ** $p < 0.001$

The results show a significant effect of the training intervention on self-reported HPD use over time ($F(2, 102) = 3.2$, $p = 0.04$). These results indicated that self-reported HPD use significantly improved post-intervention. There was no significant effect on other workers' HPD use as reported by their colleagues ($F(2,102) = 0.7$, $p=0.50$) following the intervention (Figure 8.4).

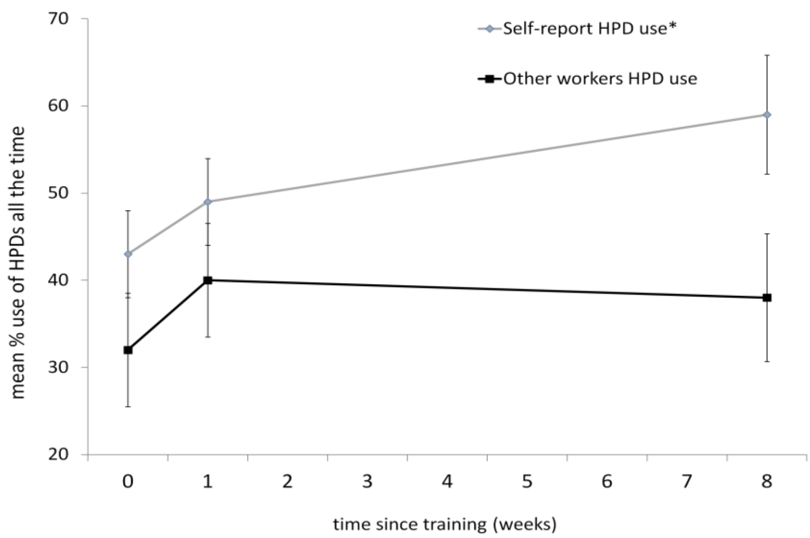

Figure 8.4 Mean percentage of self-reported HPD use and other workers HPD use at pre-training, one week afterwards, and after two months. * $p < 0.05$

There was a 26% improvement in the self-reported consistent use of HPDs in the group receiving the electronic HPDs. 44% workers in this group reported always wearing HPDs when exposed to noise before the intervention. Following the intervention and at the eight-week follow-up, 70% of workers who received electronic HPDs reported always wearing hearing protection when exposed to noise. There was a marginal interaction between the group receiving the electronic HPDs and time for reported HPD use at all times (p=0.06), suggesting that the receipt of electronic HPDs together with the training may have had an effect on hearing protection use (Figure 8.5). There was no interaction between the group receiving the electronic HPDs and time for other workers' HPD use as reported by their colleagues.

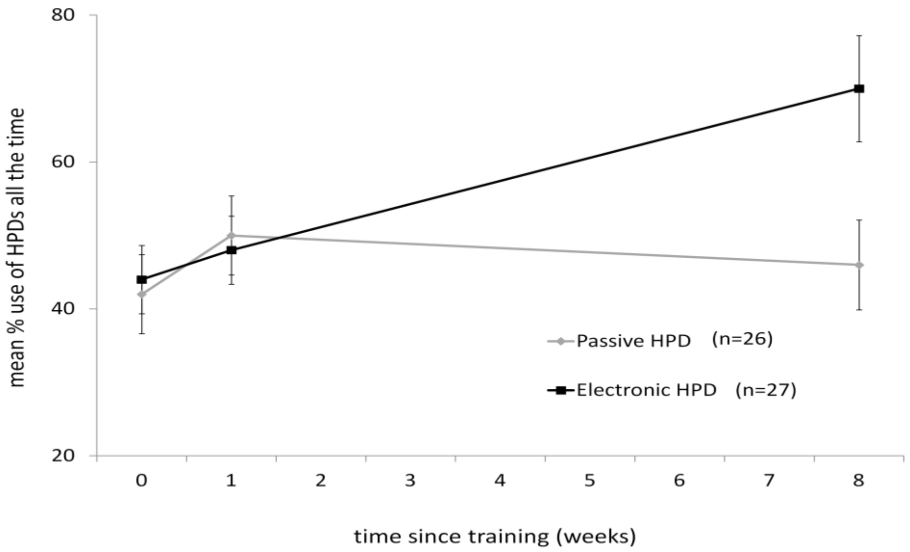

Figure 8.5 Mean percentage of participants reporting HPD use whenever noise was present in training intervention groups (with and without electronic HPDs). Error bars show one standard error of the mean.

8.3.3 **Acceptability and practicability of programme**

A number of workers and managers (n= 8) were interviewed following the programme delivery and resulting key themes are described in Table 8.2 below.

Table 8.2 Description of the key themes related to the acceptability and practicality of the programme

Key themes	
1. Delivery time	Shorter training (30mins to 1hour) is better as workers are able to concentrate and focus on what is being taught. *"Lectures and pamphlets don't really work; short and sharp interactive presentations are useful". "If it is more than an hour, the workers start to turn off".*
2. Location	On-site training is better and favoured over off-site whole day assignments. *"It is inconvenient to have workers trained off-site as production is affected".*
3. Content	There was support for the practical nature of the training where there was visual and audio demonstrations explaining concepts. *"Pipe cleaner examples showing hearing loss was particularly informative and useful".*

	The delivery of the training by an external source was supported as it provided a fresh perspective and helped workers understand the reasons and strategies for hearing conservation. *"I talk to them about it every day to put their earmuffs on; it's like a broken record so good to have a fresh perspective".*
4. Electronic HPDs	Electronic HPDs were found to be practical and useful as the need to take of HPDs to communicate was minimised. *"This will support habitual use of HPDs".* However, they were also found to be a bit heavier than passive HPDs.
5. Programme effectiveness	Managers observed some workers wearing HPDs more often than they had previously following the training programme. There was overall support for the programme and its practicality in the workplaces.

8.4. Discussion

Results from the present study demonstrated that the training programme effectively improved a number of measures influencing hearing protection use in workers. The study also demonstrated that the training intervention was effective at positively influencing factors at different levels of the ecological model (Figure 8.6). Workers showed significant improvements in knowledge, attitudes, and behavioural measures after the administration of the training intervention. In addition, there were improvements in the perceived supports subscales of behaviour motivation and safety culture. These improvements may have positively influenced HPD use in workers, as is evident in the increase of self-reported use of hearing protection post-intervention. The perceived ssupports-to-barriers ratio improved significantly post-intervention, suggesting that the programme addressed the personal and environmental factors associated with hearing protection behaviour.

The programme was well received and accepted within the workplaces. The workers and their managers appreciated the timeliness, relevance, and content of the programme. This suggests that this programme is not disruptive to workplace practices and is an encouraged form of health promotion training.

The statistically significant improvements in knowledge, attitude, and behaviour exist at the intrapersonal level (concerned directly with the individual). Behaviour motivation and safety culture at the interpersonal level include the influences of family and peer modelling on hearing protection behaviour. At the organisational level, employer modelling, adherence to workplace rules, and receipt of training influence motivation and safety culture.

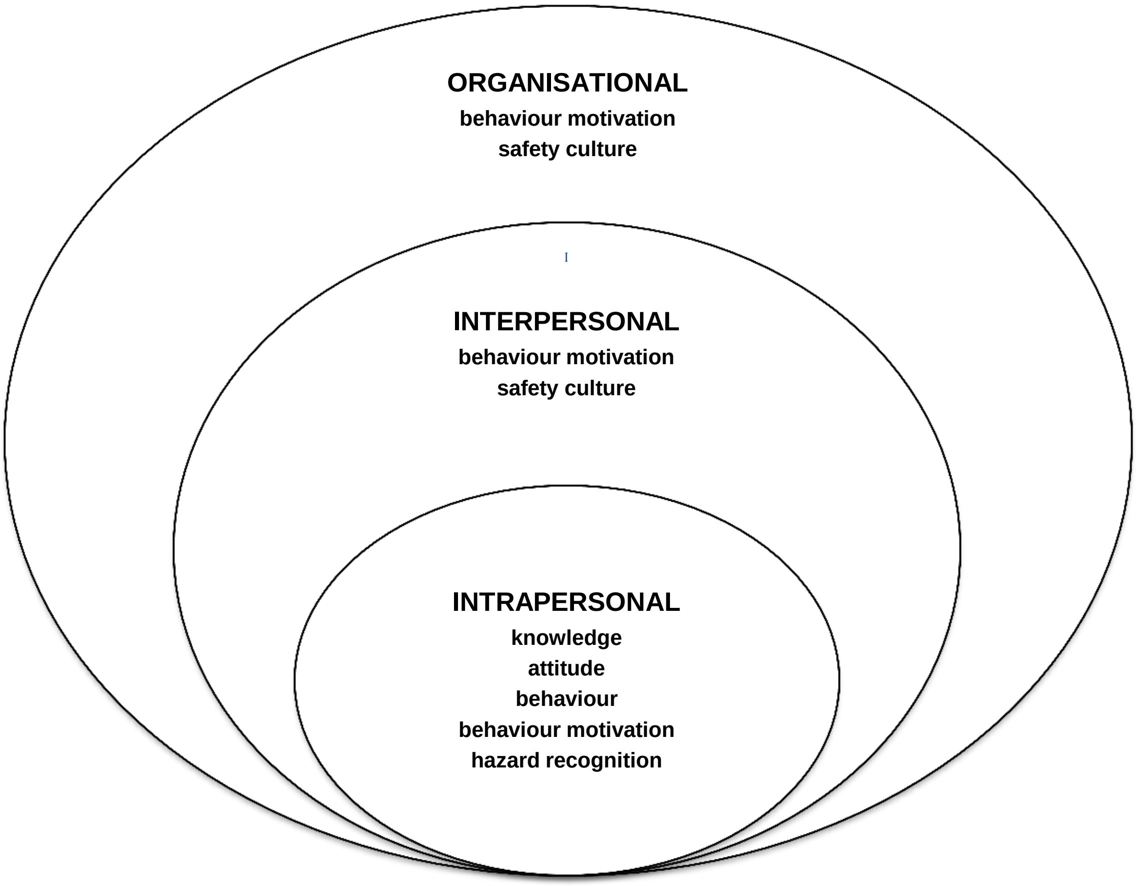

Figure 8.6 Shows the different measures that underwent significant changes across different levels of the ecological model for hearing protection behaviour

The training intervention was based on multiple models. The Health Belief Model (HBM) suggests that improvement in intrapersonal factors such as knowledge, attitudes, and behaviour will occur by changing beliefs about susceptibility and severity of hearing loss and demonstrating the utility of HPDs in preventing NIHL (Janz & Becker, 1984). Another aspect of training was the focus on the interpersonal level, which is deemed important in Social Cognitive Theory (SCT) (Bandura, 1986). Influences at the interpersonal level (behaviour motivation, safety culture) improved significantly following the intervention. This is especially important given that new employees tend to model their protective behaviour on existing workers and that good safety culture can be maintained with training and positive reinforcement (Olson et al., 2009). In addition, according to the tenets of the SCT, behaviour is initiated and maintained by the reciprocal influences between the person, the behaviour, and the environment (Bandura, 1986).

According to the ecological model, intrapersonal and interpersonal influences strengthen organisational norms and culture at the organisational level which supports health promotion efforts and programmes (B. G. Simons-Morton et al., 2012). Safety climate factors in this study were the support of supervisors and co-workers, recognition and adherence to workplace rules, and receipt of training. The findings support evidence that the acceptance and promotion of workplace safety and protective behaviour is a predictor of HPD use amongst workers (Edelson et al., 2009). Furthermore, it appears that the interactive, hands-on nature of the training intervention helped workers to grasp the concepts and appreciate hearing health promotion as a relevant issue. Training interventions employing active training methods are more effective in reducing negative health outcomes and promoting worker safety and health (Burke et al., 2006). This may have allowed the workers to think about their actions as something that they would do of their own volition, rather than through coercion. In addition, electronic HPDs were found to be useful supplements to the training programme, as reported HPD use increased after training and continued to increase over the two months post-training when they were available. The use of electronic HPDs may have potentially significant effects on hearing protection behaviour that is worth exploring further. Workers who received the electronic HPDs in addition to the training reported better HPD use at one week and two months following the intervention (Figure 8.5). This may reflect the removal of communication barriers associated with wearing passive HPDs. There is evidence that the communication capability of electronic HPDs allows workers to wear hearing protection continually in environments that have intermittent hazardous noise exposure (Azman & Hudak, 2011; Bockstael et al., 2011). However, the reporting of other workers' use of HPD did not follow the same pattern, so the reported improvement in self-use could merely be a result of gratitude to the researcher for having provided the devices.

The two-month follow-up period demonstrated improvement in outcome measures, however additional longitudinal follow-up data are needed to determine the duration of the programme effects. Future studies involving larger randomised samples should conduct impact evaluation in terms of programme effectiveness in reducing NIHL.

This programme demonstrated acceptability and effectiveness in improving key influences of hearing protection behaviour. This supports evidence that engaging training methods that utilise hands-on training, behavioural modelling, and active participation elicit greater changes in protective behaviour than less engaging techniques such as lectures, pamphlets and passive video instruction (Burke et al., 2006). In addition, workers are more likely to adopt a behaviour when they perceive its value and act of their own accord rather than simply adhering to rules (Deci & Ryan, 2008). The training intervention, which was successfully adapted from a school-based programme (Griest et al., 2007), incorporated content targeting interpersonal influences such as co-worker modelling as key drivers of behaviour change. This study also highlights the utility of the ecological model as a useful planning model when developing health-promoting interventions. The significant findings suggest that theoretical constructs guiding the training intervention are effective in influencing positive hearing protection behaviour. While the use of ecological or multilevel models has been limited in occupational health research, they have been found to be useful in investigating and promoting worker health and wellbeing (C. Wallace & Chen, 2006). This implies that future efforts towards hearing conservation intervention need to consider different theoretical frameworks targeting different levels of the ecological model to promote hearing protection in workers. This study should be replicated to measure long-term effectiveness and to test booster strategies aimed at sustaining changes in behaviour and reinforcing hearing health promotion (Griest et al., 2007). In addition, influences at the community level should be investigated and targeted to promote hearing health norms in our society. Community-level health promotion research provides opportunities to sustain individual-level health behaviour by positively influencing overall community attitudes to issues related to health and wellbeing (Curry et al., 1993). The training intervention developed may be a useful tool that could be enhanced with the addition of other components (such as electronic HPDs or booster strategies) to prevent NIHL. Finally, the findings of this pilot study establish useful foundations for the methodological development of a larger randomised control trial to test the effectiveness of this programme and additional components.

Chapter 9. Conclusion and future directions

This final chapter summarises the major findings from the research and discusses the utility of the Ecological Model for Health Promotion (McLeroy et al., 1988) with respect to hearing conservation promotion in workplaces. The strengths and limitations of the study are discussed, and recommendations are made for future directions.

9.1. Summary and implications of main findings

9.1.1 **Phase 1: Qualitative study (Chapter 4)**

The aim of Phase 1 of the research was to identify and understand individual and environmental factors that influence hearing protection behaviour in workers. The following five major themes and sub-themes were identified following semi-structured interviews regarding self-reported hearing protection behaviour with workers from noisy workplaces:

1. Perception of noise
    a. Acceptance of noise as part of work (fatalism)
    b. Noise annoyance
    c. Fear of hearing loss
2. Hearing protection use
    a. Hearing preservation
    b. Work requirement
    c. Minimise the annoying aspect of noise
3. Reluctance to use HPDs
    a. Bulky
    b. Uncomfortable
    c. Impediment to communication
    d. Quality and availability
    e. Habitual non-use
4. Workplace influence
    a. Peer mentality
    b. Peer modelling
    c. Self-image
    d. Enforcement of workplace rules

    e. Receipt of training
5. Value of Hearing – indirect influences such as maintaining a good quality of life with loved ones were suggested as motivators for promoting hearing conservation in workplaces.

The factors identified were described as existing across different levels of behavioural influence according to the Ecological Model for Health Promotion (McLeroy et al., 1988). The findings suggest that perceived supports and barriers to hearing conservation behaviour are formed by intrapersonal, interpersonal, and organisational level influences.

9.1.2 **Phase 2: Questionnaire development study (Chapters 5 and 6)**

A questionnaire was developed based on perceived supports and barriers identified in the interview phase, and administered to 555 manufacturing workers. The Hearing Protection Assessment (HPA-2) questionnaire assessing two scales (nine support items; nine barrier items) was developed. Basic demographic questions were also included and the whole questionnaire was two pages long. Internal consistency was high, and factor analyses revealed informative sub-structures. The supports sub-scales were identified as hazard recognition, behaviour motivation, and safety culture. The barriers sub-scales were described as risk justification and HPD constraints. The perceived supports, barriers, and their sub-scales could be described according to the ecological model as existing across different levels of influence (intrapersonal, interpersonal, and organisational). Only 46% of the workers reported wearing HPDs always when exposed to noise at work. Workers who reported always using HPDs when exposed to noise had more supports across these factors, while those who did not always wear them reported more barriers. The findings suggest that interpersonal and organisation level supports, which were behaviour motivation and safety culture, were more influential for workers who reportedly always wore HPDs than for those who did not. On the other hand, intrapersonal barriers, which were risk justification and HPD constraints, were more likely to be endorsed by workers reportedly who did not always wear hearing protection when exposed to noise. The questionnaire analysis also found similar common perceived supports and barriers across different ethnicities and immigrant status. The perceived supports and barriers identified across different levels of the ecological model needed to be targeted when developing hearing conservation programmes for workplaces. However, considering the diverse workforce of New Zealand, future training programmes need to be simple, interactive, and involving different learning strategies such as demonstrations and audio/visual activities to ensure effective communication of messages.

9.1.3 **Development and pilot of a hearing conservation intervention for workplaces (Chapters 7 and 8)**

Phases 1 and 2 of the study had identified supports and barriers across different levels that needed to be targeted as part of an effective hearing conservation programme. The Dangerous Decibels school-based hearing conservation programme (Griest et al., 2007; Martin et al., 2006) was adapted to a workplace setting as a training programme aimed at adults. The Multi-Level Approach to Community Health (MATCH) planning model was used to adapt and develop the workplace-based training programme. The Health Belief Model (HBM) and Social Cognitive Theory (SCT) were used as theoretical bases informing content of the programme at different levels of behavioural influence.

Five workplaces were recruited to participate in the pilot of the workplace-training programme. From these companies, which were involved in joinery and moulding works, 56 workers were trained. Participants were given a hearing assessment questionnaire before the training, one week after the training, and at two-month follow-up. The outcome measures were changes in perceived supports, barriers, knowledge, attitudes, and behavioural items. Communication barriers were identified in Phases 1 and 2 as common barriers to hearing conservation. In order to minimise this barrier, 27 workers from two workplaces were given electronic HPDs, which are designed to electronically aid communication, in addition to the training programme. The other 26 workers received class-five passive earmuffs. The feedback from the workers and managers following the training programme suggested support for the programme's content, delivery methods, relevance, and timeliness. The analysis of the pre- to post-intervention outcome measures indicates improvement in knowledge, attitudes, and behaviour at the intrapersonal level; significant improvements in behaviour motivation and safety culture at the interpersonal and organisational levels; as well as overall improvement in the perceived supports to barriers ratio. This suggested that the programme had potential to influence hearing conservation across different levels in the workplace.

9.2. The utility of the Ecological Model for Health Promotion

Ecological models have not been commonly used as theoretical frameworks for identifying factors influencing hearing conservation and developing NIHL prevention interventions. However, the Ecological Model for Health Promotion (McLeroy et al., 1988) used as the theoretical basis in this research shows the utility of such a model in developing and implementing NIHL prevention interventions. It provides pathways to analyse behaviour at different levels and guide the use of appropriate behaviour change theories. The ecological model is useful in identifying and describing factors related to hearing conservation across different levels of influence. These levels include the intrapersonal, interpersonal, organisational, community, and policy levels. The model views behaviour as being shaped by both personal and environmental influences. As seen in this research, factors influencing hearing conservation behaviour can be targeted across different levels; the focus shifts from merely the individual to both the individual and the environment. The ecological model is a simple yet robust planning model which could be implemented more often, not only in hearing conservation research but also in other health promotion behaviour change studies.

9.3. Strengths and limitations of the study

A major strength of the study is its application of the ecological model to identify and target hearing conservation behaviour across different levels of influence. The study findings support the tenets of ecological models, such as that behaviour is influenced by personal and environmental factors.

The study was also multi-disciplinary in that concepts from audiology, epidemiology, psychology, occupational health, and health promotion were used to plan and execute the different phases of the research. This also helped in gaining a wide understanding of the problem and applying concepts from different fields in developing the hearing-health promoting intervention. In addition, the use of multiple behaviour change theories at different levels of influence provided guidance and direction in formulating the intervention programme.

The HPA-5 questionnaire developed is a useful data collection tool that is time efficient and appropriate for most educational levels. It is simple and can be translated into other languages.

This research adds to existing literature regarding the factors that influence hearing conservation and worker behaviour. It provides support for the ecological model to be used in hearing conservation research.

There were limitations in the study related to the selection of participants at different phases. The selection procedure was purposive and convenient in that companies were approached via telephone directories and not by a fully random process. The purpose was to recruit workers from noisy workplaces, but randomised recruitment was not regarded as important due to the absence of a sampling frame for companies meeting the criteria for involvement. This could have led to selection bias in the types of companies and workers agreeing to participate. It is possible that companies that participated had a better level of hearing protection enforcement and overall higher level of workplace safety culture. In addition, workers agreeing to participate were those who had a better knowledge of workplace safety and were more interested in obtaining more information. Therefore, it may not be possible to generalise the findings and conclusions to all of the workers in all noisy workplaces. Saying this, the research would have been voluntary even had there been truly random sampling, so the largest likely biasing factor (agreeing to participate) would have been present anyway.

The research focussed mainly on three levels of the ecological model: intrapersonal, interpersonal, and organisational. However, there is scope for investigation and development of interventions aimed at the community and policy levels. Of course, policy-level intervention exists already in the shape of the health and safety in employment regulations (Department of Labour, 1995) and the Approved Code of Practice for the Management of Noise in the Workplace (Department of Labour, 1996). The policing of the regulations is an aspect of the ecology of workplace hearing protection that has not been properly explored, but it is reported anecdotally as being poorly carried out in New Zealand currently. The community level, on the other hand, has received very little attention and this would be a positive direction for future research.

9.4. Future directions

The studies presented in this thesis have raised several questions that need to be addressed in future work. It may be possible to design a larger randomised control trial in controlled settings where selection bias is minimised. There is also opportunity to test the intervention programme in other noisy sectors such as construction, mining, agriculture, and forestry.

The programme developed in this research was a one-component multi-level intervention. There is an opportunity to develop multi-component interventions: for example, the training programme developed and piloted in this research could be targeted at workers/managers, and another programme or intervention could be developed targeting workers' family members and employers. This would require community and policy level investigation to identify key influences that should be targeted for such interventions.

While this intervention programme was effective in influencing behaviour change in the short-term, the provision of reinforcements and boosters may be effective in sustaining health promoting behaviours in the long-term (Lusk et al., 2004) (Hong, Chin, Fiola, & Kazanis, 2012). The reinforcements and booster strategies could include monthly key messages delivered by managers or influential peers. The use of technology such as texting, internet, and social media could be used as reinforcements to health promoting behaviour. It would be interesting to assess changes after one or two years and whether reinforcement and booster strategies would add value to the training programme.

It is important to carry out impact evaluation in order to measure the effectiveness of intervention goals and objectives in the long-term (Glasgow, Vogt, & Boles, 1999; B. G. Simons-Morton et al., 2012; L. M. Wallace, Brown, & Hilton, 2013). This would help determine if the workplace-training programme has been successful in preventing NIHL in workers. While this study showed that the workplace programme intervention has value in improving behavioural outcomes related to hearing conservation, it would be valuable to collect longitudinal data to determine whether these changes are sustained over a longer period and is effective in reducing the burden of occupational NIHL.

9.5. Conclusion

NIHL is a common but preventable occupational problem affecting economies and human lives. The objective of this research was to understand the factors influencing hearing conservation behaviour in workers and to develop an intervention that promotes hearing health in workplaces. The ecological model was used as a useful planning tool to identify and understand various factors across different levels that influence hearing conservation behaviour in workers. These factors were then targeted through a workplace hearing conservation programme. The training programme intervention was able to elicit improvements in intrapersonal, interpersonal, and organisational level influences of hearing conservation behaviour in workers. These findings lend support to efforts and strategies designed to preventing NIHL and eliminate its harmful effects from society. The research also demonstrated the utility of the ecological model in developing effective health promotion programmes. This thesis provides insight into multi-level influences for hearing protection behaviour and targeting them to promote hearing health in workplaces.

Appendices

Appendix 1: Participant information sheet for companies

Section of Audiology
Faculty of Medical and Health Sciences

THE UNIVERSITY OF AUCKLAND
FACULTY OF MEDICAL AND HEALTH SCIENCES

The University of Auckland
Private Bag 92019
Auckland
New Zealand,

Section of Audiology
School of Population Health
Building 730, Level 3
Morrin Road, Glen Innes

Telephone: 64 9 373 7536
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Email: audiology@auckland.ac.nz

Participant information sheet for companies

Project Title: Development of Targeted Intervention for Noise Induced Hearing Loss in New Zealand Workers.
Researchers: Ravi Reddy, Dr David Welch, Professor Shanthi Ameratunga and Professor Peter Thorne

We would like your permission to spend up to five days in your company conducting this research project, which will involve the company's staff. Your company, along with others, has been selected at random. We wish to visit your workplace, interview your staff about their exposure to noise and their hearing protection devices, administer questionnaires and conduct focus group discussion. This process will take approximately 20-25 minutes for interviews; 10 minutes for questionnaire and 45-60 minutes for focus group discussions. The research has been funded by the Health Research Council doctoral award.

We will put up an advertisement on your staff notice board requesting people to take part in the study. The advertisement will have our contact details for interested people to contact us confidentially. We also request if you can let your workers know about our study and refer anyone who may be interested to participate to us.

We will interview people in their tea/lunch time or after hours as preferred. Questionnaire can be filled by the participants in their own time and we will organise focus group discussions in lunch time or after hours. All interviews and focus group discussion will take place at University of Auckland Tamaki Campus or at another location convenient to the participants. We will make transportation arrangements for participants for interviews and focus group discussions.

The data from this study will be kept securely and anonymously at the University of Auckland. Data will be destroyed six years after the completion of the PhD. No information will be kept that will allow the data to be identified with your company or any individual in it. Nor will anything that would be able to identify your company be passed on to ACC or any government organisation.

We seek your assurances that participation, or non-participation, will not affect the employment status of the participants.

You will have the right to withdraw your company from the research at any time up to completion of interviews, questionnaire and focus group discussions.

In the written reports based on this research, there will be no indication that your company was one of those involved. All descriptions will be general, and no names will be mentioned. You may email Ravi Reddy on completion of this study if you wish to receive a generalised summary of findings.

Contact details

Ravi Reddy
r.reddy@auckland.ac.nz
021 02663424

For queries regarding ethical concerns you may contact the:

Chair,
The University of Auckland Human Participants Ethics Committee,
The University of Auckland,
Office of the Vice Chancellor,
Private Bag 92010,
Auckland 1142.
Telephone: 09 373-7599 extn. 83711.

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS EHTICS COMMITTEE ON 09/06/2010 for (3) years, reference Number 2010/214.

Appendix 2: Participant information sheet for interviews

Section of Audiology
Faculty of Medical and Health Sciences

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FACULTY OF MEDICAL AND HEALTH SCIENCES

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Telephone: 64 9 373 7536
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Participant Information Sheet for Interviews

Project Title: Development of Targeted Intervention for Noise Induced Hearing Loss in New Zealand Workers.
Researchers: Ravi Reddy, Dr David Welch, Professor Shanthi Ameratunga and Professor Peter Thorne

Researcher introduction

Ravi Reddy is a PhD student within the School of Population Health at the University of Auckland. Dr David Welch, Professor Peter Thorne both from the Department of Audiology and Professor Shanthi Amerantunga from the Department of Epidemiology and Biostatics are supervisors of this study.

Project description and invitation

The aim of this research is to identify factors that influence the wearing of hearing protection devices. We invite you to take part in this research. Your participation is confidential. All information you provide will be reported in a way that will not identify you as the source.

Project procedures

Workplaces have been randomly chosen and will not be identified through this study. Participation in this research is voluntary. The interview will be approximately 20 -25 minutes long. This study is part of a Health Research Council funded PhD award. In partial recompense for your time and the help provided, a $10 voucher will be given to each person who takes part.

Data storage/retention/destruction/future use

Interviews will be recorded by a digital voice recorder and the data will be kept securely and anonymously at the University of Auckland. A third party who has signed a confidentiality agreement will transcribe the voice recordings. Data will be kept for 6 years and subsequently destroyed. All digital data of voice recordings will be deleted. At no point will access to the data be given to anyone else. No information will be kept that will allow the data to be identified with your company or any individual in it.

Right to withdraw from participation

You will have the right to withdraw from the research at any time up until two weeks after the completion of the interview.
Your company has given the assurance that your decision to participate or not will not affect your employment status.

Anonymity and Confidentiality

The participants' anonymity and confidentiality will be treated as highly important. At no point will you be required to disclose your names, and no identifying features of you or your workplace will be revealed in reports.

You may email Ravi Reddy on completion of this study if you wish to receive a generalised summary of findings.

Contact details

Ravi Reddy
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Dr Grant Searchfield
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09 3737599

For queries regarding ethical concerns you may contact the:

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The University of Auckland Human Participants Ethics Committee,
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Private Bag 92010,
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Telephone: 09 373-7599 extn. 83711.

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS EHTICS COMMITTEE ON 09/06/2010 for (3) years, reference Number 2010/214.

Appendix 3: Consent form for interview

Section of Audiology
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New Zealand,

Section of Audiology
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Building 730, Level 3
Morrin Road, Glen Innes

Telephone: 64 9 373 7536
Facsimile: 64 9 373 7496
Email: audiology@auckland.ac.nz

Consent Form for Interview

This form will be held for a period of 6 years

Project Title: Development of Targeted Intervention for Noise Induced Hearing Loss in New Zealand Workers.
Researchers: Ravi Reddy, Dr David Welch, Professor Shanthi Ameratunga and Professor Peter Thorne

I have read the Participant Information Sheet; have understood the nature of the research and why I have been selected. I have had the opportunity to ask questions and have them answered to my satisfaction. I realise that participation is voluntary. I also realise that my participation or non participation will not in any way affect my employment status.

I consent to your request to interview me about noise in my workplace and hearing loss. By agreeing to take part in this interview, I understand that this session will be digitally recorded.

I understand that these data will be kept securely and anonymously at the University of Auckland. The data will be kept for 6 years, after which they will be destroyed.
No information will be kept that will allow the data to be identified with me.
I understand that participation, or non-participation, will not affect my job in any way.
I understand that the interviews should take up to 20-25 minutes of my work time. A third party who has signed a confidentiality agreement will transcribe the voice recordings.
I understand that I have the right to withdraw from the research at any time up until two weeks after the completion of the interview.

I understand that written reports based on this research will have nothing in them that would allow identification of me or the company where I work.

Name ____________________

Signature __________________ Date __________________

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS EHTICS COMMITTEE ON 09/06/2010 for (3) years, reference Number 2010/214

Appendix 4: The selection of electronic HPDs

Chapters 4, 5,and 6 described communication problems associated with using HPDs as a common barriers for poor hearing conservation behaviour (Reddy, Welch, Ameratunga, & Thorne, 2014; Reddy et al., 2012). Therefore, a hypothesis was developed that provision of electronic HPDs may produce an enhancement to the workplace-training programme in improving hearing protection behaviour in workers.

Electronic hearing protection devices, also known as active HPDs or sound restoration hearing protection devices (SPHPDs), use electronic circuitry to actively reduce noise and enable communication. These HPDs may be level-dependent where they attenuate for high-level sounds but allow low-level sound to enter the ear naturally. This is especially useful when the worker can hear warning signals and be able to converse with co-workers but also receive protection from intermittent noise or unexpected impact sounds. An amplifier built in the earmuffs permits the passage of low or moderate level sounds but the amplification ceases and the earmuffs attenuate like ordinary passive HPDs when noise levels exceed 82dBA. Electronic HPDs have been found to be most effective in lower levels of noise and for workers exposed to intermittent noise, where HPDs can be continually worn while maintaining communication and protection (Azman & Hudak, 2011).

Three different types of electronic devices were selected to be assessed with a group of workers (n=7). These devices cost about NZD$100.00 on average. There was a need to first test these devices in noisy workplaces for utility and practicality. The three "Class 5" electronic HPDs selected were:

- Protector InTouch active listening level-dependent earmuffs manufactured by Scott Safety, Australia/New Zealand (Figure I, a).
- 3M Peltor Optime 'Push to Listen' earmuffs requiring the push of button on the side of the cup to listen for up to 30 seconds from time of activation (figure I, b).
- Peltor Worktune plus Radio Earmuff manufactured by 3M is level-dependent and had the added feature of am/fm radio capability (figure I, c).

Figure I: showing the three types of electronic HPDs devices

Three steel fabrication workplaces employing five to seven workers were given each type of electronic earmuffs to use for a week. After one week, a few workers from each workplace were interviewed to obtain feedback regarding the utility and practicality of the earmuffs. Following the interview, the following feedback was summarised with regard to each type of electronic HPDs (Table I). The Protector InTouch electronic HPD appeared to be the most favoured type of electronic HPDs assessed.

Table I: Summary of feedback regarding the electronic HPDs

Electronic HPD type	**Pros**	**Con**	**Cost**
Protector InTouch	- Speech and sound intelligibility enhanced in low levels of noise - Communication enabled between workers - Ability to amplify sound with turn of knob on the side of cup	- Bulky - Batteries	~NZD$120.00
3M Peltor Optime 'Push to Listen'	- Speech and sound intelligibility enhanced in low levels of noise - Communication enabled between workers	- Difficult to access the 'push' button on the side - Requires continuous pressing of button to allow longer than 30 secs of communication - Batteries	~NZD$70.00
Peltor Worktune plus Radio	- Speech intelligibility enhanced in low levels of noise - Communication enabled between workers - Ability to amplify sound with turn of knob on the side of cup	- Bulky - The AM/FM radio feature can cause work distraction - Batteries	~NZD$180.00

Considering the feedback given regarding the utility and practicability of the electronic HPDs and costs associated, it was decided to use the Protector InTouch electronic HPD as the enhancement component of the workplace NIHL prevention programme.

Conclusion

The MATCH approach has been a useful framework to adapt the school-based Dangerous Decibels programme to a workplace-based NIHL prevention programme. MATCH provided a socio-ecologic perspective and a basis for developing the NIHL prevention programme for workplaces to address personal and environmental influences at different levels. In addition, it allowed sound theoretical frameworks to inform the content and delivery of the programme. The effectiveness of the adapted and developed intervention is discussed in Chapter 8 of this thesis.

Appendix 5: Intervention programme script

EDUCATIONAL OBJECTIVES

Educational Objectives of the Workplace Presentation

- Workers will distinguish between safe and dangerous decibels.
- Workers will learn the sources of many dangerous decibels and what the effects of dangerous decibels are to their hearing.
- Workers will know correct ways to protect their hearing.

TIME:

1. Introduction 2 min.

Educational Objective:

- To familiarize the workers with the educator, educator expectations, and purpose of the visit.

2. What Is Sound? 3 min.

Educational Objectives:

Workers will know that:

- Sound is a result of vibrations.
- Sound vibrations are called sound waves.
- You cannot have sound without vibrations.
- The sound vibrations are what can cause damage to our ears

3. How Do We Hear? 3 min.

Educational Objective:

- Workers will have a general understanding of how sound waves and vibrations travel through the parts of the ear to enable hearing.

4. How Do We Damage Our Hearing? 3 min.

Educational Objective:

- Workers will know loud sounds create strong vibrations that can permanently damage hair cells in the cochlea

5. What's that Sound? 4 min.

Educational Objectives:

- Workers will understand the consequences of being exposed to dangerous sound levels
- Workers will understand what it is like to try to identify sounds with a high frequency hearing loss

6. How Loud is Too Loud? 4 min.

Educational Objectives:

- Workers begin to associate different sounds with decibel levels.
- Workers identify which method of hearing protection is the best to practise when exposed to dangerous decibels from different sources.
- Workers identify and discuss the social norms and challenges associated with practising hearing protection.

7. Measuring Decibels with Sound Level Meters 3 min.

Educational Objectives:

- Workers measure sound with a sound level meter.
- Workers learn how effective walking away from dangerous sound levels can be to reduce their exposure to dangerous sound.
- Workers will appreciate that workplace tools and activities make dangerous levels of noise

8. How to Use Ear Plugs and Earmuffs 5 min.

Educational Objectives:

- Workers will observe the proper technique and fitting of pre-formed earplugs.
- Optional: Workers will have the opportunity to practice fitting earplugs in their ears.
- Workers will learn the importance of properly wearing earplugs and earmuffs.

9. Support each other: Time To Act! 3 min.

Educational Objectives:

- To bring awareness to peer pressure that a person can encounter when practising hearing protection behaviour at work.
- Workers practise making personal decisions on individual behaviour in social settings and discuss their answers with the class and educator.

TOTAL: 30 mins.

Appendix 6: Workplace training programme index cards

1. Introduction

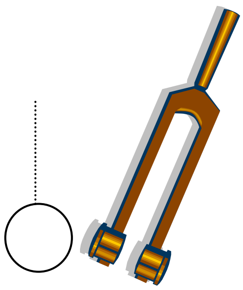
a. Hello!
b. What are Dangerous Decibels?
c. 3 Ways to Protect Your Hearing

- Being around loud sounds a lot WILL NOT help your ears get used to it.
- Hearing loss caused by loud sound is a problem for people of ALL ages.
- When sounds are too loud they can damage your hearing! If it is a very loud sound, just one exposure can damage your ears.

2. What Is Sound?

a. Explanation: Sound is Vibration.
b. Activity: Tuning Forks and Ping Pong Balls

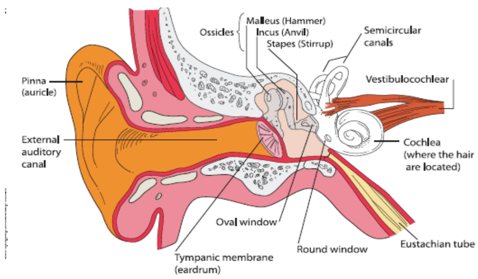
Transition: Let's start by learning about sound.



3. How Do We Hear?

a. Ear Anatomy Poster

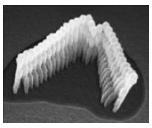
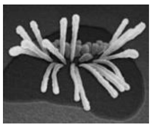
Transition: Now we know what makes a sound, now how do we hear?



4. How Do We Damage Our Hearing?

a. Hair Cell Model – Pipe Cleaners

Transition: We know that we hear sound vibrations with the tiny hair cells in our ear. We also know that vibrations from loud sounds have power. Let's see how loud sound can permanently break our hair cells and cause hearing loss? Let's do another experiment?

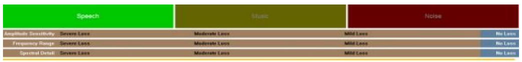
★

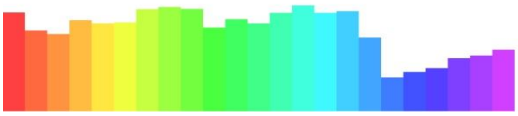
18,000 of these in each ear, must last a lifetime. They can be damaged permanently – they can't be fixed.

5. What's That Sound?

a. HearLoss Simulator

Transition: We have learned about what happens inside the ear when loud sound breaks hair cells. But what is it like to have hearing loss? Our next actitivity will how us what it is like to listen to sounds with damaged ears.





6. How Loud is Too Loud?

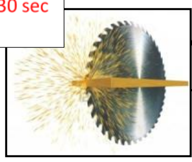
a. FLASH CARDS

Transition: Having a hearing loss is not fun. You miss out on a lot of wonderful and important sounds. We know that loud sound can cause permanent damage to our ears. Let's learn how loud some sounds are and for how long we can safely listen to them before our ears are can be hurt.

110 dB

1 minute 30 sec

★ Tools and activities in workplaces make a lot of noise that is over 85dB.

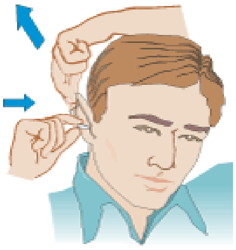



7. Measuring Decibels with Sound Level Meters

Transition: We know that decibels are measurements of sound represented in numbers. But how do we get these numbers? What type of tool or instrument do we use? We use a sound level meter.


8. How to Use Ear Plugs

Transition: It is absolutely important to correctly use earplugs and earmuffs to get maximum protection.



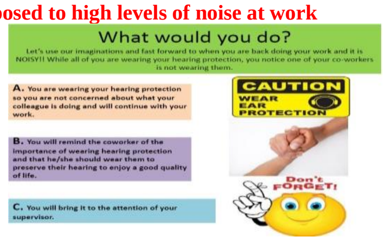

9. Support each other: Time To Act!

Transition: Explain: Up to this point we have learned…

- **how vibrations make sound, and sound has energy**
- **how we hear, and how loud sounds can damage our hair cells**
- **many things that have dangerous sound levels**
- **3 easy ways to protect ourselves from dangerous sounds**

Now, let's talk about what YOU would do if you a co-worker does not wear hearing protection when exposed to high levels of noise at work

Also reinforce that workers need to warn other workers around them before doing a noisy job.



Appendix 7: Hearing Protection Assessment Questionnaire (HPA-2)

How to answer: please fill in boxes or mark your response like this: ☑

1 **Gender** Male ☐ Female ☐

2 **Age** ☐ years

3 **Job Title** ((E.g., machinist, plant operator, etc) ☐

4 **Which ethnic group do you belong to?** Tick the box or boxes which apply to you.

NZ European ☐ Māori ☐ Samoan ☐

Cook Island Māori ☐ Tongan ☐ Niuean ☐

Chinese ☐ Indian ☐

Other ☐ → Please state ☐

(E.g., Dutch, Japanese, Tokelauan)

5 **What is your country of birth?** New Zealand ☐ Other, please specify ☐

6 **If you answered 'other' to Q5, how many years have you been in NZ?** ☐ years

7 **Please read the two statements carefully and choose the *one* which is most true for you:** ☐

Please choose ***<u>either</u>*** a or b

a. Safety is at the forefront of my mind when working

b. Safety is important, but other factors sometimes limit my ability to work safely

8 **Please read the two statements carefully and choose the *one* which is most true for you:** ☐

Please choose ***<u>either</u>*** a or b

a. Injuries occur at work because people don't take enough interest in safety

b. Injuries at work will always occur, no matter how hard people try to prevent them

9 **I have earplugs and or earmuffs to use at work** Yes ☐ No ☐

10 **I wear earplugs and or earmuffs when it is noisy at work (**please circle <u>one</u>**)**

Always	Almost always	Usually	Often	Sometimes	Rarely or Never

11 If you wear earmuffs or earplugs when exposed to noise, it is because: (please tick **all** those that apply)

a)	Your boss tells you to	☐
b)	You are doing a noisy job (e.g., working on noisy machine, banging, hammering, etc)	☐
c)	Other workers are doing noisy jobs (e.g., working on noisy machine, banging, hammering, etc)	☐
d)	You want to protect your hearing	☐
e)	You are annoyed by the noise	☐
f)	You want your hearing to be good to live a good life with your family	☐
g)	Your workmates remind you to wear them	☐
h)	It is your company rules	☐
i)	You have received training to wear them	☐
j)	Other, please specify:	

12 If you don't wear earmuffs or earplugs when exposed to noise, it is because: (please tick **all** those that apply)

a)	You are not clear as to when you should wear them	☐
b)	You can't hear properly to do your work (e.g., warning signals, machine performance)	☐
c)	You can't communicate properly with other workers	☐
d)	They are uncomfortable	☐
e)	They get in the way of other safety equipment	☐
f)	You are used to noise at work	☐
g)	Your co-workers often don't wear them	☐
h)	Your co-workers find it funny when you wear them	☐
i)	Someone else does something noisy without warning	☐
j)	Other, please specify:	

Appendix 8: Hearing Protection Assessment Questionnaire (HPA-5)

How to answer: please fill in boxes or mark your response like this: ☑

1 **Gender** Male ☐ Female ☐

2 **Age** ☐ years

3 **Job Title** ((E.g., machinist, plant operator, etc) ☐

4 **Which ethnic group do you belong to?** Tick the box or boxes which apply to you.

NZ European ☐ Māori ☐ Samoan ☐

Cook Island Māori ☐ Tongan ☐ Niuean ☐

Chinese ☐ Indian ☐

Other ☐ → Please state ☐

(E.g., Dutch, Japanese, Tokelauan)

5 **What is your country of birth?** New Zealand ☐ Other, please specify ☐

6 **If you answered 'other' to Q5, how many years have you been in NZ?** ☐ years

7 **Please read the two statements carefully and choose the *one* which is most true for you:** ☐

Please choose ***either*** a or b

a. Safety is at the forefront of my mind when working

b. Safety is important, but other factors sometimes limit my ability to work safely

8 **Please read the two statements carefully and choose the *one* which is most true for you:** ☐

Please choose ***either*** a or b

a. Injuries occur at work because people don't take enough interest in safety

b. Injuries at work will always occur, no matter how hard people try to prevent them

9 **I have earplugs and or earmuffs to use at work** Yes ☐ No ☐

10 **I wear earplugs and or earmuffs when it is noisy at work (**please circle one**)**

Always	Almost always	Usually	Often	Sometimes	Rarely or Never

11 **If you wear earmuffs or earplugs when exposed to noise, it is because:** (please tick **all** those that apply)

a)	Your boss tells you to	☐
b)	You are doing a noisy job (e.g., working on noisy machine, banging, hammering, etc)	☐
c)	Other workers are doing noisy jobs (e.g., working on noisy machine, banging, hammering, etc)	☐
d)	You want to protect your hearing	☐
e)	You are annoyed by the noise	☐
f)	You want your hearing to be good to live a good life with your family	☐
g)	Your workmates remind you to wear them	☐
h)	It is your company rules	☐
i)	You have received training to wear them	☐
j)	Other, please specify:	

12 **If you don't wear earmuffs or earplugs when exposed to noise, it is because:** (please tick **all** those that apply)

a)	You are not clear as to when you should wear them	☐
b)	You can't hear properly to do your work (e.g., warning signals, machine performance)	☐
c)	You can't communicate properly with other workers	☐
d)	They are uncomfortable	☐
e)	They get in the way of other safety equipment	☐
f)	You are used to noise at work	☐
g)	Your co-workers often don't wear them	☐
h)	Your co-workers find it funny when you wear them	☐
i)	Someone else does something noisy without warning	☐
j)	Other, please specify:	

13. **Hearing loss can be cured by getting hearing aids.** (tick only one)

☐ True ☐ False ☐ Not sure

14. **Sounds measuring _______ and over are damaging to human hearing.** (tick only one)

☐ 65 decibels (dBA) ☐ 70 decibels (dBA)

☐ 85 decibels (dBA) ☐ Not sure

15. **Sounds that are too loud can damage the _______, causing hearing loss.** (tick only one)

☐ Ear drum ☐ Ear canal

☐ Hair cells of the inner ear ☐ All of the above

16. **Hearing loss caused by loud sounds is something people ________ may have.** (tick only one)

☐ Over age 60 ☐ Over age 40

☐ Over age 50 ☐ At any age

17. **I can protect my hearing from noise at work by wearing earmuffs or earplugs** (tick only one)

☐ All the time when it is noisy ☐ Only when I am doing a noisy job

☐ Only when others are wearing theirs ☐ Only when my boss tells me to

☐ Only when the noise annoys me

18. **Having a hearing loss <u>is not a</u> big deal** (tick only one)

☐ Agree ☐ Disagree ☐ Not sure

19. **Workers who listen to loud sounds all the time don't seem to have a hearing loss, so I don't have to worry about getting a hearing loss.** (tick only one)

☐ Agree ☐ Disagree ☐ Not sure

20. **If it is noisy, and my workmates are not wearing earmuffs or earplugs. . .** (tick only one)

☐ I carry on with my work and let them do what they want

☐ I remind and encourage them to wear their earplugs or earmuffs

☐ I also take mine off because they are not wearing theirs

21. **During the past week, I have been around dangerously loud sounds at work without wearing hearing protection.** (tick only one)

☐ Yes ☐ No

22. **I wear earplugs or earmuffs when other workers are doing a noisy job at work** (tick only one)

☐ Always ☐ Almost always ☐ Usually

☐ Often ☐ Sometimes ☐ Rarely or Never

23. **How often do your workmates wear earmuffs or earplugs when it is noisy?** (tick only one)

☐ Always ☐ Almost always ☐ Usually

☐ Often ☐ Sometimes ☐ Rarely or Never

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